An IoT-based Soil and Crop Monitoring System that uses Deep Learning Algorithms

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Research Problem The Beshilo watershed is an area with prevalent land degradation and soil infertility [3]. Most of the soils are of quite low organic and inorganic matter content, display low cation exchange capacity (CEC), micro-nutrient deficieny, low aggregate stability and surface sealing, high evapotranspiration rate and poor water holding capacity [4]. These are unfavourable conditions for good quality farm products. High prevalence of crop pests and diseases and pest infestations have also been frequently reported in the watershed [5, 1]. In line with this, most of the woredas in the watershed are labelled as food-insecure as many of the households are deficit producers, and yield is insufficient to even support farmers all-year long; many households have been receiving food aid and other assistance from government as well as NGOs [1].

Climate change and showery rainfalls have caused erosion of the uppermost soil layer, leading to deforestation, aggravated by a growing population, traditional and intuitive farming practices, policy impediments, lack of precise and timely information, lack of extensive and adequate extension services. These are amongst the challenges that farmers face and that hinder improvements to their yield and productivity.

Crop and soil characterization at the farm plot level can play a significant role in informed decisions in sustainable agricultural practices and hence reduce the severe prevalence of food insecurity. However, there is an extreme scarcity of data at the watershed level, both in terms of quality and quantity, from which such characterizations can be formulated. Thus, the research problem focuses on how to develop robust, usable, trusted and yet cost-effective soil and crop data. A tool to acquire, process and present can fill this gap. An integration of remote sensing and IoT technology will be deployed to collect spatial, temporal and other soil data that affects the yield off a farm parcel. We thus create a platform for improved information flow from multiple sources to make useful predictions and projections.

Research Area The Beshilo watershed has been selected because of its frequent drought and severe soil erosion problems, leading to nutrient deficits and infertile soil, thus, causing poor crop yields. There is a high water stress level in the soil as well, in part caused by high evapotranspiration rates. Sorghum, teff, maize and haricot beans are the dominant crops in the watershed and their yield is affected by acidity level, moisture and macro-nutrient availability in the soils [2]. A closer monitoring and analysis of soi/crop relationship at the watershed appears wanted and needed. The watershed encompasses 16 woredas both in the lowlands and highlands, presenting a coverage difficulty for this research project[3]. Accordingly, we plan to take one woreda from the highland and one from the lowland as sample areas, considering qualitative and quantitative parameters like distance from the other woredas, severity of food insecurity risks, population size, and accessibility.

Temporal Scope The research work is anticipated to be completed as a pilot during the EENSAT project, which ends by 2022. The first year is to be used for proposal preparation. Actual data collection will be carried out in the second and third year of the project, once required devices are put in place. In the third and fourth year we will develop, test and analyze the system and its products and provide an evaluation.

Required Data sets Required data sets are: imagery data from Landsat-8 or Sentinel-2 for mapping land use and land cover, elevation, land mask, crop type and other vegetation index calculations and soil data from Ethiosis, AfSIS or EthioGIS, weather and past rainfall data from the Ethiopian Meteorology Center, or possibly other source, and survey data needed for the work.

Data to be Collected The research aims to gather a bulk of soil and environment information from as many sources as can be realistically found in an unprecedented way. Soil pH, moisture and humidity level data will be collected using sensor nodes, soil NPK levels with soil test kits and imagery data through UAV drones, if exists, or through a simple digital camera of a phone owned by local stakeholders.

Equipment Required To carry out the project successfully, a number of data collection devices are required including soil testing kits, digital camera integrated phones or UAV drones. A sensor network will be set up comprising gateways, antennas, transceivers, micro-controllers and sensing devices for soil pH, moisture and humidity. For the sample area frames identified for the research, 2 gateways, 4 sensors of each type, number of soil testing kits, 2 antennas, 2 micro-controllers and 2 transceivers are required. However, the exact number of such set-ups and number of sensors to be deployed will be determined at later stage.

Proposed System The general objective of the project is to design real time, robust, usable and affordable soil data collection and analysis tools. An Internet of Things (IoT) network architecture, that allows data communication through a low-range radio frequency (LoRa) for the sample areas, will be designed and deployed to collect and transmit data on soil pH, moisture and humidity level data using cheap in-field sensors. We will study optimality in sensor deployment schemes to optimize data outcomes.

Moreover, soil testing kits will be used to capture the nitrogen, phosphorus and potassium (NPK) levels of the soil, which will then be converted to spatial information and be captured through camera. The research opts to engage with the community with a data acquisition tool with a localized, easy-to-use interface to collect and transmit soil NPK data. In addition, UAV-captured soil and vegetation reflectance will be analyzed through digital image processing (DIP). Environmental and soil factors affecting crop productivity will be modeled using a GIS tool while Deep Learning algorithms will be implemented to pre-process and analyze collected data. An associated inference engine will generate new and useful data that allows to offer advisory information for improve crop yields, such as the kind of actions to take and when, dose, time, and type of fertilizers needed, as well as producing a projection for crop yield.

With such technological intervention and inclusive platform, local stakeholders will obtain a sense of ownership, while a substantial amount of data is collected that can document changes at the farm level and allow farmers to monitor and adjust to changing soil and environmental conditions.

The study addresses the research and information gap at the watershed level and aims to generate valuable research output that can benefit farmers, public and private sector entities who are working in agricultural development, as well as policy makers in planning appropriate mechanisms that improve actor integration, knowledge and information sharing towards sustainable farming, early damage detection and disaster prevention as well as other important farming scenarios.

The research work can be extended to a larger scale with minimal investment either with sensors' network rotation making use of existing resources at different site of interest or new set up on existing architecture.

Possible MSc Research Topics

- Optimal Identification and Acquisition of Soil's NPK content
- Deep Learning Algorithms for Sustainable Agriculture
- Towards inclusiveness of local stakeholders for data collection and dissemination

Summary

Determination of the soil nutrient level, texture, pH and other properties accurately can help stakeholders take timely and logical corrective actions, which are key factors for better crop productivity and regulation of nutrient uptake as well as determining the type, amount and timing for fertilizer applications. The research work has a win-win-win character; enhance crop yield for

farmers, increased adaptation and resilience to climate change and reduce the land degradation of the area. We believe the output of this research can be used by all stakeholders working on enhancing food security while providing a basis for further research work.

Bibliography

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