Predicting Soil Moisture Levels with Long Short-Term Memory: A Deep Learning Approach Integrated with Internet of Things Data

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***Abstract*— Water is essential for plant growth, so it is crucial to adjust watering practices to the specific needs of the plant. Factors that affect the watering process include air temperature and soil moisture. This research aims to predict soil moisture levels. Technologies are needed to support this research in obtaining accurate data on soil moisture levels. This research uses Long Short-Term Memory (LSTM) integrated with Internet of Things (IoT) technology. The data will then be processed and analyzed using a quantitative methodology, focusing on the development and application of the Long Short-Term Memory (LSTM) model. Several prediction steps (n) will be analyzed, specifically at steps 6, 12, 18, and 24. We present model performance metrics, including Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and the coefficient of determination (R^2), in both graphical and tabular formats. The results illustrate that the LSTM model achieved the best performance at n = 12, with RMSE = 0.4683 and R^2 = 0.8970, indicating a high degree of correlation between predicted and actual values and a low prediction error. This method is expected to improve accuracy and efficiency in predicting soil moisture levels, support decision-making for irrigation strategies, and raise awareness about sustainable water use in agriculture.**

Keywords—soil moisture, prediction, deep learning, Iot, lstm

I. INTRODUCTION

Water is essential for plant growth, so it is crucial to adjust watering practices to the specific needs of the plant. Factors that affect the watering process include air temperature and soil moisture [1]. Soil moisture in an important component in agriculture, climate studies, and hydrological modeling [1], [2], [3]. Changes in soil moisture levels have a direct impact on water consumption and plant development [4]. As a results, the need of precise and effective soil moisture prediction is increasing, especially for optimizing agricultural practices and water resource management [5].

Recent studies have discussed improving the accuracy of soil moisture measurement and prediction. The scientific [6] article titled "Sustainable Irrigation Requirement Prediction Using Internet of Things and Transfer Learning" provides insights highly relevant to this research topic. The study explored the integration of K-Nearest Neighbor (KNN), Internet of Things (IoT), cloud storage, Long Short-Term Memory (LSTM), and Adaptive Network Fuzzy Inference System (ANFIS) to create an efficient prediction model. The goal of this article is to predict current and future water requirements with several time steps, which are 3, 8, 12, 24, and 48 hours.

The scientific article [7] entitled "An IoT Low-Cost Smart Farming for Enhancing Irrigation Efficiency of Smallholders Farmers", published in 2022, discusses the application of Edge-IoTCloud platform that utilized deep learning methodology. The platform performed to monitor and predict the capability of farmers to satisfy crop water needs during periods of insufficient rainfall. This article presents physical variables in smart farming system that can be used as guidelines for the LSTM predictive model.

Another scientific paper [8] entitled "Developing a Long Short-Term Memory (LSTM) based Model for Predicting Water Table Depth in Agricultural Areas" discusses long-term water table depth prediction in agricultural areas. The presented model in this study integrates an LSTM layer followed by a fully connected layer, with a dropout method applied to the initial LSTM layer. A dataset for 14 years was divided into two sets: a training set (2000-2011) and a validation set (2012-2013). The proposed model shows higher R^2 scores (ranging from 0.789-0.952) in predicting water table depth, which is better than the traditional artificial neural network (FFNN), which achieved much lower values (ranging from 0.004-0.0495).

The scientific paper [9] entitled "Development of a Soil Moisture Prediction Model Based on Recurrent Neural Network Long Short-Term Memory (RNN-LSTM) in Soybean Cultivation" discusses a predictive model for soil moisture (SM) using RNN-LSTM. This model evaluates the feasibility of predicting SM levels in soybeans farmland, providing to maintain optimal moisture for crop growth. The study shows that utilizing time-series weather data for soil moisture prediction can help in determining appropriate irrigation needs for agricultural practices.

This research aims to integrate soil moisture data with temperature and humidity levels to predict soil moisture levels in the coming minutes. The development of this research on IoT devices is essential to improve irrigation efficiency. This research integrates IoT Technology, cloud computing, and deep learning methodologies. IoT is instrumental in gathering environmental parameters, including soil moisture, temperature, and air humidity, using sensors installed on plant. Furthermore, this data is sent through cloud services to be processed with deep learning algorithms to generate accurate predictions of soil moisture levels. Long Short-Term Memory (LSTM) is used as the primary method to collect and process this data.