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Abstract

The use of unmanned aircraft systems (UASs), or consumer drones, in agriculture has the potential to revolutionize the way certain farm practices are conducted and the way science, technology, engineering, and math principles can be taught. Currently, there is need for UAS training for both adults and youths, and that need will increase with the expected growth of the UAS industry. This article addresses the need to include UASs in Extension programming, the associated legalities, and the best types of UASs to use in such programming.

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Introduction

An unmanned aircraft system (UAS), or consumer drone, is an aircraft that can be flown remotely by a human operator or programmed to fly autonomously for a specified purpose. In agriculture, this purpose is usually for the collection of digital imagery to help identify and troubleshoot issues in the field. UASs also can be useful in education as tools for teaching science, technology, engineering, and math (STEM) fundamentals. UAS technology can be a great asset to Extension professionals in creating adult and youth programs that result in high levels of engagement and impact, assuming that specific interests and needs are identified first. Therefore, an understanding of how these systems can be incorporated into Extension programs can benefit a broad range of Extension professionals and have a wide variety of impacts for Extension. This article addresses (a) the need to incorporate UAS technology into Extension agricultural programming for adults and 4-H youths, (b) the best method for establishing such programming under current legal requirements, and (c) various UASs and the uses they may have in Extension programming.

Need for UAS Technology in Extension Agricultural Programming

Background for Use of UASs in Adult Agricultural Programming

A report by the World Resources Institute, World Bank, and United Nations indicated that food production would need to increase 32% faster from 2006 to 2050 than it had from 1962 to 2006 to produce enough food for a world population that is expected to exceed 9 billion (World Resources Institute, 2014). Additionally, a recent report from the U.S. Department of Agriculture indicated that U.S. farmland decreased by 1 million ac between 2014 and 2015 (U.S. Department of Agriculture [USDA] National Agricultural Statistics Service [NASS], 2016). More optimistic news is that consumer drones have huge potential for use in advancing sustainable agricultural systems. According to the American Farm Bureau Federation, the use of UASs in agriculture could provide a return on investment of $12 per acre for corn and $2 to $3 per acre for soybean and wheat (Wihbey, 2015). Other researchers observed that collecting data by using UASs was cheaper than doing so by using a plane or a satellite for areas of 5 ha (12.4 ac), although collecting data via UAS was more costly at 50 ha (124 ac) (Matese et al., 2015). UASs have been used to collect data on soil properties (Abbas, Khan, Hussain, Hanjra, & Akbar, 2013; Ge, Thomasson, & Sui, 2011; López-Granados, Jurado-Expósito, Peña-Barragán, & García-Torres, 2005); weed prevalence (De Castro, López-Granados, & Jurado-Expósito, 2013; Mesas-Carrascosa et al., 2015; Peña, Torres-Sánchez, Serrano-Pérez, de Castro, & López-Granados, 2015); yield, plant cover, and plant nitrogen concentrations (Bendig et al., 2014; Vega, Ramíreza, Saiza, & Rosúab, 2015); precision chemical application (Huang, Hoffman, Lan, Fritz, & Thomson, 2015); plant pathogen detection (Calderón, Montes-Borrego, Landa, Navas-Cortés, & Zarco-Tejada, 2014); drip irrigation performance (Jimenez-Bello, Royuela, Manzano, Zarco-Tejada, & Intrigliolo, 2013); and plant water status (Baluga et al., 2012). Although many foreign countries are creating opportunities for farmers to use UAS technology, the United States has been much slower in doing so. The U.S. commercial UAS market lags behind those of countries in Asia, Europe, and South America. For example, Japan currently has about 10,000 consumer drones in agriculture-related operations (Wihbey, 2015); India is working toward using UASs to monitor the health of coffee crops (Nair-Ghaswalla, 2016); and UASs are used in Panama in sugarcane, banana, and rice production (Saldaña, 2015).

In addition to being useful in specialized applications, such as those described previously that involve various sensor capabilities (e.g., determining nitrogen status, identifying crop stress), UASs also are valuable for the normal digital images and video they can produce. Farmers can use UASs to identify changes in a field related to characteristics such as soil moisture and crop quality that are not apparent from the ground. For trouble spots identified by a UAS, the farmer can investigate further on the ground, thereby improving his or her overall efficiency. Also, the ability to take multiple images or video over time allows farmers to determine general temporal changes in their fields. UAS systems also can help save time and labor by monitoring animal or forest production systems. For example, a farmer in New Zealand has used his UAS to identify ewes that have become separated from the herd or are having trouble lambing as well as to check on water supplies on his 466-ha farm (Daneshkhu, 2016). This daily routine had taken 2 hr to accomplish, but with his UAS, he was able to do it in 20 min, allowing for more frequent monitoring and lower risks of animal mortality (Daneshkhu, 2016). Moreover, using UASs to monitor crop and animal systems can allow U.S. farmers, for whom the average age is over 58, to reduce overall labor requirements (USDA NASS, 2012). Of course, the use of UASs will not fully replace important crop scouting at the field scale, but it can reduce some in-field visits by the farmer.

Background for Use of UASs in Agriculture-Related Youth Programming

According to Dr. Kathryn J. Boor, dean of the College of Agricultural and Life Sciences at Cornell University, the ability to continue to feed a growing world population necessitates having "a new workforce attracted to agricultural careers" and "partnerships with the public to ensure that our citizens support adoption of innovative technologies into our agricultural systems" (Boor, 2016, para. 2). Boor (2016) also identified the need to "introduce younger students—elementary, middle and high school students—in urban as well as rural areas to the possibilities of careers in agriculture and related research fields" (para. 4). Developing this understanding and awareness early on can lead to greater numbers of agricultural students trained for agricultural careers. Currently, almost 40% of all new positions in the areas of agriculture, food, renewable natural resources, or the environment will be left unfilled because there are not enough college graduates with applicable training (USDA, 2015).

To prepare for future careers in agriculture and related fields, today's students must be proficient in STEM. The National Science Foundation (NSF) (2016) concluded that most fourth, eighth, and 12th graders did not demonstrate proficiency in the knowledge and skills taught at their grade levels in mathematics. Specifically, only about 42% of fourth graders, 36% of eighth graders, and 26% of 12th graders performed at or above the relevant proficiency level in mathematics on the National Assessment of Educational Progress tests in 2013 (NSF, 2016). Moreover, of developed nations, the United States ranked 17th and 24th, respectively, for 15-year-old students' science literacy assessment scores and math literacy assessment scores in 2012 (NSF, 2016). Also in 2012, the United States conferred only 14% of the natural science and engineering degrees bestowed in total in the eight countries ranking highest in that regard (NSF, 2016). Though the United States ranked second of the eight countries, China ranked first, having conferred 60% of the degrees (NSF, 2016). And the need for science and engineering graduates nationwide will only continue to grow. According to the Bureau of Labor Statistics, employment levels in computer/mathematical occupations and engineering occupations are expected to grow by 22% and 10%, respectively, throughout the decade ending in 2020 (Lockard & Wolf, 2012).

Though there is no research related to the impact of UAS use on student learning, there are many programs in which UASs are used for STEM education (Central Michigan University, 2016; Passwaters, 2015; University of New Mexico, 2016; Villegas, 2016). For one program curriculum that involved UASs and was related to the Next Generation Science Standards, student participants reported that the UASs made learning science and math more fun (Gillani & Gillani, 2015). Additional information on the use and impacts of robotics in the classroom can be related to the use of UASs. Hussain, Lindh, and Shukur (2006) found that youths showed better performance in mathematics as a result of robotics training. In addition, Barker and Ansorge (2007) reported that the use of robotics was effective in teaching youths about STEM concepts such as computer programming, mathematics, and engineering. Lastly, Sullivan (2008) reported that nearly all youth participants in a robotics program used seven out of eight thinking skills (observation, estimation, and manipulation) and science process skills (evaluation of solution, hypothesis generation, hypothesis testing, control of robotics). Sullivan (2008) also noted that students improved their systems understanding through robotics.

Need for UAS-Related Educational Materials for Adults and Youths

According to the Association for Unmanned Vehicle Systems International, annual UAS sales for agriculture are expected to increase by around 400% through 2025 (Jenkins & Vasigh, 2013). This means there will be a significant increase in the need for information related to UASs, including information about procedures for flying them safely, available options and features, troubleshooting for equipment malfunctions, and legality of use by individuals and within educational programs, as well as development of UAS-related adult and youth agricultural curricula. There is no published research related to farmer knowledge of UASs; however, in a recent survey of agricultural cooperative managers, about 55% indicated having very little knowledge of UASs, and about 13% indicated having none (Turner, Kenkel, Holcomb, & Arnall, 2016). As the technology is relatively new and relevant regulations have only recently been eased, it is highly probable that most farmers also have little knowledge of how to use UASs on their farms. Extension specialists are in a position to develop and implement curricula to meet UAS-related educational needs. Yet there is little or no practical information on interest in UASs, relevant programming needs, or methods for implementing UAS technology in Extension activities.

How to Use UASs Legally in Extension Programming

The best way for an Extension specialist or agent to be able to use UASs to provide hands-on training to farmers or teach youths important STEM principles is to apply for a remote pilot certificate with a small UAS (4.4 lb to 55 lb) rating. (New rules will be forthcoming related to micro UASs, those under 4.4 lb, which may involve even fewer requirements.) Having a small UAS remote pilot certificate would allow the specialist or agent to conduct fee-based trainings while remaining within the parameters of federal law. The remote pilot certificate is a relatively new designation, having come into existence in August 2016, under Part 107 of the Code of Federal Regulations (Federal Aviation Administration, 2016). The Part 107 regulation represents a loosening of earlier restrictions, allows for greater application of UAS technology, and provides for greater ease of use by Extension professionals. Under the small UAS regulations, to receive and maintain a remote pilot certificate, an operator must be at least 16 years old and must pass a Transportation Security Administration background check, a written (multiple-choice) aeronautical knowledge exam at a Federal Aviation Administration (FAA)–approved testing center (test cost is $150), and recurrent aeronautical knowledge tests every 2 years. All UASs must be registered through the FAA; registration can be done online (https://registermyuas.faa.gov/) and is $5 per UAS for 3 years. The small UAS regulation sets forth the following basic rules: The operator must conduct a preflight check to ensure safe operation; operation is allowed during daylight or twilight hours only; and the UAS should remain within line of sight and should not be flown directly above other individuals. Most restrictions may be waived; however, a waiver must be applied for and granted by the FAA. A UAS can be placed in an autonomous ("autopilot") mode; however, the operator must be able to take over if something were to happen. Also, a UAS may be flown to a maximum altitude of 400 ft and at a maximum ground speed of 100 mph. It can operate in Class G airspace without air traffic control approval. Lastly, an uncertified person may fly a UAS under an operator's supervision.

How to Select the Right UASs for Extension Programming

There are essentially three main types of UASs that can be implemented in Extension programming. They vary according to size, price, and ease of use.

Smaller, less expensive UASs are most appropriate for a youth program where multiple crashes could occur. In such a situation, it also is important to ensure that the UAS can be repaired easily and that replacement parts are available. These UASs can come as part of a kit that allows the user to assemble the UAS and, thereby, learn about its components and how they are important for flight. These kits usually include their own curricula comprising various activities and cost $2,500 to $4,000. Individual hobby UASs can be purchased for much cheaper ($50), but additional accessories and a curriculum would be needed, and they might not have the same versatility with regard to various learning applications as kit UASs do.

The next level of UAS is one that could be used in adult agriculture programs or advanced-level STEM programs. These UASs are the more professional models that a farmer might use in the field. They usually cost around $2,000, are relatively durable and easy to repair, and are better than higher end models for first-time users.

The last option is a UAS that has greater imaging functions, with the ability to measure field issues such as crop stress using the infrared spectrum. These systems (which include a FLIR [forward looking infrared] camera) can cost $7,000 and are necessary only for teaching advanced courses focused on using the imaging technology to make specialized assessments, such as those related to plant nitrogen concentrations or water status. These systems also can be incorporated into GIS software training (Milla, Lorenzo, & Brown, 2005) to address methods used for integrating digital images captured by UASs to create field maps containing this specific information.

Conclusions

Developing and implementing UAS curricula to use in training agents, farmers, and youths is a current need that will continue to increase as more UASs are purchased and used in agriculture. Due to modified federal regulations, Extension professionals can become certified remote pilot operators and conduct fee-based programs for stakeholders, with the variation in available UASs providing the flexibility needed to make these programs successful. It is important, however, for Extension professionals to follow current legal restrictions and identify systems that are right for their audiences to ensure safe, sustainable programming with relevant impacts.

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