Opinion

Can Remote Sensing and Artificial Intelligence Based Technologies Benefit Modern Agriculture and Food Production Systems?

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Abstract

The ever-changing climate coupled with increasing demand for more land and water resources along with the threats of global pandemic have put a lot of pressure on modern agriculture and food production systems. It is critical to maintain environmental and economic sustainability of current and future food supply systems in order to secure enough food to feed and sustain a fast-growing global population. To this end, new innovations in scientific and technological advances are thought to be essential to gain insights into the interaction of various components of the agricultural system ranging from the cell to the field level. There have been advances in genetic tools that have enabled superior food production. However, the large-scale assessment of crop status in the field still remains a formidable challenge. Recent innovations in remote sensing and Artificial Intelligence (AI) based agriculture and food production have shown a lot promise in quantifying field scale phenotypic information accurately. In addition, studies have suggested the possibility to integrate the big data into predictive and prescriptive management tools. In this opinion, we have assessed the use of remote sensing and AI technologies that could potentially improve the resilience of agricultural systems and help address the agricultural and human nutrition challenges over the next decades.

Keywords: *Remote sensing; artificial intelligence; food production; agriculture; big data*

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INTRODUCTION

During the past several decades, systems that oversaw worldwide agriculture production faced serious challenges. These include limited water supply for irrigation, significant increases in production costs and a reduced farm workforce along with climate change. In addition, it is to be noted that the recent global pandemic from COVID-19 caused significant disruption of food production and supply systems almost everywhere in the world. It is believed that all these factors could harm the economic and environmental sustainability of the current and future food supply systems that are critical to feed the increasing global population [1-4].

Various recent studies have indicated that despite research advances made in agriculture tools, processes and strategies, a renewed drive in new innovations in the agriculture biotechnology sector will be needed in order to mitigate the challenges faced by persistent climate change and other factors listed above. The key issue is developing capability to produce sufficient quality food for the fast-growing global population sustainably. To this end, biotechnologists and agriculture scientists have focused on utilizing state-of-the-art technologies along with developing strategies to integrate them into highly productive agriculture systems [4].

Among existing techniques, dynamic crop simulation models are considered useful tools for integrating diverse components of agriculture systems. This enables to explore how those components function within the system. Recent advances in artificial intelligence (AI) within agriculture disciplines have shown tremendous potential to leverage big data for developing modern agriculture and food production systems. To make it easily accessible, the use of Unmanned Aircraft Systems (UAS) and remote sensing is of high interest and currently gaining attention. UAS based strategies offer unprecedented opportunity to empower advanced analytics for managing agricultural systems. This can result in improving the resiliency and efficiency of production systems. To this end, substantial research and developments have focused on the use of remote sensing technology for sustainable agriculture by adopting UAS technologies. This is believed to open up new avenues in future studies focusing on integration with space borne remote sensing data for national and global scale studies [4-7].

UAS technology platform is based on the concept of Unmanned Aerial Vehicle (UAV) structure that is used to mount extra tools and sensors. Several such platforms are available to employ that include parachutes, blimps, gliders, rotorcrafts, and fixed-wing aircrafts. Among all these technology platforms, the frequently used platforms in agriculture are fixed-wing aircrafts and rotorcrafts and are popular because of their ability to cover vast areas of land quickly and create datasets with relatively high temporal resolution [8]. These platforms are considered promising for applications in large-scale field mapping and spraying. Especially, rotorcrafts are very attractive for their ease of use that does not require runway, lower cost, and their ability to hover that results in high spatial resolution imaging (Figure 1) [4].

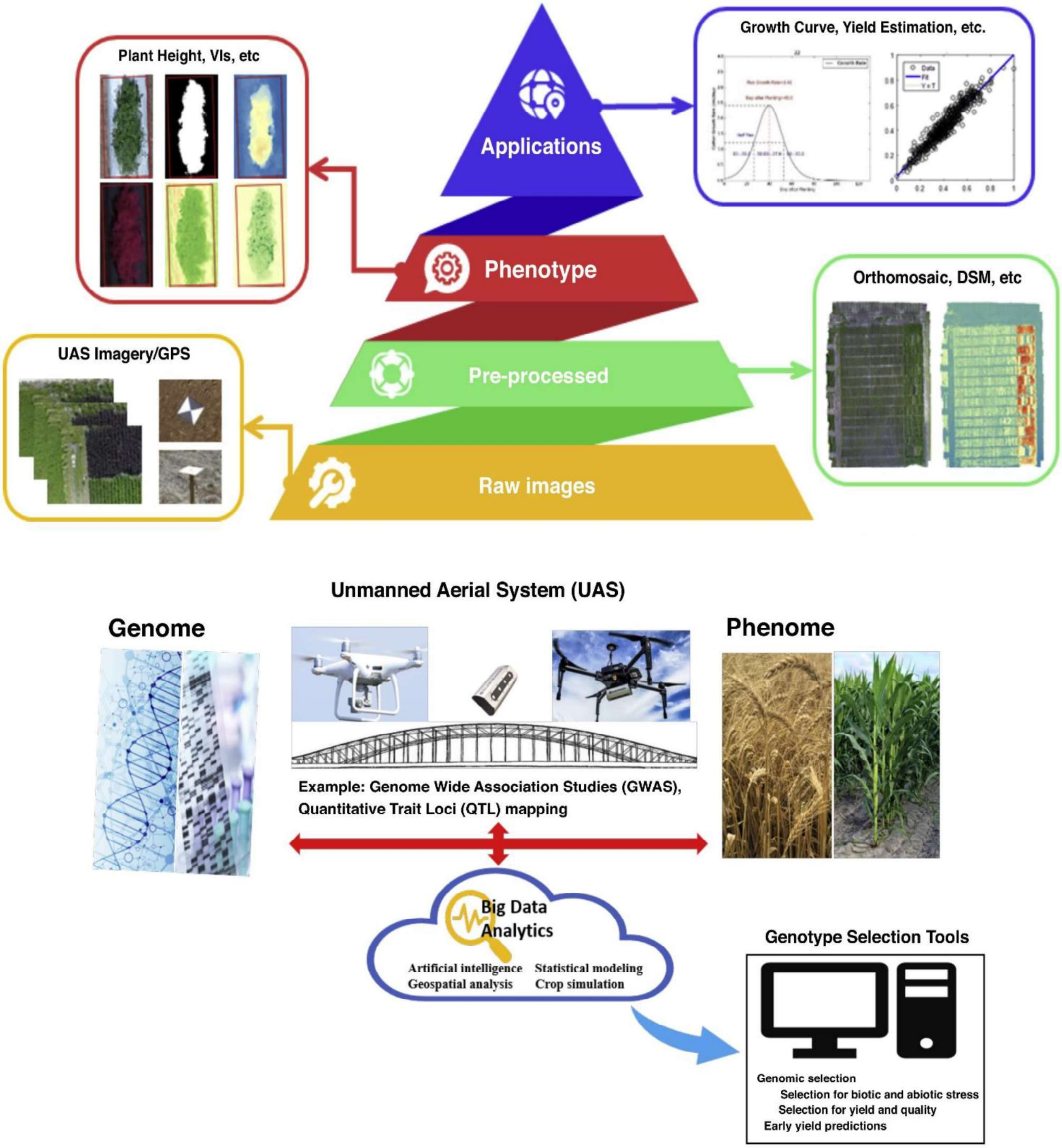

Figure 1: *(Top) The development workflow for UAS based HTP application. Using this platform, the quality of raw data can result in the accuracy of developed applications (VIs-Vegetation Indices, GPS-Global Positioning System, DSM-Digital Surface Model). (Bottom) The technology concept for bridging the genome-phenome gap using an Unmanned Aerial System (UAS) based High Throughput Phenotyping (HTP) system [**Source:** Current Opinion in Biotechnology (2021)].*

Despite the promise of UAS based operation, it is often challenging to deploy individual physical sensors because they are costly and time-consuming. In addition, to keep them operational in the field is somewhat also challenging due to the fact that they often interfere with field operations that include tillage, planting, spraying, and harvesting [4]. To overcome these challenges, one viable route has been suggested that involve plants integrate genetics and its surrounding environments. This can be done by responding to soil physical and chemical properties, moisture availability, biotic and abiotic factors along with management practices. For example, researchers have proposed a strategy that involves plants serving as field-based biological probes, which can be assessed by sensors on-board UAS (Figure 1) [4].

An area of concern is the limitation of conventional methods of collecting crop data that often fail to capture in-field variations. This happens because of limited sampling size that are prone to a certain level of subjectivity. Researchers have proposed a route to address this issue by employing UAS equipped with appropriate sensors. This strategy can result in a cost-effective process to rapidly measure the time course of plant growth most accurately. These are considered relatively affordable systems that can be leveraged for collecting fine spatial and high temporal resolution data that are not possible to obtain otherwise by using traditional airborne and space borne remote sensing platforms [5-7].

The common use of UAS in agriculture is based on aerial imaging. This has been the driven factor for the design and development of imaging sensors and cameras that can be employed to operate these systems on board. There are several important considerations for on board operation. For example, a particular payload is required in every UAV platform. However, it limits the sizes of imaging equipment. Similarly, it has been observed that the UAS suffer from decreased speed, stability, and flight time with increasing payload. Further, an important consideration for effective equipping a UAV is the velocity at which it will be flying at the time of capturing images. Blurring in images is also a subject of concern at higher flight speeds. This can result in motion without the proper cameras and supporting algorithms. This problem can be overcome by rotorcrafts with greater hovering capabilities. Researchers have demonstrated devices comprising important sensors and cameras that include standard RGB cameras, multispectral and NIR cameras, hyperspectral cameras, thermal sensors, and also depth sensors [8-10].

While several breeding programs have been shown by adopting UAS, critical long-term challenges still remain to be addressed. These are related to data collection/processing and interpretation of the processed data that are required to address before breeders can be fully operational embracing these systems. It is believed that integrity and quality of the raw data will be crucial with the current rapid progress in raw data moving through the application development pipeline in all future applications. This will be needed to ensure the accuracy of predictive models (Figure 1) [4]. To this end, researchers have proposed developing standard protocols for data collection, processing, and interpretation. It is believed that UAS based High Throughput Phenotyping (HTP) system can have a significant impact on the rapidly evolving AI sector. Some studies have shown notable performance using a large dataset to train AI models even when noisy data is involved. This suggests that it is probably essential to obtain the volume of training data for developing robust AI models for agriculture applications [4].

Another area is currently being explored that includes advanced genomics for leveraging analytical tools for crop breeding programs. It is believed that it will help understand the molecular basis of complex traits. For example, next-generation sequencing (NGS) technology can be employed to improve the efficiency of marker-assisted and genomic selection. This is considered advantageous as it reduces the amount of time and also cost that is required needed to genotype a large number of breeding lines. Researchers have shown significant breakthrough in the development of high yielding, superior quality rice varieties. This was achieved by pyramiding multiple complex traits using high-throughput genotyping methodologies [4]. Further, there is a possibility of obtaining multi-temporal phenotypic traits. This can be accomplished by using UAS that can reveal important information about the genotype, environment, and interactions. Thus, merging the fields of genomics and UAS based phenomics could pave the way to future breakthroughs to dissect complex agronomic traits and identify genes governing these traits. Future research and developments are anticipated to focus on this integration of genomics and UAS based phenomics to achieve the ultimate goals of increasing the size, efficiency, and genetic gain of breeding programs (Figure 1) [4].

In conclusion, over the years, a significant volume in agriculture research has focused on developing sustainable crop management practices. In all future studies, it is believed that the attention will be shifted towards improving resource use efficiency of agricultural systems in order to meet current challenges and future needs for enhanced food production. To achieve the goals, it is anticipated that UAS based HTP system will be critical to provide a reliable platform that can be leveraged to quantify phenotypic information at field scales. Further, the possibility to integrate with the GWAS will be a promising strategy that will help speed up breeding cycles in many crops. To this end, new innovations are already taking place that involves coupling the UAS based HTP system with space borne remote sensing, AI, and crop simulation models, these are critically important steps to develop large-area digital agriculture applications in the future.

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