<u>Project Title</u>: Interaction Effects of Landscape Position and Soil Management Practices On Soil Nutrient Availability

Introduction/Background

Increasing food productivity for the increasing global population is an agricultural and socio-economic dilemma. To feed the projected 9 billion people by 2050, current crop production rate must be increased by 60-100% (Gilland, 2002; Royal Society London, 2009). This problem is further exacerbated by pedogenic and anthropogenic factors that often lead to soil degradation and reduced crop productivity. Thus, it is imperative to understand the individual and combined influence of certain pedogenic and anthropogenic factors that influence crop production in regions like Middle Tennessee.

Several pedogenic factors like soil texture and landscape position can influence crop production through their influence on water retention and nutrient availability. For example, Tremblay et al. (2012) reported that medium textured soils (silty) and fine textured soil (clay) increased corn (*Zea mays*) productivity by a factor of 1.6 and 2.7, respectively, under high nitrogen rates compared to coarse textured soils (sand). Besides soil texture, the position of the soil on the landscape can also influence soil nutrient availability (Changere and Lal, 1997). These landscape slope positions include summit, shoulder slope, back slope, foot slope and toe slope (Brady and Weil, 2008). Changere and Lal (1997) reported that corn growth was 13.5% greater in the lower slope position (foot and toe slopes combined) compared to the upper (summit) and middle slope (shoulder and backslopes combined) positions. These researchers also reported that nutrient uptake was 36.9% and 56.8% higher in the lower slope position compared with the upper and middle slope positions, respectively.

Soil management practices (henceforth referred to as cropping systems) is an important anthropogenic factor that determines nutrient availability and overall economic viability of crop production systems. These cropping systems include crop rotation, perennial grasses (forage crops), cover crops, mixed cropping, etc. In a study on the influence of cover crops, crop rotation and tillage management system on soil chemical properties and nutrient availability, Haruna and Nkongolo (2019) and Haruna and Nkongolo (2020) reported that corn/soybean (*Glycine max* L.) rotation significantly influenced soil organic matter (SOM), cation exchange capacity and nutrient availability compared with either continuous corn or continuous soybean. Specifically, Haruna and Nkongolo (2019) reported that corn/soybean rotation increased SOM by 4 and 9% compared to continuous corn and continuous soybean, respectively.

As a result of geologic and pedogenic evolution of the landscape of Middle Tennessee region (and other parts of the U.S. and the world), many farming activities are conducted on different slope positions which has the ability to influence crop yield and environmental sustainability. It is the goal of this project to investigate the combined influence of cropping systems (grazing, perennial forage, corn/soybean rotation) and the various slope positions on soil nutrient availability and environmental sustainability.

Specific Aims/Objectives

The objective of the proposed study is to evaluate how the relationship between three cropping systems and five slope positions influence soil nutrient availability. It is hypothesized that perennial forage grass production system (no grazing) will retain more nutrients than corn/soybean rotation at all slope positions. This hypothesis will be tested through two objectives; 1) evaluating the spatial variability of soil nutrient across five slope positions, and 2) evaluating the interaction effects of cropping systems and slope positions on soil nutrient availability.

Design and Methodology of Research

Objective 1: Evaluating the Spatial Variability of Soil Nutrients across Five Slope Positions

The proposed research will be conducted at MTSU Farm Laboratories. This farm is unique because it consists of 3 cropping systems on 3 landscapes each with the five slope positions: Summit (2% slope gradient, slope shape: linear), Shoulder (9% slope gradient, slope shape: convex), Back (17% slope gradient, slope shape: linear), Foot (5% slope gradient, slope shape: concave), Toe (3% slope gradient, slope shape: linear). The 3 management practices include corn/soybean rotation, perennial fescue (*Festuca*) grass with rotational grazing, and perennial fescue grass without grazing. Soybean was planted in the Spring of 2020 and will be harvested during Fall 2020. Corn will be planted in Spring of 2021 and harvested in Fall of 2021. It is hypothesized that, regardless of land-use, soil nutrients (NO_3-N, P, K, Ca, Mg, Mn, Fe, Zn, SOM, and soil pH) will vary spatially across the different slope positions.

Work plan

January – June 2021

Soil samples will be collected using soil sampling cores of known volume using a grid method at three depths; 0-6 cm, 6-12 cm, and 12-18 cm. These samples will be collected from the 3 cropping systems and 5 slope positions (3 cropping systems x 5 slope positions x 3 soil depth = 45 soil samples). Soil bulk density will be analyzed by the core method (Grossman and Reinch, 2002). Soil organic matter will be determined by loss-on-ignition (at 350 ^{0}C). Soil pH will be measured by potentiometry using an electronic pH meter. Soil NO_3-N will be determined using the nitrate electrode method. Available K, Ca, Mg, Mn and Cu will be determined using the Melich-3 method. Available P will be measured using the Bray I method. Due to the current lack of instrumentation at MTSU Soil Science Laboratory, these analyses will be conducted at a commercial laboratory. Dr. Samuel Haruna will lead this effort.

June-September 2021

The results of this objective will be analyzed using various analytical tools. Analysis of variance will be conducted on soil data using the general linear model (GLM) procedure in Statistical Analysis System (SAS). Spatial variability analysis will be conducted using kriging method in Geostatistics for Environmental Sciences (GS+) ver. 9. This will provide information on spatial autocorrelation and fractal characterization of soil nutrients, which will be important in dictating future sampling plan. Dr. Samuel Haruna will lead this effort.

Objective 2: Evaluating the Interaction Effects of Cropping Systems and Slope Positions on Soil Nutrient Availability

Soil samples will be collected from all 3 cropping systems and 5 slope positions (45 samples) and analyzed for the nutrient availability (same nutrients and procedure as objective 1 above). It is hypothesized that a combination of corn/soybean rotation and the various slope positions will significantly reduce nutrient availability as compared to other combinations. Results will be analyzed using the SAS software.

Work plan

June-August 2021

Soil samples will be collected from the aforementioned land management practices and slope positions for the determination of available soil nutrients. A potential challenge may be unpredictable weather patterns (precipitation). However, this will provide an important perspective on how the various management practices respond to precipitation with respect to nutrient availability or loss. Dr. Haruna will lead this effort.

September – December 2021

The results of this objective will be analyzed using the SAS software. Analysis of variance will be conducted on the data using the GLM procedure in SAS. Single degree of freedom contrasts will be divided into 'cropping system vs. slope position'.

Milestones and Timetable

Table 1 below outlines the important phases of the proposed project as a function of time.

Table 1: Project timetable

	Project Period of Performance			
Activity	Jan. – March 2021	April – June 2021	July – Sept. 2021	Oct. – Dec. 2021
Objective 1				
Soil sample collection	X	X		
Analyze soil samples			X	
Prepare manuscript for publication				X
Objective 2				
Soil sample collection		X	X	
Analyze soil samples			X	
Prepare manuscript for publication				X

Resources

Available resources for the research include MTSU farm laboratories, Soil Science laboratory with work benches, water distillation system, an isotemp oven, and glassware.

Other equipment and supplies necessary for this research that are not currently available and will be purchased include brass cylinders (with plastic caps) for soil sample collection, beakers and flasks, and Buchner funnels.

Other Available Funding

The principal investigator will use the information and resources from this project as leverage for future studies. The future direction of the proposed work will be to understand how various cropping systems on various slope positions influence nutrient runoff, water quality and environmental sustainability. This aligns with and addresses strategic goal No. 5.3 of the USDA-NIFA strategic plan (2018 – 2022). Potential funding sources include USDA Capacity Building Grants for Non-Land Grant Colleges of Agriculture (USDA-NLGCA), and Southern Region Sustainable Agriculture Research and Education (SSARE) grants.

Dissemination and Potential External Funding Requests

The result of the proposed study will be disseminated to peers at scientific meetings and through publication of peer-reviewed journal articles. As with the PI's previous FRCAC grant, data collected in this project will be used to prepare a future proposal to USDA with the goal of understanding the role of cropping systems and various slope positions on crop productivity and soil and water conservation.

References

Brady, N.C., and R.R. Weil. 2008. The nature and properties of soils. 14th ed. Prentice Hall, Upper Saddle River, New Jersey, USA

Changere, A., and R. Lal. 1997. Slope position and erosional effects on soil properties and corn production on a Miamian soil in central Ohio. Journal of Sustainable Agriculture. 11:5-21. doi.org/10.1300/J064v11n01_03.

Gilland, B. 2002. World population and food supply: can food production keep pace with population growth in the next half-century? Food Policy. 27:47-63. doi.org/10.1016/S0306-9192(02)00002-7.

Grossman, R.B., and T.G. Reinsch. 2002. Bulk density and linear extensibility. In: Methods of soil analysis. Dane, J.H., and G.C. Topp (Eds.). Soil Science Society of America, Madison, WI. USA.

Haruna, S.I., and N.V. Nkongolo. 2019. Tillage, cover crop and crop rotation effects on selected soil chemical properties. Sustainability. 11:2770. doi:10.3390/su11102770.

Haruna, S.I., and N.V. Nkongolo. 2020. Influence of cover crop, tillage, and crop rotation management on soil nutrients. Agriculture. 10:225. doi:10.3390/agriculture10060225.

Royal Society of London. 2009. Reaping the benefits: science and the sustainable intensification of global agriculture. Royal Society, London.

Tremblay, N., Y.M. Bouroubi, C. Belec, R.W. Mullen, N.R. Kitchen, W.E. Thomason, S. Ebelhar, D.B. Mengel, W.R. Raun, D.D. Francis, E.D. Vories, and I. Ortiz-Monasterio. 2012. Corn response to nitrogen is influenced by soil texture and weather. Agronomy Journal. 104:1658-1671. doi.org/10.2134/agronj2012.0184.

Significance

Innovation

This project is unique and innovative because it will be one of the pioneering efforts to understand the combined influence of cropping systems and slope positions on nutrient availability.

Significance to PI's Field

Due to the very limited information on the relationship between land-use management on various slope positions, the proposed study will provide significant contribution to current knowledge by linking slope position and cropping systems to soil nutrient availability and, potentially, crop productivity. This will provide a strong basis for educating rural farmers in regions like Middle Tennessee on enhancing crop productivity.

Benefits to Applicants' Long-Term Research Goals

The applicant's long-term research goals include identifying various soil and crop management practices that can improve crop productivity while reducing environmental degradation. The proposed project, if funded, will form a significant part the foundation for the applicants' long-term research goals.

Furthermore, if approved, funds from the proposal will enable the applicant pay for the publication fees of manuscripts currently under review and in preparation. These manuscripts are a result of studies carried out at MTSU either directly by the applicant or by undergraduate students under the supervision of the applicant. This will further improve the applicants' portfolio in applying for external grants as it demonstrates the applicants' continuous research in this area.

Potential Impact on Middle Tennessee State University

If funded, this study will be used to leverage future collaborative research between faculty at MTSU and other institutions across the state and region. Furthermore, this research also has the potential of improving undergraduate research opportunities at MTSU. During the proposed study, students will be able to visit the research site, thus improving their experiential exposure. The publication of peer-reviewed manuscript is another important positive impact on MTSU as it showcases current research being undertaken with the help of the Office of Research Services.

HARUNA, SAMUEL IDOKO

EDUCATION

University of Missouri, Columbia, Missouri, USA.	Ph.D.	2017.	Soil Science
Lincoln University, Jefferson City, Missouri, USA.	M.S.	2013.	Environmental Science
Kogi State University, Anyigba, Nigeria.	B.Sc.	2008.	Geology

MOST CURRENT PROFESSIONAL EXPERIENCE

2017 – Present. Assistant Professor of Plant and Soil Science, School of Agriculture, Middle Tennessee State University, Murfreesboro, TN.

SELECTED PROFESSIONAL SERVICE

Invited Grant Review: Israeli Science Foundation, Southern Sustainable Agriculture Research and Education (SSARE).

Journal Reviewer: Scientific Reports, European Journal of Soil Science, Soil Science Society of America Journal, Archives of Agronomy and Soil Science, Journal of Soil and Water Conservation, Canadian Journal of Soil Science, Australian Soil Research Journal, Agronomy Journal, Agriculture, Sustainability journal, Water Journal, Land, South African Journal of Plant and Soil.

FUNDED RESEACH GRANTS

Haruna, S.I., S. Ku, S. Cui, M. Chaney, E. Ritchey, and A. Gamble. 2020. Cover crops and cropping system sustainability in a changing global climate. Southern Sustainable Agriculture, Research and Education grant. $299,995 (PI)

Ku, S., T. Johnston, **S. Haruna**, and Y. Gao. 2019. Early detection of food pathogens via crossflow nano/microfiltration process from leafy greens and irrigation water. Tennessee Department of Agriculture Specialty Crop Block Grant. $36,964. (Co-PI).

Strobel, D., N. Phillips, and **S. Haruna**. 2018. Pollinator week and field day for honeybees. Middle Tennessee State University Public Service Fund. $2,465. (Co-PI).

Haruna, S.I., and N.S. Chong. 2017. Influence of cover crop on greenhouse gas emissions. Middle Tennessee State University Faculty Research and Creative Activity Grant. Index Number: 221729. $9,860. (PI).

SYNEGISTIC ACTIVITES

Dr. Haruna's research has revolved around understanding the influence of crop and land management practices on soil health indicators. He has also conducted research into the spatial variability of soil physical and chemical properties. Furthermore, he has also conducted research into the influence of cover crops on soil hydraulic properties, laboratory measured soil thermal properties and *in situ* infiltration parameters. *He has taught classes in Fundamentals of Soil Science, Soil and Water Conservation, Soil Physical Properties, Genesis of Soil Landscapes, and Soil Fertility at Middle Tennessee State University* and assisted with teaching Soil Physics laboratory at University of Missouri, Columbia. He has also assisted with teaching Geographic Information Systems at Lincoln University, Missouri. His knowledge and expertise will ensure the successful completion of the project objectives.

REFEREED PUBLICATIONS (Since 2018)

Haruna, S.I., and S.H. Anderson. 2020. No-till farming systems for enhancing soil water storage. In: Dang, Y., Dalal, R., and Menzies N. (eds). No-till farming systems for sustainable agriculture. Springer, Cham. Pp. 213-231. https://doi.org/10.1007/978-3-030-46409-7_13.

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Zaibon, S., S.H. Anderson, K.S. Veum, and **S.I. Haruna**. 2019. Soil thermal properties affected by topsoil thickness in switchgrass and rowcrop management systems. Geoderma. 350:93-100. doi.org/10.1016/j.geoderma.2019.05.005

Haruna, S.I., S.H. Anderson, N.V. Nkongolo, and S. Zaibon. 2018. Soil hydraulic properties: influence of tillage and cover crops. Pedosphere. 28(3): 430-442. https://doi.org/10.1016/S1002-0160(17)60387-4

Haruna, S.I., N.V. Nkongolo, S.H. Anderson, and S. Zaibon. 2018. In situ infiltration as affected by tillage and cover crop management. J. Soil Water Conservation. 73 (2): 164-172. doi:10.2489/jswc.73.2.164.

Cercioglu, M., S.H. Anderson, R.P. Anderson, and **S.I. Haruna**. 2018. Effects of cover crop and biofuel crop management on computed tomography-measured pore parameters. Geoderma. 319: 80-88. doi.org/10.1016/j.geoderma.2018.01.005.

Haruna, S.I. 2018. Musing on conservation agriculture. Current Investigations in Agriculture and Current Research. 1(5)-2018. CIACR.MS.ID.000125.