Chapter 8
Predicting Weather Conditions for Improving Crop Productivity Using Machine Learning Approaches

Vicky Anand
https://orcid.org/0009-0003-3684-1696
Southern Federal University, Russia

Vishnu D. Rajput
https://orcid.org/0000-0002-6802-4805
Southern Federal University, Russia

Tatiana Minkina
Southern Federal University, Russia

Saglara Mandzhieva
https://orcid.org/0000-0001-6000-2209
Southern Federal University, Russia

Aastha Sharma
Jamia Millia Islamia, India

Sunil Kumar
Directorate of Census Operations, Punjab, India

Elizaveta Konstantinova
https://orcid.org/0000-0002-9836-8721
Southern Federal University, Russia

ABSTRACT

Agricultural systems are becoming increasingly prone to a range of non-climatic and climatic stressors. Constituently, there is food insecurity and economic distress throughout the world. To address these challenges, machine learning (ML) techniques have gained attention in the field of agriculture. Monitoring weather information is crucial for resource management and prioritizing the areas where efforts could be made to strengthen agricultural production. The objective of this chapter is to explore the effectiveness of ML for future simulation of agro-climatological variables. The chapter investigates the methodologies, limitations, and potentialities of ML related with employing ML for weather prediction in the context of sustainable agriculture. Chapter it is stressed on the potential benefits of these predictive models for enhancing crop management methods, resource allocation, and overall agricultural productivity. The use of ML in weather forecasting offers the prospect of helping sustainable and resilient agricultural practices, ultimately contributing to global food security.

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1. INTRODUCTION

From its early roots in the evolution of civilization, improving crop production has grown into a highly scientific interest. Through selective breeding and trial-and-error procedures, the specialization of cultivated crops occurred over the millennia, with the most dramatic developments occurring in this century. Genetics, improved fertilizers, enhanced resistance, and climatic analyses of farming systems have all contributed to remarkable gains in yield. It follows that much study has been conducted into the identification of ideal circumstances to generate the highest yields, with light, heat, and moisture conditions being of key importance. Researchers have devoted extensive efforts to understanding the optimal conditions for crop growth and sustainable farming methods. With the advancement of technology, farmers now have access to weather forecasts and real-time data, allowing them to better plan and adapt to climate change.

The weather system plays a significant role in the growth and productivity of the agricultural system more directly than any other factor (Lobell & Gourdji, 2012). Nearly 80% of the climate variability may be attributed to the uncertainty in weather patterns, especially for rainfed crop systems (Fageria, 1992; Petr, 1991). This could have serious impacts on crop yields and food security (Gautam et al., 2013). The magnitude and nature of these consequences are influenced by the changing dynamics of the climate system as well as the interplay between weather patterns and crop yields (McKeown et al., 2006). Temperature, precipitation, and sun radiation are the essential agrometeorological parameters that drive the growth, development, and yield of crops (Hoogenboom, 2000). Variability in temperature is intricately associated with various physiological processes and can impede the pace of vegetative and reproductive growth (Hodges, 1999). For instance, excessive heat leads to stress conditions, impacting enzyme activity, protein denaturation, and cellular functioning (Essemine et al., 2010). Solar radiation, necessary for photosynthesis, provides the energy needed for plant growth and development (Monteith, 1972). Adequate amounts of sunlight are crucial for the production of chlorophyll, which is responsible for the green color in plants and plays a vital role in photosynthesis (Boote et al., 1996). Insufficient sunlight can result in stunted growth and reduced crop yields. Similarly, precipitation is essential for supplying water to crops, promoting nutrient uptake, and maintaining soil moisture levels. However, excessive rainfall can lead to waterlogging, causing root damage and increasing the risk of disease. The quality of soil is essential for plant growth as it provides the necessary nutrients and serves as a support system for the roots (Daily et al., 1997). Adequate amounts of organic matter, nutrients, and a balanced pH level are necessary for healthy plant development. Thus, a delicate balance between these agrometeorological parameters is crucial for optimizing crop production and ensuring food security.

Weather forecasting is described as "*foretelling the state of the atmosphere for a given area using the principles of physics, statistics, empirical approaches, and technology*" (Nyasulu et al., 2022). It can cause inherent complex problems in precision agriculture, as accurate weather predictions are crucial for making informed decisions regarding irrigation, crop management, and pest control (Chattopadhyay et al., 2020). By analyzing meteorological data and patterns, farmers can optimize their agricultural practices and minimize environmental impact. There are various common ways of weather prediction such as persistence forecasting, climatology forecasting, gazing at the sky, barometric pressure, atmospheric model, and ensemble forecasting (Islam, 2011). Persistence forecasting involves predicting the future weather based on the current conditions, assuming that the weather will remain unchanged (Slingo & Palmer, 2011). Climatology forecasting uses historical weather data to predict future patterns and trends (Immerzeel, 2008). Gazing at the sky involves observing cloud formations, wind patterns, and