MATCHING CROPS TO SOILS AND CLIMATIC CONDITIONS UNDER VARYING CROP MANAGEMENT PRACTICES USING CROP SIMULATION MODELS

A project proposal
submitted to
NATIONAL SCIENCE TECHNOLOGY AND INNOVATION COUNCIL (NSTIC)
Ministry of Technical and Higher Education
Government of Sierra Leone

Under the
"CALL FOR FULL PROPOSALS TO FUND A PROJECT THAT PROMOTES FOOD SECURITY AND MODERN AGRICULTURE"

1. **Name and Address of the Organization**
   Eastern Technical University of Sierra Leone
   Combema Road, Kenema, Sierra Leone.

2. **Duration of the Project**
   2 Years (2024 – 2025)

3. **Total Cost of Project**
   USD 44,840 (Forty-Four Thousand, Eight Hundred and Forty US Dollars)

4. **Name of the key person, who will be the In-Charge of implementation of the project**
   Apostle (Dr.) Denis M.K. Amara
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5. Technical Staff

Name and Qualification	Position	Task
Dr. Denis M.K. Amara PhD. Soil Science (Soil resource inventory and climate change modelling)	Team Leader (Principal Investigator)	The Team Leader and Lead Researcher will bear principal responsibility for the delivery of the project. He will lead in all aspect of project implementation, negotiations (if any) and coordination with sponsors and other relevant stakeholders. He will provide overall leadership and guidance for data quality and results delivery.
Dr. Senesie Swaray PhD. Genetics and Breeding (Crop Science)	Co-Investigator I (Plant Breeder)	He will lead in all aspect of breeding the breeder and foundation seeds of improved crop varieties focusing on varietal selection and their management in the selected agro-ecologies.
Mr. Emmanuel Alpha MSc. and MPhil. Crop Science	Co-Investigator I (Qualitative Data Analysist)	He will be responsible for the design and development of tools and training materials, support data transcription, data processing, analysis and drafting of qualitative report component.
Dr. Gelejimah A. Mokuwa PhD. Agronomy (Crops)	Team Leader (Principal Investigator)	He will provide overall leadership and guidance for data quality and results delivery.
Mr. Osman Sidie Vonu MSc Soil Science and Climatology	Co-Investigator II (System Agronomist)	He will support the setting-up of crop cutting experiments, monitoring, data collection, analysis and interpretation of results.
Mr. Daniel H. Saidu MSc. Soil Science	Co-Investigator III (System Agronomist)	He will assist in the preparation of technical reports, workshop outlines and reports.

1. EXECUTIVE SUMMARY

Sierra Leone is one of the poorest countries in the world, with a Gross Domestic Product (GDP) of SLL 48,905,104 in 2021, GDP per capita income of $627.16 and an estimated population at mid-2021 of 7,541,641 million, with 39.4% within the age of 15-35. It has an estimated 56.17% of the population living in rural areas (World Bank, 2023). Agriculture is the most significant sector in the economy of Sierra Leone, contributing to about 57.4% of the gross domestic product (GDP) and employing about 65–70% of the population (SSL, 2022), thus making agricultural development not only important in its own right but also having positive implications for the development of other sectors of the economy. Though the sector is characterized by food production involving mostly smallholder farming for subsistence with land holding size of about 0.5–2 ha, there are opportunities such as adequate arable land, abundant water resources, favourable climate, hard-working farmers and encouraging government and donor partner support. However, the greatest challenge throughout history is for the country to feed its ever-increasing population on a permanent basis. Several initiatives and interventions have been pursued over the years but the yield still continues to be appalling. There is a wide gap between potential and actual yield of major crops due to poor cropping systems, inherent poor soil physical and chemical properties especially high soil acidity and associated low nutrient reserves. Hence, developing effective and efficient soil nutrient management models that are able to predict crop-nutrient relationships for Sierra Leone situation is indispensable for enhancing crop productivity and sustainable yield. This project seeks to test and validate crop and soil modelling tools such as DSSAT, APSIM and NuMaSS, which have been developed, tested and found useful for modelling cropping systems and nutrient relationships in similar agroecologies of the subregion. In savannah agro-ecologies of West Africa, DSSAT, APSIM and NuMaSS models have been accurately used to inform farmers, extension agents, researchers, and policy planners at the household level, community level, regional and national level, respectively on cropping systems and nutrient diagnosis and recommendations with existing soil nutrient management practices. In this project, Eastern Technical University of Sierra Leone (ETU-SL) intends to produce crop and soil simulation models to guide quality decision making and policy planning in climate smart agriculture, train farmers in interpreting crop and nutrient predictions and weather forecasts, and using these in deciding on timely agronomic practices such as optimal planting and weeding times, and also enhance the capacity of the University. The information generated will not only increase productivity and incomes along value chains but also offers more opportunities to system transformation and upgrading. The project will cover a period of two years, with a total cost of 44,840 USD.

2. BACKGROUND AND RATIONALE

The Sierra Leone agriculture is mainly subsistence and rainfed, which is characterized by low and variable rainfall, poor soils and pest and diseases. The soils cannot support crop production without addition of external amendments. The distribution of rainfall is becoming increasingly erratic over the growing season making investments into agriculture a risky venture. Emerging pests like Fall Army Worm (FAW) and diseases are also posing greater threats to crop production. Another major cause of low yield is the low quality of planting materials that are in use. Most of these varieties grown by farmers are low yielding and vulnerable to environmental and other abiotic stress factors. Over the years, national and international agricultural research institutes in the sub-region have developed crop production technologies that will help the farmers respond to the variability in climate change. For example, IITA has developed cowpea and maize varieties that combine tolerance to drought with resistance to parasitic weeds, *Striga*. They have also identified crop management practices such as optimal plant population, planting dates, fertilizer rates and types to close the maize and cowpea yield gap on farmers' fields in the several regions of West Africa. ICRISAT has also worked with national research centers to develop and test extensively groundnut, pearl millet and sorghum varieties along with soil and water management technologies for the semi-arid regions of West Africa. These technologies have however, been tested in only few locations. Hence, their performance can be considered to be site specific and cannot be extrapolated in wider areas. There is a wide variation in the soils and weather characteristics spatially in the different agroecologies of sub-Saharan Africa. Thus, the yield of any particular crop variety will depend on the nature of soil and topographical characteristics, rainfall distribution as well as other crop management practices. We are of the opinion that sound recommendations to farmers on appropriate varieties and management practices suitable for their specific location can only be adequately provided if long-term experiments are replicated over the entire region. This can be time consuming and very expensive. Cropping systems and soil management simulation models provide the opportunity to achieve these based on limited experimentation. Cropping systems simulation models such as DSSAT and APSIM, and soil management simulation models such as the Nutrient Management Support System (NuMaSS), which have been validated in the West African sub-region can be used to assess varietal responses to abiotic stresses and complimentary crop management practices as well as response to changes in climate. While DSSAT and APSIM models simulate the yield and growth of crops based on daily weather (minimum and maximum temperature, rainfall and solar radiation), soil profile information, site information, and crop management practices on the one hand, NuMaSS on the other hand is a decision support system that diagnoses a nutrient deficiency in nitrogen (N), phosphorus (P) and soil acidity, and recommends the best management methods. Users can compare diagnoses and economic implications of management recommendations across multiple scenarios of soils, crops, cultivars, and sources of lime and nutrients. Multiple scenarios enable the users to determine the consequences of their agronomic decisions and allow them to make better informed cropping system choices. We intend to work with diverse national institutions such as SLARI and Njala University to develop production domains for major crops grown in Sierra Leone using simulation models.

3. PROJECT GOAL AND SPECIFIC OBJECTIVES

3.1. Development Goal

The development goal of this project is to enable resource-poor farmers to achieve food security without compromising the sustainability of the environment by adopting the knowledge generated from the testing and calibration of crop simulation models.

3.2. Specific objectives

1. To improve land productivity and increase the productivity of crop production systems.
2. To test and validate DSSAT, APSIM and NuMaSS predictions on cropping systems and nutrient diagnosis and recommendations with existing soil nutrient management practices of farmers, extension agents, researchers, and policy planners at the household level, community level, regional and national level, respectively.
3. To produce crop and soil simulation models to guide quality decision making and policy planning in climate smart agriculture.
4. To train farmers in interpreting crop and nutrient predictions and weather forecasts, and using these in deciding on timely agronomic practices such as optimal planting and weeding times.
5. To enhance the capacity of the University.

4. PROJECT METHODOLOGY/APPROACH

4.1. Conceptual and theoretical framework

Theory of Change (TOC) is premised on the fact that:

- If yield maps and production domains within project locations for various crop varieties are produced from models in conjunction with weather, soil and crop management practices; and historical and current weather data collected from strategic locations in the country and used in model calibration, validation and application; then crops and crop varieties matching soils and climatic conditions under varying crop management practices will be established.
- If response of the models to mineral fertilizer application are evaluated; and processes that underlay yield response to fertilizer application and other management practices to inform further use of the model in supporting decisions regarding agricultural practices are identified; then appropriate genetic coefficients for new and existing crop varieties for calibrating the DSSAT and APSIM models will be derived.
- If crops and crop varieties matching soils and climatic conditions under varying crop management practices are established; and appropriate genetic coefficients for new and existing crop varieties for calibrating the DSSAT and APSIM models are also derived; then high yielding crop varieties suitable for different soils and climatic conditions will be identified for adoption in future, which will facilitate development of production domains for different crops using simulation models.
- Because this project will match the biophysical requirements of cropping systems and nutrient management technologies to the socioeconomic characteristics of the target communities, its framework will satisfy the availability and accessibility of information to support household decision making and adoption of sustainable crop production practices. By providing a protocol for testing and adapting NuMaSS to local conditions and households at several local communities, it will provide a methodology for scaling up from a few households to the hundreds of households which will never have an opportunity to be involved in participatory soil management technology testing and adoption.
- By developing a methodology to enhance adoption of improved soil management practices in the face of market constraints to farm profitability and affordability of inputs, the project will identify market constraints to farm profitability and to adoption of inputs and improved soil management practices. This will be done in the farmer decision making module, because each nutrient management decision model

will contain constraints such as distance to market, cost and affordability of inputs, that usually constrain small farmers from adopting new nutrient-management technologies such as organic and inorganic fertilizer management.

- The nutrient management decision models in the farmer decision module will contain institutional and informational constraints (e.g., knowledge and riskiness of the nutrient management innovations) and will therefore help to identify human and institutional factors that block technology adoption, and enhance the availability and accessibility of information to support public policies that encourage adoption of sustainable crop production practices.
- Because the project will test and validate the adoption of NuMaSS recommendations by a variety of users at all levels of the information continuum (i.e., farmers at the household level, extension agents at the community level, and researchers and policy planners at the regional and national level), it will solve the problem of ineffective transfer of soil management technologies from research to decision makers at the farm and policy levels, and reaching out decision makers and integrating decision making at different levels in the value chain and agroecosystems hierarchy.

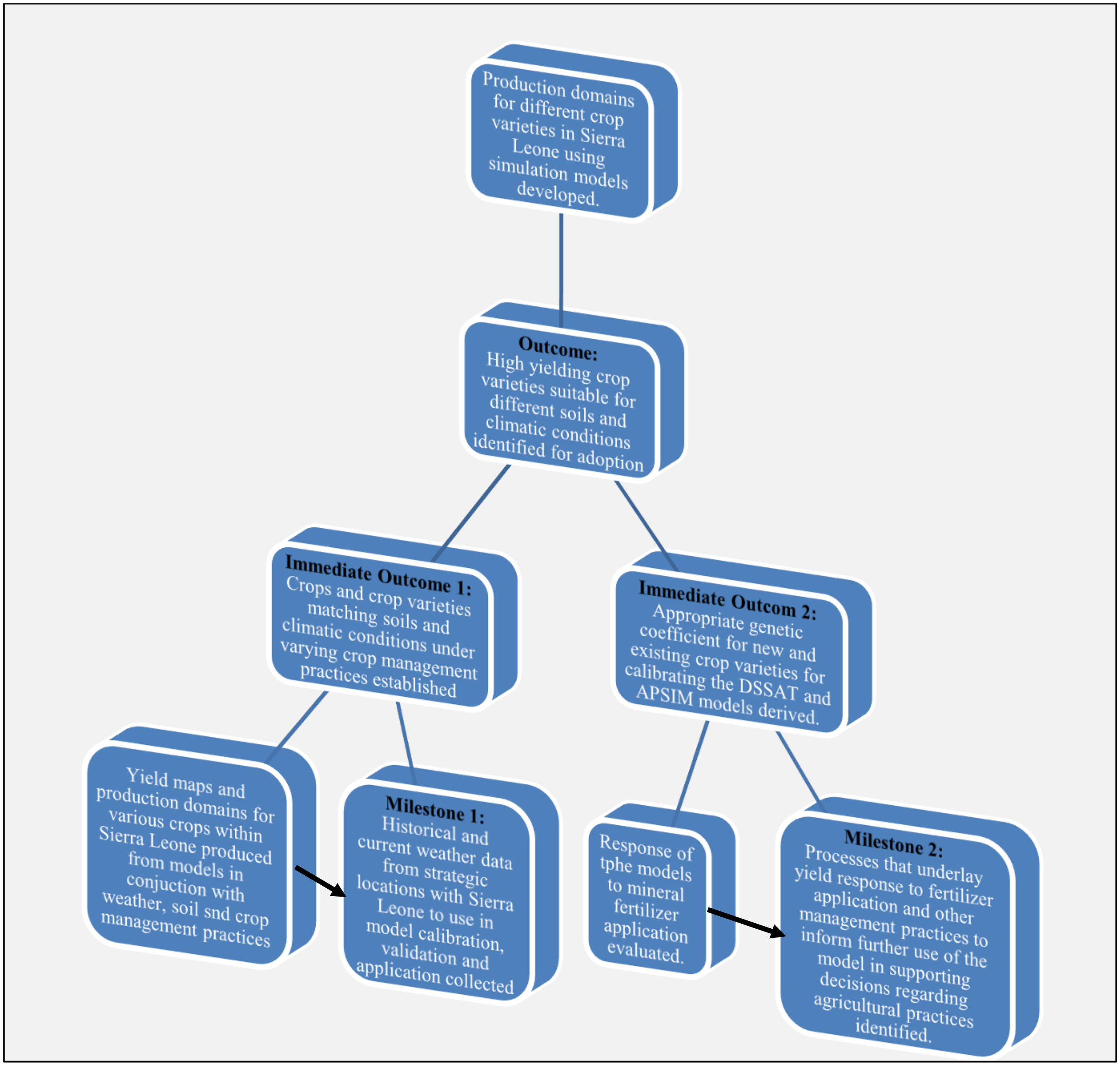

Figure 1. Theory of Change for the various interventions proposed in the project.

4.2. Research Approach

Objective 1

Activity 1.1. Introduce released drought-tolerant and Striga-resistant maize varieties and hybrids with varying maturity periods from the subregion and test for registration and release to farmers in Sierra Leone.

Some hybrids and open-pollinated maize varieties of extra-early, early, intermediate and late maturity with tolerance to drought and resistance to *S. hermonthica* have been released in the subregion. As the production zones where the released varieties and hybrids share similar production conditions in Sierra Leone, testing seeds of these maize varieties in Sierra Leone will facilitate the selection of elite maize varieties for adaption by farmers. ETU-SL will then supply breeder seeds of parents of the released hybrids and open-pollinated maize varieties to government-supported agencies like the Seed Multiplication Programme (SMP) to support the production of foundation seeds. This approach may also accelerate access to sufficient quantities of certified seeds from seed companies such as Bantus Brother Foundation (BBF) to meet the seed demand for scaling out in the focal regions in Sierra Leone.

Activity 1.2. Facilitate farmer adoption of appropriate climate smart agricultural practices, soil fertility management, and natural resource management (NRM) practices)

Extension methods including demonstration plots and field days, are some of the major strategies for introducing the findings of modern research in agricultural practices to increase agricultural production and uplift of the rural masses in general. Field demonstrations and field days are effective means of communication to transmit knowledge and skills, and the interested may easily see, hear, and learn the things conveyed by extension workers. Demonstration plots are one of the best methods to improve technology uptake by smallholder farmers. In this project, we will work with farmers groups in the selected communities to select lead farmers to manage technology demonstration plots on their behalf. Selected best-bet technologies will be promoted in lead farmers' managed on-farm demonstration plots. Each lead farmer representing a community-based organization (CBO) in his community will have two plots each measuring 400 m^2. The first plot will consist of the improved crop production and management technologies with the farmers taught to manage the crops using the supplied inputs. The second plot will serve as control where the farmer will be allowed to use his own crop varieties and crop management systems. A total of 75 demonstration sites, containing 150 plots (2 plots per site) will be established. To facilitate farmer to farmer transfer of knowledge, and create more awareness among farmers, lead farmers in selected communities will be encouraged to bring members from the CBOs they represent to demonstration fields to learn from what he/she is doing. Mid and end of season evaluations and field days will be organized periodically during the cropping season to popularize crop production and management technologies and create demand. In addition to field demonstrations and field days, the project will create awareness through radio and TV programs and through video clubs on the performance of crop production and management technologies in the target communities.

The project will also link farmer organizations to agro-dealers in the target region to enable them access to legal and effective chemicals for pest control. Pearl millet, sorghum and groundnut are all susceptible to insect pests (pearl millet head miner, sorghum midge) and diseases (groundnut rosette), which contribute to the low productivity. For pearl millet, we will mainly emphasize on the dissemination of the biological control approach (Ba et al., 2014) for controlling the pearl millet head miner, one of the most devastating insect pests. For sorghum and groundnut, we will mainly focus on dissemination of existing sorghum midge resistant varieties and groundnut rosette resistant varieties already available in the subregion.

Activity 1.3. Testing and demonstration of Striga resistant, drought tolerant and downy mildew resistant pearl millet varieties in different agro-ecologies of Sierra Leone.

Several varieties of pearl millet with resistance to *Striga hermonthica* and downy mildew including ICMV 147141, ICMV 147142, ICMV 147143, ICMV 147144 and ICMV 167012 have been developed and released by several research institutions in the subregion for further dissemination to farmers. These varieties have not only proven to be resistant to *Striga hermonthica* and downy mildew but also contain high concentration of micronutrients such as Fe (38-40 ppm) and Zn (35-37 ppm). These varieties will be demonstrated in large number of farmers' fields in selected communities. The best-bet varieties will be identified and recommended to farmers and seed companies.

Activity 1.4. Produce and supply of breeder seeds of parents of released maize hybrids and varieties to national seed companies and other seed production entities to increase certified seed production for marketing in the country.

ETU-SL will multiply and market quality seeds of the released multiple stress tolerant maize varieties and hybrids. The project will embark on the production of breeder and foundation seeds of parents of stress resilient maize hybrids and varieties under in different agro-ecologies and supply them to seed production entities for certified seed production and marketing in the country. This activity will also focus on the training of technical staff of seed producing companies involved in monitoring the day-to-day field management and operations. The training will be practical to equip the support staff of the seed producers with skills in the production of good quality sees of parental lines of hybrids and in the maintenance of the genetic purity of parents during the multiplication of foundation and certified seeds.

Activity 1.5. Train smallholder farmers and extension agents on appropriate climate smart crop production and management practices

It is not enough to introduce and demonstrate technologies without training the stakeholders on their proper use. We propose to strengthen stakeholders at three levels. Firstly, we will train extension service providers (public sector, NGOs and private sector) in the correct use of the technologies to enable them pass on the training to the smallholder farmers. In addition, we will provide training to the lead farmers in the use of the technologies. The lead farmers will also be trained in leadership skills. Each lead farmer will be assigned about 25 farmers in a group to train in the use of the introduced crop production and management technologies.

Activity 1.6. Sensitize and train farmers on monitoring, surveillance and scouting for the identification, early warning and appropriate control measures for Fall Army Worm (FAW)

FAW is a new emerging threat to cereal crop production in Africa. Due to its rapid spread and distinctive ability to inflict widespread damage across multiple crops, FAW poses a serious threat to the food and nutrition security and livelihoods of hundreds of millions of farming households in SSA – particularly when layered upon other drivers of food insecurity such as aberrant weather conditions. FAW has the potential to cause yield losses in maize for example, of 8.3 to 20.6 M metric tons per year, in just 12 of Africa's maize producing countries in the absence of proper control methods (CABI, 2017). In the absence of maize, FAW is reported to attack over 80 other crops including pearl millet, sorghum, and groundnut. We will demonstrate the use of "early warning" and the "available and judicious use of environment friendly agrochemical products as a short-term control measure" to manage FAW at the various experimental sites. We will also train farmers and extension service providers on monitoring, surveillance, scouting and identification for use as an early warning system, and train extension personnel and smallholder farmers on the safe handling and use of the available and legal environment- friendly agrochemical products.

Objective 2

Activity 2.1. Collect historical and current weather data from strategic locations in target communities to use in model calibration, validation and application.

One of the most important inputs in modeling crop growth in different environment is the acquisition of quality historical data from the location or sites in the target zones of the project. The project will work with the Sierra Leone Meteorological Agency (SLeMet) and other research institutions to acquire weather data for use in short and long-term simulation of crop performance.

Activity 2.2. Train farmers in interpreting weather forecasts and using these in deciding on their agronomic skills such as optimal planting and weeding times.

If farmers have access to appropriate weather forecasts, they can better plan their farm activities. In this project, the farmers will be trained on the use of seasonal and short-term weather forecasts. In addition, agronomic tests will be conducted to assess farmers' benefits of using weather forecast under traditional and improved crop management. The project will use mobile telephones to provide weather forecast to the farmers.

Activity 2.3. Collect soil profile data from target communities for input into the models.

In addition to weather data, information on soil physical and chemical properties enables researchers to simulate the performance of any crop variety in a given location. In this project, we intend to use spatial modelling GIS tools to select strategic sites in the target communities where we will dig profiles and characterize the soils for both physical and chemical properties. From the onset of the project, the technical team will endeavour to fully understand the terrain on google map, including the various locations, communities, landforms, and rivers along/across which the transect line will cross. The coordinates of these locations and the transect points to be examined for digging profile pits and/or auger borings will be inputted into a GPS handset. The “Go To” command of the GPS will then be activated to guide the navigation of the survey team to the point/place of interest on the transect line. Soils with same sequence will be identified as soil associations and labelled as mapping units. The isolated landforms will be traversed to identify the different land facets (i.e., landscape elements) for possible excavation and study in order to establish soil–landscape relationships and identify the unique toposequences associated with them. Representative soil profile pits of dimension 2m x 1.2m x 1.5m will be excavated at each landscape position for detailed morphological description using the FAO 2006 guidelines for soil description. These guidelines for soil description will be transformed into a digital format from which a Kobo Collect app version will be developed and used for field data entry. Soil samples will be collected from each horizon and analysed for physicochemical properties at the ETU-SL soil laboratories following standard analytical procedures.

Activity 2.4. Conduct field trials in strategic locations to collect data for model calibration and evaluation

Here, we will conduct on-farm trials on farmers’ fields in each site under optimal conditions generate data for calibration of DSSATT and APSIM models for various crop varieties to enable us to simulate the performance of these crops in different environments, and to determine farmers' current crop and nutrient management practices and needs. In addition, multi-locational trials will be conducted in strategic sites in under rainfed conditions to generate data for evaluation of the models for accuracy in the prediction of crop performance under varying management practices. We will compare crop and nutrient management by the farmers and determine where the DSSAT, APSIM, and NuMaSS software and knowledgebase can contribute to improving their cropping systems and soil health.

Objective 3

Activity 3.1. Calibrate, validate models and run simulations to predict performance of crop varieties under changing management practices.

Field data collected will be used to calibrate and evaluate the models. Once the models are calibrated and validated with accuracy, we will apply the models to simulate crop performance under changing environments and management practices.

Activity 3.1. Produce simulation maps and graphs.

A digital map of the performance of the crop varieties will be produced and shared with relevant stakeholders such as Farmer-Based Organizations (FBOs), Non-Governmental Organizations (NGOs), Government Agencies, and the private sector.

Objective 4

Activity 4.1. Interpret crop and nutrient simulation results to guide quality decision making and policy planning in climate smart agriculture.

Simulation results of the performance of different crop varieties under changing management practices will be interpreted using standard interpretation keys (SIKs) and the information will be shared with farmers and other relevant stakeholders to enhance their ability to make sound decisions for improved crop productivity.

Activity 4.2. Assess the level of adoption of the generated knowledge over time.

Our expectation is that there is a continuum of users of the knowledge that would be generated from this project, ranging from farmers at the household level, extension agents at the community and district level, and policy planners and researchers at the regional and national level. For this reason, we will conduct three different tests of adoption. To assess adoption level by farmers, we will generate recommendations for each prediction model under study for a set of farmers in each site, and then survey those farmers and collect extensive data from them about their soil-fertility amendment use. For adoption by extension staff, we will assess whether or not the amounts and kinds of nutrients recommended by the model predictions are appropriate for the farms in the area being studied. We will survey extension agents about what they recommend to farmers regarding their soil-fertility amendments, and correlate predicted recommendations from models with the recommendations of the extension agent. If the model predicted recommendations do not correlate with extension agents' reported recommendations, then farmer and extension agents will be surveyed to determine whether model predicted recommendations are appropriate and why if not. In the case of adoption by policy planners and researchers, our assumptions are that either more training is necessary and more accurate information needs to flow from researchers to local extension agents and vice-versa, or models do not generate good accurate socioeconomic predictions and need to be refined, for which case we would need to source a new funding.

Objective 5

Activity 5.1. Strengthen the capacity of the Agronomy Department of the Faculty of Development Agriculture and Natural Resources Management.

There is a long-standing need for human capacity development of staff of the Department of Agronomy in the Faculty of Development Agriculture and Natural Resources Management at the postgraduate level. Presently, only two staff of this department hold a PhD degree. This project will train one additional staff at PhD level. Eventually, the department will be able to enhance its teaching and research capability. Additionally, hands-on training will be organized every year to strengthen the capacity of both field and laboratory technicians of the faculty through short courses, workshops, and seminars.

Activity 5.2. Develop a web database and publish study findings in reputable domains/platforms.

Here, the information generated will be converted into a web database and this will be held on the website of the Directorate of Research and Innovation at the main web portal of the university. In addition, the finding will be presented at workshops, conferences, seminars and published as articles and conference proceedings in referred journals.

5. ANTICIPATED OUTPUTS AND OUTCOMES

S.N.	Activity	Output(s)	Outcome(s)	Impact	Risks and Assumptions
1.1	Introduce released drought-tolerant and Striga-resistant maize varieties and hybrids with varying maturity periods from the subregion and test for registration and release.	Released drought-tolerant and Striga-resistant maize varieties and hybrids with varying maturity periods from the subregion introduced, tested and released.	Increased level of adoption of available and improved crop varieties and management practices.	Reduction in the use of low-quality traditional crop varieties.	Willingness of farmers to adopt the improved technologies.
1.2	Facilitate farmer adoption of appropriate climate smart agricultural practices, soil fertility management, and NRM practices.	Farmer adoption of appropriate climate smart agricultural practices, soil fertility management, and NRM practices facilitated.	Increased adoption of improved crop production and NRM practices.	○ Percent increase in the number of farmers who have adopted improved crop production and NRM practices. ○ Percent increase in number of farmers using improved crop varieties.	Willingness of farmers to adopt the improved technologies.
1.3	Testing and demonstration of Striga resistant, drought tolerant and downy mildew resistant pearl millet varieties in different agro-ecologies of Sierra Leone.	Striga resistant, drought tolerant and downy mildew resistant pearl millet varieties in different agro-ecologies of Sierra Leone tested and demonstrated.	Increase in number of framers and farm size.	Increased crop production and productivity.	Willingness of farmers to adopt the introduced technologies.
1.4	Produce and supply of breeder seeds of parents of released maize hybrids and varieties to national seed companies and other seed production entities to increase certified seed production for marketing in the country.	Breeder seeds of parents of released maize hybrids and varieties released to national seed companies and other seed production entities.	Increased access to quality planting materials.	Percent increase in average yield.	Adulteration of improved seeds along the distribution chain.
1.5	Train smallholder farmers and extension agents on appropriate	Training in appropriate climate smart crop production and	Improvement in the knowledge level of famers and extension	Increased in climate resilient cropping systems.	Willingness of farmers to adopt

	climate smart crop production and management practices.	management practices conducted.	agents in appropriate climate smart crop production and management practices.		the introduced technologies.
1.6	Sensitize and train farmers in monitoring, surveillance and scouting for the identification, early warning and appropriate control measures for the Fall Army Worm (FAW) and other pests.	Farmers sensitized and trained in monitoring, surveillance and scouting for the identification, early warning and appropriate control measures FAW.	Incidence of FAW reduced in target communities.	Double season cropping of maize due to control of FAW incidence.	Willingness of farmers to attend sensitization programmes.
2.1	Collect historical and current weather data from strategic locations in target communities to use in model calibration, validation and application.	Historical and current weather data from strategic locations in target communities to use in model calibration, validation and application collected.	Database of quality weather data will be available for calibrating and running simulation models.	Robust prediction mechanism in place to guide decision making in farming.	Availability of technicians who understand the model framework and are ready to upscale the use of model predictions in agro-advisory services.
2.2	Train farmers in interpreting weather forecasts and using these in deciding on optimal planting and weeding times.	Farmers trained in interpreting weather forecasts and their applications in agronomic practices.	Increased farmer adaptation to climate smart technologies based on real time information.	○ Increased number of farmers who have skills in interpreting weather data application in decision making. ○ Minimized weather shocks.	Willingness of farmers to adopt the introduced technologies.
2.3	Collect soil profile data from target communities for input into the models.	Soil profile data from target communities collected and inputted into the models.	Database of quality soil data will be available for calibrating and running simulation models.	Improvement in soil health and fertility related issues due to robust information sharing and decision-making platforms.	Absence of post-survey efforts to update database.
2.4	Conduct field trials in strategic locations to collect data for model calibration and evaluation.	Field trials conducted in strategic locations to collect data for model calibration and evaluation.	Location based and crop-based information available for testing and calibrating models.	High yielding crop varieties suitable for different soils and climatic conditions identified for deployment in future.	Tools and methods to assess, monitor, and understand climate change impacts on various crops and available.
3.1	Calibrate, validate models and run simulations to predict performance of crop varieties under changing management practices	Simulation models for different crop varieties developed and validated.	Crop, soil, and weather relationships fully established.	Timely information on agronomic practices such as optimal planting and weeding times guiding crop production.	Timely data is collected for running the simulation models.
3.2	Produce simulation maps and graphs	Model based yield maps and production domains for various crop varieties produced from models in conjunction with weather, soil and crop management practices.	Validated yield maps disaggregated by crop and production domain.	Improvement in crop and soil productivity	Ability of technicians to fully understand how to interpret yield maps and production domains in real time situations.

4.1	Interpret crop and nutrient simulation results to guide quality decision making and policy planning in climate smart agriculture.	Model for variety, soils and management practices developed and validated.	Crops and Crop varieties matching soils and climatic conditions under varying crop management practices established.	Field estimated response curves and experimental yields recommendations guiding crop production.	Ability of technicians to fully understand how to interpret crop and soil simulation results in varying situations.
4.2	Assess the level of adoption of the generated knowledge over time	Results of user evaluations and comments regarding the generated knowledge is assessed.	Realistic number of potential users of the generated knowledge established.	Information sharing among potential users sustained.	o Potential users are available and willing to evaluate the models. o Potential users will provide direct feedback on usability.
5.1	Strengthen the capacity of the Agronomy Department of the Faculty of Development Agriculture and Natural Resources Management	Capacity of the Agronomy Department of the Faculty of Development Agriculture and Natural Resources Management strengthened.	Improvement in the teaching and research ability of the trained staff.	Increased profile of trained and qualified staff of the institution.	Commitment of staff to finish the programme within the specified time.
5.2	Develop a web database and publish study findings in reputable domains/platforms.	A web database developed and study findings published in reputable domains/ platforms	Real time information available on soil health and fertility status, cropping systems, agricultural calendars and climate early warnings to local population.	Sustainable increase in crop yields through the use of quality information in farming.	Potential users may lack the good ICT experience in application of web-based information.

6. KNOWLEDGE UTILIZATION AND DISSEMINATION PLAN

To capture, share and disseminate the knowledge, lessons learned, and good practices gained in the implementation of this project, we will 1) identify the lessons learned, processes and key stakeholders through which the lessons will be collected and disseminated, 2) collect the information through structured and unstructured processes such as project critiques, written forms, and meetings, 3) verify the accuracy and applicability of lessons, 4) store the information, and 5) disseminate the information. Steps 1–4 are intended to capture the knowledge, lessons learned, and good practices gained in the implementation of this project, while Step 5 is dissemination stage.

The project has a plan for information dissemination through:

- Holding conferences and events to reach out to and influence a wide audience. This will foster partnerships during and after the project.
- Create direct contact through face-to-face meetings, small group meetings, site visits, workshops, training, presentations, etc., as a communication tool to create personal enthusiasm, insight and more responses from stakeholders as well as target and non-target beneficiaries of the project.
- Engage the electronic and print media including radios and newspapers to create interactive forums and platforms to inform the general public about the project concept, benefits, successes and challenges.
- Well designed and illustrated success stories in the form of brochures, poster and handbills will be published. These are vital ways to give the general public a sense of longer-term value of the project.
- Visibility programmes involving printing of banners during conferences, workshops and site visits, T-shirts and caps (with inscribed topical messages) for free distribution in communities, exercise books (with annotated illustration of products) and pens for school children, can serve as valuable source of information dissemination mechanism about the project.
- Validated data will also be published in peer-reviewed academic journals as a way to share and

disseminate the knowledge, lessons learned, and good practices gained through the implementation of the project.

- We also plan to use the “Third Party Information Dissemination Approach” where government Ministries, Agencies and Departments (MDAs) like the Ministry of Agriculture and Forestry, Ministry of trade and Industry would be partnered with to become ambassadors and champions of vermicompost and vermiwash fertilizer production in the country. These people work with large groups of farmers, who can be adopters of the technology.
- We plan to create a website for the project. Because of easy accessibility and possibilities of up-dating, the website can serve as a popular platform to share and disseminated the knowledge, lessons learned, and good practices gained through the implementation of the project to the general public.

7. PROJECT GOVERNANCE

A Project Steering Committee (PSC) will be set up that will comprise of key stakeholders including the ETU-SL team (Vice Chancellor and Principal (VC&P), Director of Research and Innovation (DRI), Director of Partnership and Resource Mobilization (DPRM), Finance Director, Internal Auditor), District Agriculture Officers (DAOs), and farmers’ representatives. The PSC will provide guidance to the implementation of this project. It will advise on issues and problems arising during project implementation; facilitate cooperation among project partners and collaboration between the projects and other relevant programs, projects and initiatives in the countries. The ETU-SL team through the Principal Investigator, will be responsible for overall project management and overall coordination of activities. The DRI will be the secretary of the PSC and he shall present a quarterly report to the PSC. The DAOs will play a vital role in the selection of target communities and beneficiaries due to their long-standing experience in dealing with famers in their districts. The farmers’ representatives will serve as points of contact (POC) for their FBOs. They will be responsible for organizing members of their FBOs, and facilitating communication between farmers and the technical team. The PSC will also conduct a regular monitoring and evaluation of the project in line with project outputs, indicators and activities.

8. SUITABILITY OF THE HOST INSTUTUION

The ETU-SL is a technical university that is located in the eastern region of Sierra Leone, which tends to be the bread basket of the country. The institution has campuses located at Bunumbu Campus having 615 acres in Kailahun district, Woama Campus having 317 acres in Kono district, and Kenema Campus with two locations, namely Kenema having 25 acres and Panderu having 100 acres. The region is also endowed with adequate climatic and environmental conditions that favour the growth of crops and general agricultural development.

ETU-SL has well-structured faculties and programmes that are career-driven, with qualified staff for teaching, research and community services. As a technical university, it caters for the development of the middle man power and contributes to improving the quality of life for citizens, increasing agricultural productivity, promoting the environmental wellbeing of families and conserving the natural resources. Project of such nature is well suited to the mission and development objective of the institution and could serve as a gateway to the eastern region and the country as a whole.

Lastly, the university has undertaken a series of project since its inception in collaboration and partnership with several national and international, governmental and non-governmental organizations including MAFS, MTHE, Ministry of Youth, Gola Forest, WHH, BADIA etc. The university also has standard infrastructure that could facilitate the implementation of this project.

With these potentials and experiences, the university is well positioned and capacitated to undertake such project.

9. CAPACITY BUILDING

The project will base its implementation strategy on the core principles of a livelihoods framework. This framework will guide project interventions in support of technical innovations, through a process of building human skills and improving the capacity of local institutions. Major activities will include technical innovations such as testing, calibration, validation, adoption of improved crop and nutrient modelling techniques for improved crop and soil management practices, and institutional strengthening. The proposed project will contribute towards individual and organizational capacity building in several ways including hands-on practical demonstration on how to interpret weather forecast data and use them in decision making, and monitoring, surveillance and scouting for the identification, early warning and appropriate control measures for FAW. The project intends to offer scholarship to one Junior Lecturer in the Agronomy Department of the Faculty of Development Agriculture and Natural Resource Management to pursue PhD in Agronomy. In addition, the project will train farmers, students and extension staff of MAFS in several climate smart crop production and management practices.

10. MONITORING AND EVALUATION STRATEGY

The monitoring of this project will start right from its inception. The project will be regularly monitored by the Project Technical Team headed by the PI and the Project Steering Committee that will comprise of various stakeholders. The PI has a wealth of experience in dealing with core project outputs, indicators and activities in previous projects. This M&E plan will serve two functions: first, periodic assessment of project implementation and performance of activities (M&E of Project Performance), and second, evaluation of vermicompost and vermiwash fertilizers in terms of its relevance, effectiveness and impact in increasing soil fertility and improving crop productivity (M&E of Project Impact). The M&E system will provide answers on the progress and impact made in achieving the project's outputs and outcomes.

- **Project Performance**: Performance evaluation, which is referred to as mid-term and final evaluation, will assess the project's success in achieving the outputs with the inputs provided and activities conducted. The project performance will be monitored on half-yearly basis and findings incorporated into the annual technical reports.
- **Project Impact**: Evaluation of the project's success in achieving its outcomes will be monitored continuously throughout the project. The impact of the project in respect of indicators and expected outcomes will be evaluated on quarterly basis through joint meetings with the project beneficiaries.

The project performance and impact will be monitored and evaluated using the following M&E Matrix/Logframe

Specific objective / Result chain	Indicator	Target	Means of verification	Risks / Assumptions
To improve land productivity and increase the productivity of crop production systems.	○ Standard of living of target beneficiaries. ○ Number of improved crop varieties available for farmers' use.	25% increase in yield of crops grown in project locations.	○ Project records. ○ Household surveys.	The social-economic political and weather conditions will allow for the process of awareness, training and more importantly adoption and implementation of the ideas.
To test and validate DSSAT, APSIM and NuMaSS predictions on cropping systems and nutrient diagnosis and recommendations with existing soil nutrient management practices of farmers, extension agents, researchers, and policy planners at the household level, community level, regional and national level, respectively.	○ Predictions on cropping systems and nutrient diagnosis and recommendations under Sierra Leone condition. ○ Number of models tested and validated.	Three models including DSSAT, APSIM and NuMaSS tested and validated in different agro-ecologies of Sierra Leone by end of project.	○ Project records. ○ Photos of field trials,	The social-economic political and weather conditions will allow for the process of awareness, training and more importantly adoption and implementation of the ideas.
To produce crop and soil simulation models to guide quality decision making and policy planning in climate smart agriculture.	○ Number of model-based yield maps and production domains produced. ○ Type and quantity of information hosted on website.	○ Model based yield maps and production domains for various crop varieties produced. ○ 1 website established to hold the generated data.	○ Project records. ○ Established website displaying relevant information.	Sustainable ICT network maintained taking cognizance of the poor mobile network and internet facilities with weak signals in the country.
To train farmers in interpreting crop and nutrient predictions and weather forecasts, and using these in deciding on timely agronomic practices such as optimal planting and weeding times.	○ Number of farmers trained. ○ Number of workshops, seminars and conferences organized.	○ 75 lead farmers trained interpreting crop and nutrient predictions and weather forecasts. ○ 150 demonstration plots established in farmers' fields. ○ 1875 farmers trained by end of project through Trainers of Trainers (ToTs) approach and	○ Project records. ○ Training manuals. ○ Training photos.	The participants will have an interest in vermicomposting technology i.e., avail themselves for the trainings, and play their duly part during training and implementation of the project in order to make a lasting impact

		Farmer Field Schools (FFSs).		
To enhance the capacity of the University.	○ Number of staff and technicians trained. ○ Number of workshops, seminars and conferences organized. ○ Number of publications.	1 staff trained at PhD level, and field and laboratory technicians giving hands-on training.	○ Project records. ○ Registration status of staff pursuing the PhD programme.	ETU-SL will continue with its mandate without changing focus and its mission.

11. GENDER, ETHICS AND SUSTAINABILITY

11.1 GENDER

To sustain project activities, the project will develop a gender mainstreaming strategy to reduce gender inequalities through participation in identifying relevant interventions for achieving gender equity, encouraging gender-specific activities and increased participation by women. The increased participation of women and youths in the project will help increasing benefit among households leading to more investments in technologies being promoted. For this reason, both male and female will be incorporated into the project to reduce gender inequalities.

11.2 ETHICAL ISSUES

The proposed project involves the testing, calibration, validation and adoption of modelling tools, which are well known and widely tested in similar agro-ecologies in West Africa and other subregional countries. They have been proven to offer a range of options for better productivity of crops and soils combined with good resource management. They are based upon existing changing climate, in the context of farming systems that are evolving. In addition, participatory mechanisms of technology transfer which treat farmers as equal partners in project implementation will facilitate technology adoption. However, the efficiency and adoption of these models depend both on their performance in predicting real time crop and soil management issues that are topic in agricultural productivity. The project will pay special attention to these issues to ensure that the due diligence is done to enable optimum local conditions for the smooth implementation of the key activities under the project. In addition, the project will endeavour to see that all literature consulted are properly acknowledged, cited and referenced.

11.3 SUSTAINABILITY

Five key elements will contribute to the sustainability of this project after its lifespan. These are 1) the development of strong partnerships, 2) the use of participatory approaches, 3) strengthened local institution, 4) the mainstreaming of gender, and 5) the use of research knowledge and proven technologies. The project will forge a partnership with relevant stakeholders to work together to deliver the outputs targeted by the project. The stakeholders will participate in the identification of the problem and work together to provide solutions through technology deployment. Farmer participation in the process will provide feedback to the technical team to fine tune models for user-friendly capabilities. Working with existing groups and encouraging the formation of new ones, building their capacity through technical, organizational and leadership training will lead to the formation of common interest groups, which will evolve into farmer-owned and managed organizations that are capable providing services to members. Training will be undertaken in ways which will reinforce each other based on the principles that people learn from practical experience and better from their peers. A gender mainstreaming strategy will be developed to reduce gender inequalities through participation in identifying relevant interventions for achieving gender equity, encouraging gender-specific activities and increased participation by women. The increased participation of women and youths in the project will help increasing benefit among households leading to more investments in technologies being promoted. The strong use of research knowledge and technologies through backstopping by researchers will increase productivity of the production systems and reduce poverty. This will allow for further investments in agriculture and lead to sustainable livelihoods after the project phases out.

12. PROPOSED PROJECT TIMELINE

The proposed project will follow two main phases of implementation. Initial activities (months 1-6) will be to identify 100 target beneficiaries, establish 1 demo vermicomposting enterprise, establish baseline data in the target communities using participatory diagnostic appraisal tools, and train target beneficiaries through Farmer Field School (FFS) study plots and community level demonstration sites. As from month 7 of the project, the activities will be to organize the target beneficiaries into 4 FBOs, register the FBOs with relevant institutions, and train the FBOs in managing a vermicomposting business. Each FBO will be trained through the FFS study approach and empowered to start with one vermicomposting enterprise. The FFS process is central to the community learning-by-doing process on how to establish and manage a vermicomposting enterprise. Moreover, many more community members would be encouraged to adopt the technology. The project will target 3 districts, 35 chiefdoms, 75 towns/villages, and 100 farmers.

Proposed Project Timeline

Project Objective: The development goal of this project is to enable resource-poor farmers to achieve food security without compromising the sustainability of the environment by adopting the knowledge generated from the testing and calibration of crop simulation models.			**Timing/Duration of Activity (Quarterly)**																							
			2024												**2025**											
Project Framework	**Responsible Party**	**Indicator, including means of verification**	**Q1**			**Q2**			**Q3**			**Q4**			**Q1**			**Q2**			**Q3**			**Q4**		
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Objective 1: To improve land productivity and increase the productivity of crop production systems.																										
1.1 Introduce released drought-tolerant and Striga-resistant maize varieties and hybrids with varying maturity periods from the subregion and test for registration and release.	ETU-SL, community stakeholders and target beneficiaries	○ Project records. ○ Household surveys. ○ Number of varieties introduced and tested																								
1.2 Facilitate farmer adoption of appropriate climate smart agricultural practices, soil fertility management, and NRM practices.	ETU-SL	○ Number of farmers adopting the practices.																								
1.3 Testing and demonstration of Striga resistant, drought tolerant and downy mildew resistant pearl millet varieties in different agro-ecologies of Sierra Leone.	ETU-SL and target beneficiaries	○ Number of pearl millet varieties tested and demonstrated ○ Photos and videos of field trials conducted																								
1.4 Produce and supply of breeder seeds of parents of released maize hybrids and varieties to national seed companies and other seed production entities to increase certified seed production for marketing in the country.	ETU-SL	○ Number of improved crop varieties available to seed companies and other seed producing entities for multiplication.																								
1.5 Train smallholder farmers and extension agents on appropriate climate smart crop production and management practices.	ETU-SL	○ Number of farmers trained ○ Number of farmers applying the practices. ○ Photos and videos of events																								
1.6 Sensitize and train farmers in monitoring, surveillance and	ETU-SL	○ Number of awareness meetings conducted																								

scouting for the identification, early warning and appropriate control measures for the Fall Army Worm (FAW) and other pests.		○ Number of farmers sensitized and trained ○ Number of farmers applying the knowledge. ○ Photos and videos of events
Objective 2: To test and validate DSSAT, APSIM and NuMaSS predictions on cropping systems and nutrient diagnosis and recommendations with existing soil nutrient management practices of farmers, extension agents, researchers, and policy planners at the household level, community level, regional and national level, respectively		
2.1 .Collect historical and current weather data from strategic locations in target communities to use in model calibration, validation and application.	ETU-SL and SLeMet	○ Type of weather data collected ○ Predictions on cropping systems and nutrient diagnosis and recommendations under Sierra Leone condition.
2.2 .Train farmers in interpreting weather forecasts and using these in deciding on optimal planting and weeding times.	ETU-SL	○ Number of farmers trained ○ Photos and videos of training sessions ○ Number of farmers applying the knowledge.
2.3 .Collect soil profile data from target communities and analyze them for input into the models.	ETU-SL	○ Quantity of soil samples collected and analyzed
2.4 Conduct field trials in strategic locations to collect data for model calibration and evaluation.	ETU-SL and target beneficiaries	○ Number of field trials conducted ○ Number of models tested and validated.
Objective 3: To produce crop and soil simulation models to guide quality decision making and policy planning in climate smart agriculture.		
3.1 .Calibrate, validate models and run simulations to predict performance of crop varieties under changing management practices	ETU-SL	○ Number of models tested and validated.
3.2 .Produce simulation maps and graphs	ETU-SL	○ Number of maps and graphs produced
Objective 4: To train farmers in interpreting crop and nutrient predictions and weather forecasts, and using these in deciding on timely agronomic practices such as optimal planting and weeding times.		
4.1. Interpret crop and nutrient simulation results to guide quality decision making and policy planning in climate	ETU-SL	○ Predictions on cropping systems and nutrient diagnosis and recommendations under

smart agriculture.		Sierra Leone condition.
4.2 Assess the level of adoption of the generated knowledge over time	ETU-SL, farmers, extension agents, researchers, and policy planners.	○ M&E reports ○ Number of questionnaires administered
Objective 5: To enhance the capacity of the University.		
5.1 Strengthen the capacity of the Agronomy Department of the Faculty of Development Agriculture and Natural Resources Management	ETU-SL and project sponsor.	○ Number of staff and technicians trained. ○ Number of workshops, seminars and conferences organized.
5.2 Develop a web database and publish study findings in reputable domains/platforms.	ETU-SL	○ Website address ○ Type of data held on website ○ Number of publications.

13. LITERATURE CITED

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