Recent applications of UAVs in sustainable horticulture: A review

J.S.R. De Silva*, N.M.P.M. Piyasena

Department of Surveying and Geodesy, Faculty of Geomatics, Sabaragamuwa University of Sri Lanka
** rasanjalijayamuni7@gmail.com*

1. Introduction

With the increasing demands in food production and consumption, the modern farming industry has gained more prominence than ever before from several decades (Davis et al., 2016). For streamlining the farming operations in a sustainable agricultural management system, to accurately plan and monitor the existing and ongoing improvements for researchers, agronomists, agricultural engineers, and farmers, the use of unmanned aerial vehicles (UAVs) is a steadily blooming effective approach. Smart agriculture is an active field of science with the usage of robust data analytics to gain effective insights into the crops and fields has a high possibility for future avenues (Sekaran et al., 2020). Particularly for planet well-being and minimizing the adverse health impacts, while acquiring economic benefits, optimizing the sustainability credentials remains a priority (Legun & Sautier, 2018).

Precision agriculture plays a major role to achieve enhanced sustainability measures while enabling agriculture professionals to focus on the existing resources and techniques more effectively to make farming practices more sustainable (Monteiro et al., 2021). Using unmanned aerial vehicles, with the combination of communication and information technologies, artificial intelligence, and advanced data models is one of the most recent applications in precision agriculture, and with high technical advancements like positioning systems, remote sensing abilities with soil and crop sensing software and variable rate technologies (Daponte et al., 2019). Hence, UAVs can be used for a wide range of agricultural applications in horticultural practices including field mapping for crop growth assessments, detection of pests and disease, and apply remedial measures at the early stages, crop and nursery monitoring (Radoglou-Grammatikis et al., 2020). We review the most recent applications regarding UAVs for precision agriculture based sustainable horticulture in this systematic review.

2. Results and Discussion

Most Recent Applications of UAVs on sustainable horticultural practices:

Precision agricultural practices can help farmers in making better-informed decisions for increasing production level, security of constant supply, and profitability (Yost et al., 2019). Though UAVs are not only less expensive than most other agricultural machines, they are also easily operated within a range of technical knowledge (Perz & Wronowski, 2019). However, even though UAVs are not made widely into the agriculture mainstream, they can reduce working hours which is resulting in increased stability of the production upon the demand, measurement accuracy, and productivity (Boursianis et al., 2020). In various environmental conditions UAVs can perform numerous agricultural tasks basically in horticulture with the steadily increasing demand as follows:

A. Mapping

By using high-resolution UAV images within a farmland area, soil conditions of the respective land area and mainly the crop growth status can be measured (Candiago et al., 2015). Since UAVs have the ability to provide 2D and 3D maps, agricultural experts can take advantage of model enhancements and when deciding crop efficiencies (Mahmood et al., 2012). The generated maps by UAVs allow for increasing the profit margin by giving information on homogeneous zones of the vast cultivated fields.

B. Crop Monitoring

Crop monitoring is the task conducted to predict the yield or quality of a crop via analysis of crop data. Crop monitoring is essential for optimal crop production. However, monitoring a large farm requires significant time and labor (Harshani, 2017). Very large farms are often monitored via satellite. However, this is not suitable for precision crop monitoring. Crop monitoring via UAVs has been proposed for this. Thus, high-resolution data has been obtained, and weather effects have been reduced. UAVs are providing important indicators of improvement and productivity by the vegetation index data (Dutta & Goswami, 2020). Nowadays there are more sophisticated UAVs available in the market which are having the self-calculating ability of the vegetative indices such as NDVI and GNDVI (Candiago et al., 2015).

C. Phenotyping

UAVs can quickly gather efficient phenotypic information non-destructively (Yang et al., 2017) to make management and breeding decisions for optimizing agricultural production with the demand of the booming human population all over the world (Tilman et al., 2011). For example, leaf color can be estimated by using UAV-based color sensors that can capture diverse data (Abdulridha et al., 2019), size of plants (Han et al., 2018), canopy cover (Lee & Lee, 2011) average number of flowers (Adamsen et al., 2000), and quantity of fruits in plants (Dorj et al., 2017). To estimate the nitrogen content of plant leaves (Serrano et al., 2002), leaf area index (Boegh et al., 2002), leaf chlorophyll content, plant biomass and to quantify the yield from a field (Solari et al., 2008) spectral sensors of UAVs can also be used. Thermal sensors of UAVs have the ability to roughly measure canopy temperature which is important in calculating water use efficiency and water potentials and can measure stomatal conductance (Santesteban et al., 2017).

D. Yield assessment

Crop yield quantification and quality assessments are vital to commercial level farmers, researchers, insurance agents, agricultural policymakers, local and international agencies (Rembold et al., 2013). By using UAV-based imagery, particularly in combination with artificial intelligence, not only enhancing assessment accuracies but also offers possibilities for reducing or eliminating the need for ground-based surveys (Mekonnen et al., 2020). The collective data is useful for financial planning, estimating prior crop requirements to go for a reasonable yield, insurance purposes, timely harvest for optimization of the yield quality, and to predict storage requirements.

E. Planting

Planting can be made more efficient in vast fields using UAVs. They make it possible to plant in an uneven field as well. Nowadays there is a modified system for perfect plant growth: properly distributed seeds in proper environmental conditions can be accomplished by UAVs. Although to produce efficient planting tasks, the use of UAVs is still in the development stage, and UAVs that are equipped with high image recognition capacity can optimize planting tasks efficiently (Lu et al., 2021).

F. Spraying

Compared to a conventional chemical sprayer or a wide range-area sprayer, UAVs can maximize the efficiency of chemical applications such as pesticides, herbicides, and nutrient solutions by spraying only to the identified areas which are in extreme need of those chemicals (Zhu et al., 2019). A selective application can be done by drones to reduce the unnecessary applications of chemicals to the field while reducing the impact on the environment and increasing the profit margin by eliminating the higher costs for chemicals. Also, this strategy can achieve chemical applications up to 50 ha per day in large-scale farms and it requires only about 10 min of work per 0.5 ha of area. Thus, UAVs can help commercial-level farmers to reduce labor requirements as well (Islam et al., 2021). Recent studies have shown that UAVs are used to spray chemicals onto the plant canopies at various heights by using height sensors. Recently researches have also been conducted by developing precision algorithms to improve the accuracy of control over crops (Burgués & Marco, 2020).

G. Irrigation

UAVs with multi-spectral cameras and heat sensors can use to detect areas with water scarcity and recent researches show that UAVs with electromagnetic spectrum sensors and RGB and NIR cameras can be used to obtain data for water management and irrigation control to achieve maximum irrigation effects (Hassan-Esfahani et al., 2015). Most recent studies have focused on image processing and data acquisition of drones. However, some UAVs also perform plant irrigation tasks in areas where water is scarce by loading water instead of pesticides (Talaviya et al., 2020). With future smart farming, an irrigation automation system will be applied effectively by using a collaborative system of integrating UAVs, Unmanned Ground Vehicles (UGVs), or swarms (Choi & Kim, 2013).

H. Diagnosis of Insect Pests

Pests and diseases caused enormous damage to the field and it resulted in the high reduction of the profit in huge lots compared to other problems (Tsouros et al., 2019). Early diagnosis is essential because pest damages spread quickly in a blink of an eye. To achieve this target high-resolution RGB cameras and multi-spectrum sensors mounted on UAVs were combined to examine fields for infections. They provide maps with high accuracy and fast pathogen detection using high-quality spectral measurements.

I. Artificial Pollination

As the population of natural pollinators such as honeybees continues to decrease worldwide with the environmental pollution, people tend to do artificial pollination. Since it was a labor-intensive practice, people nowadays trying to do artificial pollination through small UAVs which can carry pollen from its extraction site to the field with the integration of artificial intelligence, ground positioning systems (GPS) as well as cameras with UAV robots (Fan et al., 2021). Pollination has also been carried out using the wind power generated from UAVs, rather than by direct contact. Some recent research shows that the wind field created by UAV exerted an asymmetrical influence on pollen distribution (Jiyu et al., 2017).

3. Conclusions

Agricultural UAVs show diverse potential in agriculture mainly in horticultural practices regarding sustainable development. This study investigated the importance and the application of UAVs for agricultural practices on horticulture and presented a systematic review of the agricultural UAVs which have outstanding utilization and potential in mapping, phenotyping, crop assessments, pest and diseases early detection, irrigation, chemical spraying, and planting mainly. Therefore, this paper contributes to future research, markets, and modifications of existing capabilities of agricultural UAVs on horticulture.

4. References

Boegh, E., Soegaard, H., Broge, N., Hasager, C., Jensen, N., Schelde, K., & Thomsen, A. (2002). Airborne multispectral data for quantifying leaf area index, nitrogen concentration, and photosynthetic efficiency in agriculture. *Remote Sensing Of Environment*, *81*(2-3), 179-193.

Dutta, G., & Goswami, P. (2020). Application of drones in agriculture: A review. *International Journal of Chemical Studies*, *8*(5), 181-187.

Mekonnen, Y., Namuduri, S., Burton, L., Sarwat, A., & Bhansali, S. (2020). Review—Machine Learning Techniques in Wireless Sensor Network Based Precision Agriculture. *Journal of The Electrochemical Society*, *167*(3), 037522.

Monteiro, A., Santos, S., & Gonçalves, P. (2021). Precision Agriculture for Crop and Livestock Farming - Brief Review. *Animals*, *11*(8), 2345.

Perz, R., & Wronowski, K. (2019). UAV application for precision agriculture. *Aircraft Engineering and Aerospace Technology*, *91*(2), 257-263.