Machine Learning Applications Using Drone Acquired Data in Agriculture

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ABSTRACT

Agriculture is facing significant challenges such as rising food demand, food safety concerns, environmental sustainability issues and climate change, all of which are severely affecting global food security. Currently, over 815 million people are chronically hungry, with nearly 64% of them living in Asia (Friha *et al*. 2021; Pathak *et al*. 2020). In traditional farming systems, the late detection of crop stress, diseases and nutrient deficiencies often leads to reduced yield, lower crop quality and inefficient use of resources such as water, fertilizers and pesticides. Therefore, the adoption of modern technologies like drones and machine learning has become essential to improve risk assessment, disaster response and transparent evidence-based decision-making to support vulnerable farmers and enhance food security (Debangshi 2021). In recent years, unmanned aerial vehicles (UAVs) have gained increasing popularity due to their flexibility, ease of operation and ability to capture high spatial resolution data, enabling rapid and non-destructive extraction of crop phenotypic information (Deng *et al*. 2018). Equipped with RGB, multispectral and thermal sensors, drones generate large volumes of high-resolution data across different crop growth stages and field conditions. These data can be efficiently analyzed using machine learning

algorithms such as Random Forest (RF), Support Vector Machine (SVM), Artificial Neural Networks (ANN) and Convolutional Neural Networks (CNN). This integration enables early detection of crop stress and diseases, accurate yield prediction, improved irrigation scheduling and precise input management. Overall, it enhances productivity, resource-use efficiency and supports sustainable agriculture.

INTRODUCTION:

Agriculture is changing quickly because there is a growing need to produce more food, use resources efficiently and deal with problems like climate change and environmental damage (Zhang and Kovacs 2012). Traditional farming methods mostly depend on manual observation and applying the same amount of fertilizers or water across the whole field. This often leads to problems such as late detection of crop diseases or stress, uneven use of resources and difficulty in managing large farms. As a result, productivity and sustainability are affected, especially with increasing population and limited natural resources. In recent years, the use of Unmanned aerial vehicles (UAVs) or drones, along with machine learning (ML), has become a promising solution in agriculture (Zualkernan *et al*. 2023). Drones can capture high-quality images and data using different types of sensors like RGB, multispectral, hyperspectral and thermal cameras. These images help farmers understand crop health and variations within the field. However, the large amount of data collected by drones is complex and cannot be easily understood without advanced analysis. Machine learning, which is a part of artificial intelligence, helps in analyzing this data and turning it into useful information. Techniques like Convolutional Neural Networks (CNNs) can automatically identify crop diseases, detect weeds, monitor crop growth and even predict yield. By combining drone technology with machine learning, farmers can monitor their fields in real time, detect problems early and apply inputs only where needed. This improves crop production and makes farming more sustainable (Liakos *et al*. 2018).

Classification of drones

- **Multi Rotor Drones:** Multi-rotor drones are widely used in farming because of their versatility and reliability. Hovering in the air, flying at a low altitude, and producing high resolution photographs are all possible because of the UAVs having numerous rotors (Lisein *et al*. 2015).

- **Hybrid UAVs:** Hybrid drones are a type of Unmanned aerial vehicle (UAVs) that combines the capabilities of both multi-rotors Unmanned aerial vehicles and fixed wing UAVs (Verma *et al*. 2022; Sriram Reddy *et al*. 2022) they are capable of vertical take-off and landing (VTOL) as well as covering longer distances across vast fields in a single mission.

Components of drone

Agricultural drone is a regular drone with an extra eye for detail. Main components of drone are the lightweight frame, brushless motors, propellers and ground control unit for flight. But the key difference lies in its high-resolution camera or sensor.

Sensors

Drones equipped with specialized sensors drones are becoming powerful sensing systems that complement the IoT-based technique.

1) **Visible light sensors (RGB)-** are the most commonly used type of sensor for crop

monitoring. These sensors are relatively low cost compared to the others provide high resolution imagery are lightweight and easy to use and operate.

2) **Thermal infrared sensors-** generate an image that displays objects based on their temperature and not their visible properties. Thermal cameras use infrared sensors and an optical lens to receive infrared energy.

3) **Multispectral or hyperspectral sensors-** embedded in UAVs can obtain information related to the spectral absorption and reflection of the crops in several bands.

4) **NDVI Sensor-** It helps us to know about the health status of the plant. Healthy plants have a strong near infrared (NIR) reflectivity, called the "Red Edge".

Ranges of NDVI: 0-1

Table 1: Most used vegetation indices.

Vegetation index	Abbreviations	Formulae
Red vegetation index	RVI	$\frac{NIR-R}{R}$
Normalized vegetation index	NDVI	$\frac{NIR-R}{NIR+R}$
Normalized difference red edge index	NDRE	$\frac{NIR-RE}{NIR+RE}$
Green normalized difference vegetation index	GNDVI	$\frac{NIR-G}{NIR+G}$

Table 2. Role of sensors in agriculture applications

Applications	Sensors
Water-stress monitoring	Multispectral or Hyperspectral sensors and NDVI, GNDVI and PRI model Thermal infrared sensor and RGB Sensor
Nutrient disorders	RGB, Multispectral and Hyperspectral sensors
Disease monitoring	RGB sensor Multispectral images sensor Hyperspectral and thermal sensor
Weed detection	Hyperspectral sensor RGB sensors
Spraying	GPS sensor

Table 3: Most common software tools used for image processing.

Software Tools	Description
Adobe Photoshop	Mostly used for editing, enhancing anf manipulating digital images and creating graphic designs
Agisoft Photoscan	Exploited for the generation of 3D models and ortho mosaic images from overlapping photographs. It also allows the calculation of vegetation indices
QGIS	Usually exploited for the mapping, visualizing, analyzing and managing geo-spatial data
MATLAB	Applied mainly for the data analysis, mathematical modelling and algorithm development
Pix 4D	The most commonly used tool. Mainly used to process drone images into orthomosaic maps, 3D models, point clouds and digital elevation models (DEMs)

Role of machine learning using drone acquired data

Machine learning combined with drone technology enables efficient and smart farming. Drones capture high-quality images and data from fields, which are then analyzed using machine learning algorithms.

a. **Crop monitoring:** Drones can be used for monitoring the conditions of crops throughout the crop season so that the need-based and timely action can be taken. Drones equipped with high-resolution cameras and sensors enable detailed crop monitoring (Fawcett *et al*. 2020).

b. **Irrigation monitoring:** The characterization of water stress on crops is a complex task because the effects of drought affect can be affected by several factors. Drones equipped with thermal or multispectral sensors can identify areas experiencing water stress in crops.

c. **Weed detection:** Weeds are not desirable plants which grow in agricultural crops and can cause several problems. They are causing losses in agricultural yields and growth because they are competing for scarce resources like space, water and nutrients (Zhu *et al*. 2010). Drones collect data and photos from the whole field which can be utilized to create an accurate map of the weed cover that shows the areas that require chemical.

Case Studies

Zha *et al*. (2020) predicted nitrogen status through nitrogen nutrient index (NNI) using random forest (RF) model in rice using fixed-wing unmanned aerial vehicle (UAV)-based remote sensing for collecting spectral reflectance imagery, an important data source for precision N management. The N status diagnosis maps for the study area were created based on the predicted NNI using RF model. The majority fields had deficient or surplus N status, with less area's deficient areas. The results indicated that ML methods could significantly improve the estimation of rice NNI compared to other models especially using an optimized RF algorithm.

Dadras *et al*. (2019) inspect the capability of low altitude UAV equipped with a multispectral camera for detection of healthy and diseased trees in citrus orchards by collecting data with multispectral sensors. In this study, as pixel-based binary support vector machine (SVM) classification was used. They obtained overall classification results based on check. They observed that that low altitude multispectral imagery has the potential to be applied for fast detection of “greening” infected trees in citrus orchards.

Romero *et al*. (2018) estimated stem water potential through artificial neural network (ANN) model and observed stem water potential in china. They concluded that Ψ_{stem} below −1.2MPa (orange to red colours) were considered between moderate and severe water stress, Ψ_{stem} between −0.8 and −1.2MPa (light blue to green colour) corresponded to moderate stress and finally Ψ_{stem} over −0.8MPa (blue colour) was considered with no water stress.

Bahuguna *et al*. (2020) conducted a field experiment in CSIR- Palampur Himachal Pradesh in 22 plots of *Rosa damascena* (Damask Rose) for the study of canopy temperature by using machine learning models. Results were compared to the ground-based measurements, obtaining accuracy percent of 98.54%.

CONCLUSION

Traditional farming, which mainly depends on farmer's experience and uniform field practices, often leads to delayed detection of problems, inefficient use of inputs and lower productivity. In today's scenario, with increasing population pressure, limited natural resources and climate variability such methods are no longer sufficient to meet food demands. The integration of drone-acquired data with machine learning has emerged as a powerful solution to these challenges. Drone provide high-resolution, real-time information about crop conditions while machine learning algorithms analyze this data to detect patterns, identify crop stress, predict yield, manage irrigation and optimize the use of fertilizers and pesticides, this combination enables timely accurate decision-making at the field level. Furthermore, this technology supports precision agriculture by allowing site-specific management, reducing unnecessary input use and minimizing environmental damage. Although there are challenges such as high initial cost and for technical expertise, continuous advancements and increasing accessibility are expected to overcome this limitation. Therefore, machine learning applications using drone-acquired data represent a significant step toward smart, efficient and sustainable agriculture, ensuring better productivity and long-term food security.

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