Article ID 240204060

Drones for Climate-Smart Agriculture

Aveen Ragh and Suma Nair

[1]PG Research Scholar, Department of Farm Machinery and Power Engineering, KCAET, Tavanur, KAU

[2]Assistant Professor, Agricultural Research Station, Mannuthy, KAU

*Corresponding Author: aveenragh2013@gmail.com

Climate change presents one of the most significant challenges to global agriculture, threatening food security and the livelihoods of millions. Traditional agricultural practices often aggravate environmental degradation. Climate-smart agriculture (CSA) aims to address these issues by promoting practices that enhance productivity, resilience, and reduce greenhouse gas emissions; encouraging producing more from less. Among the various technological advancements supporting CSA, drones stand out for their versatility and precision. Equipped with advanced sensors and imaging technologies, drones provide detailed, real-time data on various aspects of farming, enabling more informed decision-making. The roles, benefits, challenges, and future prospects of use of drones are discussed below.

Role of drones in climate smart agriculture

1. Precision Agriculture

Precision agriculture is the precise management of all agricultural practices and resources, from land preparation to harvest, based on detailed observations and measurements, i.e., data. Drones play an important role in precision agriculture by offering high-resolution imagery and data that can be analysed to optimize farming practices.

a. Crop health monitoring and assessment

Fig. 1. Navigation of drones in farming

(Source:https://theagrotechdaily.com/exploring-pros-and-cons-of-drones-in-farming)

Early identification of stress factors such as disease, pest infestation, or nutrient deficiencies allows for timely interventions, thereby minimizing crop losses and reducing the need for chemical treatments. Drones equipped with multispectral, hyperspectral, and thermal sensors can capture detailed images across various wavelengths, providing insights into plant health and physiological conditions. These images help assess plant health by analyzing various spectral indices such as the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Soil-Adjusted Vegetation Index (SAVI). These indices help identify areas of stress, disease, or nutrient deficiency within a field. NDVI measures the difference between near-infrared (reflected by healthy vegetation) and red light (absorbed by plants), providing a reliable indicator of plant health (Rouse et al., 1974). EVI is better than NDVI in that it reduces atmospheric and soil background effects, offering a more accurate representation of vegetation cover (Huete et al., 1997). SAVI incorporates soil brightness correction factor, making it suitable for areas with sparse vegetation (Huete, 1988).

b. Variable Rate Technology (VRT)

Variable Rate Technology (VRT) is a cornerstone of precision agriculture, allowing for the differential application of inputs such as fertilizers, pesticides, and water. Drones facilitate VRT by mapping fields and identifying specific areas that require attention. This targeted approach not only enhances crop productivity but also reduces input costs and minimizes environmental impact.

2. Early Detection of Stress Factors

Drones enable the early detection of stress factors such as water stress, pest infestations, and nutrient deficiencies, allowing for timely interventions. Thermal cameras on drones can detect variations in canopy temperature, which are indicative of water stress. Plants under water stress typically exhibit higher temperatures due to reduced transpiration rates. Timely identification of these hotspots helps optimize irrigation schedules and prevent crop loss (Zarco-Tejada et al., 2012).

High-resolution images and detailed spectral data enable the detection of subtle changes in crop conditions that are not visible to the naked eye or through satellite imagery (Lamb et al., 2008). They can help identify and assess the signs of pest infestations or disease outbreaks before they become visually apparent. For example, changes in reflectance patterns can indicate pest damage or disease stress (Mahlein et al., 2013). This allows for prompt and targeted interventions, reducing the reliance on broad-spectrum pesticides and minimizing crop damage. The use of drones for monitoring also reduces the need for manual scouting, saving time and labour.

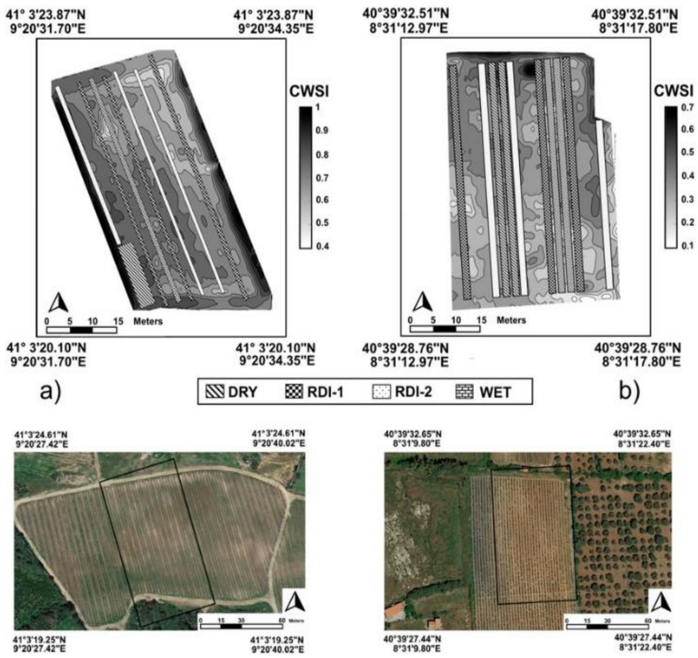

Fig. 2 Crop water stress index (CWSI) acquired from unmanned aerial vehicle (UAV) at (a) Arzachena and (b) Usni (Matese *et. al.*, 2018)

3. Efficient resource management

a. Field Mapping and Surveying

Fig. 3. Land surveying and mapping by drone

(Source: https://www.atomaviation.com/land-surveying-mapping-by-drone)

Topographic Mapping using drones can create detailed topographic maps of fields, which are essential for precision farming practices like variable rate application of inputs (fertilizers, pesticides).

b. Soil analysis and management

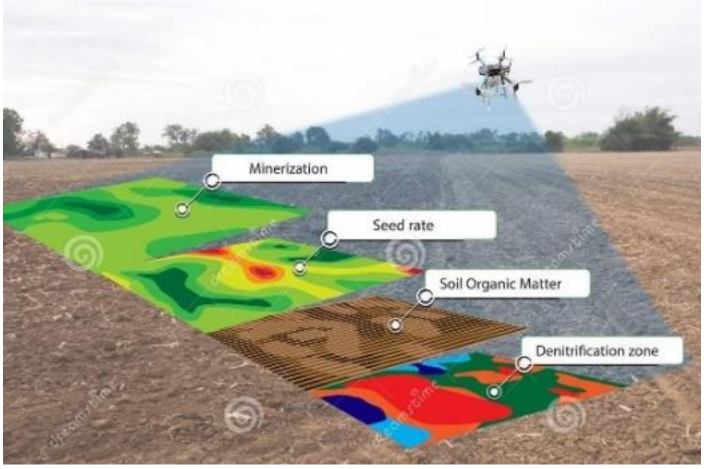

Fig. 4. Soil and field analysis

(Rajani and Samruddhi, 2023)

Healthy soil is fundamental to productive agriculture. Drones assist in soil analysis by capturing high-resolution images that reveal soil texture, structure, and organic matter content. This information is essential for determining appropriate crop rotations, soil amendments, and other management practices such as irrigation. Regular monitoring of soil health helps maintain its fertility and productivity, contributing to long-term agricultural sustainability.

c. Irrigation management

Fig. 5. Irrigation management drone

(Source:https://specdrones.us/agriculture/irrigation-management-drones)

By ensuring that water is applied only where and when needed, drones help conserve water resources and enhance crop yields. They can also monitor irrigation infrastructure, detecting leaks or blockages that could lead to water wastage. Drones offer two main benefits for irrigation: they can detect water-stressed areas using sensors and cameras, enabling precise irrigation adjustments, and they can apply pesticides and water efficiently, especially in emergencies. Matese *et al.*, 2018 reported that a fixed-wing UAV captured multispectral images of citrus crops to identify changes, and also sprinkled water accurately over stressed areas. This frequent and targeted irrigation makes UAVs an effective tool for water conservation.

d. Planting and Seeding

Fig. 6. (a) Tree planting using drone

(Source:https://www.fastcompany.com/40450262/these-tree-planting-drones-are-about-to-fire-a-million-seeds-to-re-grow-a-forest)

Precision Planting: Some drones are equipped with systems to plant seeds accurately and efficiently, which is particularly useful for reforestation and cover crops.

Fig. 7. Seeding using drone

(Source:https://hamiltonnativeoutpost.com/drone-seeder)

Variable Rate Seeding: By understanding the variability within a field, drones can assist in planting seeds at variable rates to maximize yield.

e. Precision spraying

In addition to monitoring, drones can be equipped with spraying systems to apply pesticides or biological agents precisely where needed. This targeted application minimizes the amount of chemicals used, reducing environmental contamination and the risk of developing pesticide resistance. Precision spraying also enhances the effectiveness of treatments, improving crop health and yield. Targeted spraying of fertilizers, pesticides, or herbicides can be done using drones. They carry tanks filled with plant protection chemicals and apply them precisely where needed, reducing waste and environmental impact. Advanced drones can autonomously navigate fields and spray crops based on pre-determined maps and real-time data, called automated spraying.

Fig. 8. Drone spraying

4. Yield Estimation and Harvest Planning

Fig. 9. UAV imaging

(Source: https://www.pix4d.com/blog/uav-imaging-future-of-yield-prediction-research)

Accurate yield estimation and mapping are critical for planning and resource allocation. Drones can provide detailed spatial data that improve the accuracy of yield predictions. By analyzing growth patterns and health data, drones can help estimate crop yields, aiding in planning harvests and market strategies. They can also determine the optimal time for harvesting by monitoring the ripeness and health of crops.

5. Biomass Estimation and Crop Damage Assessment

By using multispectral imagery, drones can estimate biomass and crop growth stages. Indices such as NDVI correlate strongly with biomass, allowing for precise yield predictions (Tilly *et al.*, 2015). After extreme weather events or pest attacks, drones can quickly assess crop damage, providing critical information for insurance claims and recovery planning (Mulla, 2013).

Environmental, economic and social benefits of drone technology

Drones in agriculture significantly reduce greenhouse gas emissions by optimizing input use and improving efficiency. They provide precise data on crop and soil needs, reducing the need for synthetic fertilizers and pesticides, and lower emissions from agricultural machinery by minimizing field operations. Drones also support soil health and carbon sequestration by monitoring key parameters, enabling practices like cover cropping and reduced tillage to store more carbon. Furthermore, they conserve biodiversity by targeting interventions precisely, reducing harm to non-target species, and managing habitats essential for biodiversity, making it an environment friendly technology.

The economic and social benefits of drone adoption in agriculture are substantial, particularly for smallholder farmers. Drones cut input costs, boost yields through early stress detection, and enhance farm profitability. Advances in technology have made drones more affordable and accessible, with service providers offering affordable solutions, especially in developing regions. Drones democratize access to precise agricultural data, empowering farmers with real-time insights, improving productivity and sustainability. They also create employment and entrepreneurial opportunities, contributing to social equity, rural development, and enhanced food security in rural areas.

Drone technology adoption - challenges and solutions

Regulatory frameworks governing the use of drones vary widely across countries and regions, posing significant barriers to their adoption in agriculture. Restrictions on airspace, privacy concerns, and certification requirements can limit the deployment of drones. Harmonizing regulations to balance safety and innovation is crucial for promoting drone use in agriculture (Barnes et al., 2019; Huang et al., 2020). Moreover, technical expertise is a critical challenge. Operating drones and interpreting data require specialized skills, which many farmers, especially in developing regions, may lack. Training programs and extension services are essential to build local capacity and ensure effective utilization of drone technology (Li et al., 2018).

Despite decreasing costs, affordability remains a barrier, particularly for smallholder farmers. Subsidies, financial incentives, and cooperative models can help lower entry barriers and promote wider adoption (Zhang et al., 2017). Additionally, ensuring that drones and related technologies are accessible to farmers in remote and underserved areas is crucial. Another challenge is data management; the vast amount of data generated by drones poses issues related to storage, analysis, and integration with existing farm management systems. Developing user-friendly platforms and tools for data management and decision-making is essential to maximize the benefits of drone technology (Jones et al., 2021; Thompson et al., 2019).

Conclusion

Drones have emerged as pivotal tools in climate-smart agriculture, offering a wide range of applications that enhance sustainability and efficiency in farming practices. By providing detailed, real-time data on crop monitoring, soil and water management, pest control, and more, drones enable farmers to make informed decisions that optimize resource use and reduce environmental impact. Despite the economic, social, and regulatory challenges associated with drone adoption in agriculture, the benefits they bring in terms of increased productivity, reduced greenhouse gas emissions, and improved livelihoods for farmers are substantial. Moving forward, it is essential to address these challenges through targeted policies, investments in training and capacity building, and the development of user-friendly data management systems to maximize the potential of drone technology in advancing climate-smart agriculture practices. With continued innovation and collaboration, drones are poised to play a crucial role in shaping the future of sustainable agriculture and food security worldwide.

References

Barnes, K., Li, Y., and Wang, N. 2019. Regulatory Considerations for the Adoption of Drones in Agriculture. *J. Agric. Technol.* 12(3):345-362.

Huete, A., Didan, K., Miura, T., Rodriguez, E. P., Gao, X., and Ferreira, L. G. 1997. Overview of the radiometric and biophysical performance of the MODIS vegetation indices. *Remote Sens. Environ.* 83(1-2):195-213.

Huete, A. R. 1988. A soil-adjusted vegetation index (SAVI). *Remote Sens. Environ.* 25(3):295-309.

Huang, J., Zhang, L., and Hu, X. 2020. Drones in Agriculture: Opportunities and Challenges. *Precis. Agric.* 21(2):345-360.

Jones, D., Smith, R., and Patel, K. 2021. Data Management Challenges in Drone-Assisted Agriculture. *Agric. Informatics. J.* 15(3): 229-245.

Lamb, D. W., Brown, R. B., and Adams, M. L. 2008. Precision agriculture: Remote-sensing and ground-based sensor technologies for spatially variable control of crop pests and diseases. *Precis. Agric.* 9(5):277-279.

Li, S., Wang, M., and Wu, J. 2018. Building Technical Expertise for Drone Operations in Agriculture. *Agric. Educ. Training*. 7(4):245-260.

Mahlein, A. K., Rumpf, T., Welke, P., Dehne, H. W., Plümer, L., Steiner, U., and Oerke, E. C. 2013. Development of spectral indices for detecting and identifying plant diseases. *Remote Sens. Environ.*128:21-30.

Matese, A., Baraldi, R., Berton, A., Cesaraccio, C., Di Gennaro, S.F., Duce, P., Facini, O., Mameli, M.G., Piga, A. and Zaldei, A., 2018. Estimation of water stress in grapevines using proximal and remote sensing methods. *Remote Sens*.10(1):114.

Mulla, D. J. 2013. Twenty-five years of remote sensing in precision agriculture: Key advances and remaining knowledge gaps. *Biosystems Eng.* 114(4):358-371.

Rajani, M and Samruddhi S. 2023. Iot based smart farming. *Int. J. Res. Appl. Sci. Eng. Technol.* 2(4):2321-9653.

Rouse, J. W., Haas, R. H., Schell, J. A., and Deering, D. W. 1974. Monitoring vegetation systems in the Great Plains with ERTS. *NASA Spec. Publ.* 351:309.

Thompson, G., Liu, Z., and Miller, P. 2019. Integration of Drone Data with Farm Management Systems. *J. Farm Manag. Syst*. 11(2):150-168.

Tilly, N., Aasen, H., Bareth, G., and Seeling, S. 2015. Fusion of spectral and three-dimensional information for the remote sensing of plant height, biomass, and yield of barley. *Photogrammetrie-Fernerkundung-Geo-Inf.* 6:351-368.

Zarco-Tejada, P. J., González-Dugo, V., and Berni, J. A. 2012. Fluorescence, temperature and narrow-band indices acquired from a UAV platform for water stress detection using a micro-hyperspectral imager and a thermal camera. *Remote Sens. Environ.*117:322-337.

Zhang, Y., Han, X., and Chen, J. 2017. Financial Incentives and Subsidies for Promoting Drone Adoption. *Agric. Econ. Rev.* 9(1):78-93.

https://chatgpt.com/c/e3b94192-09f7-471b-86c7-9ba332584ace.

* * * * * * * *