Economic Potential of Unmanned Aircraft in Agricultural and Rural Electric Cooperatives

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Selected paper prepared for presentation at the Southern Agricultural Economics Association (SAEA) Annual Meeting, San Antonio, Texas, 6-9 February 2016

Introduction

The Association of Unmanned Vehicle Systems International (AUVSI) predicts that 80% of the United States' unmanned aerial vehicle (UAV), market will be in agriculture (2015). Leaders of agricultural cooperatives and rural electric cooperatives have noted this potential but are unsure as to how this technology could lead to cost savings or revenue growth.. Previous research indicates that UAVs also referred to as, unmanned aerial systems (UAS), could potentially be beneficial in completing routine tasks already performed by electric and agricultural cooperatives. Additionally, they could potentially provide services that cooperatives currently are not offering. The broad goal of this research is to investigate the economic feasibility of UAVs for farm supply and rural electric cooperatives.

Impact of the Cooperative Firm

Agricultural cooperatives store, market, process and transport agricultural commodities and supply a wide range of inputs including feed, fertilizer, petroleum and crop protectants. Many farm supply cooperatives also provide services such as crop input application, soil testing and crop scouting. As of 2013, the United States Department of Agriculture (USDA) reported 2,186 agricultural cooperatives with over 2 million member-owners collectively generated over $246.1 billion in gross business volume. (2014). In addition, those same cooperatives provided over 136,000 full-time jobs and 55,000 seasonal or temporary jobs in areas where employment may be limited (USDA 2014).

Rural Electric Cooperatives (RECs) own and maintain 2.5 million miles, or 42 percent, of the nation's electric distribution lines, while delivering 11 percent of the total kilowatt‑hours sold in the U.S. each year. (NCERA 2014). The National Rural Electric Cooperative Association reports that over 900 rural electric cooperatives (RECs) employed more than 70,000 people (NRECA 2014) across the U.S. in 2014. Those 900 cooperatives serve an estimated 42 million people and 18.5 million different establishments, including both homes, businesses, and industrial locations. RECs generate a relative low average of $15,000 in revenue per mile of line, compared to the much larger $75,500 and $113,000 per mile generated by IOUs and publicly owned firms, respectively (NRECA 2014). Much of this disparity can be attributed to the sparsely populated areas in which cooperatives often provide service and the low ratio of members per mile of line. Cooperatives average 7.4 customers (member-owners) per mile, compared to publicly owned utilities and IOUs at 48 and 34 customers per mile, respectively. Inherently, RECs face tighter profit margins as a result of the vast network and sparse population of their rural member/customer base. This poses challenges in efficiency, yet presents opportunities for research and improvement in areas such as UAVs. Because they service more sparsly populated rural areas, RECs are challenged to service and maintain their distribution infrastructure in a cost effective manner.

. Both farm supply and rural electric cooperatives are alert to potential technologies that would add value to their member-owners. Many farm supply cooperatives have adopted variable rate fertilizer application services and some are assisting members with precision agricultural data. Agricultural cooperatives operate as an extension of the farm firm. They are therefore interesting in technologies that either allow them to operate more efficiently or those that add value at the farm level. Rural electric cooperatives (RECs) are also continually interested in adopting new technologies. Historically, many of those investments have concentrated on improving service reliability and minimizing downtime of their expansive network. Many RECs have invested in renewable energy technologies and in “smart meters” that allow two way communications between the customer meter and the central system.

UAVs as a Proposed Alternative

Because of these unique, yet interrelated goals mentioned above, both agricultural cooperatives and RECs could benefit from utilizing imagery and geospatial data relevant to their members’ farms or electric distribution system, respectively. Many agricultural cooperatives are currently offering crop scouting services to visually inspect fields and improve management practices. However, manual crop scouting is labor intensive and results in human-error which can impact the effectiveness of the inspection process. The use of UAVs could add efficiency to the crop scouting operation by allowing the technician to rapidly identify potential problem areas in the field. Similarly, RECs practice routine line inspection primarily by driving through the distribution area and visually inspecting the line condition. Generation and transmission cooperatives (the centralized cooperatives that supply the power to the local RECs) may also use fixed wing and helicopter-aided inspection methods. However, those technologies are typically not practical at the local REC level. It is anticipated that unmanned aerial vehicles (UAVs) could increase the efficiency and precision of the inspection process. The use of a UAV could allow a technician to inspect line more rapidly and the UAV could also be outfitted with near infra red cameras that could potentially detect arching and other problems which are not obvious in visual inspection. In many areas, REC distribution lines are not accessible by roads. That necessitates the technician to walk the line or travel in an all terrain vehicle. UAV adoption could therefore also have advantages in worker safety. As a relatively new topic, little research exists in way of utilizing unmanned aircraft specifically in agricultural or rural electric cooperatives. However, some research does attempt to quantify and qualify some of the potential uses, benefits, and limitations of UAVs in the broader realm of agriculture and the electric utility industry. That research proves to provide valuable insight into this area of interest.

UAVs in Agriculture

Dating back to as early as the 1950s, precision agriculture is a popularized management technique that has revolutionized the agriculture industry (Colewell 1956). By managing fields with spatial variability, there are potential savings on the efficient application of inputs such as herbicide and fertilizer. Crop scouting, also referred to as field scouting, is historically the method which producers would use to manually determine pest and weed pressure, among other things, to make recommendation on the application of inputs and other management decisions. However, manual crop scouting is time consuming and relies on random sampling which may produce inaccuracies through human-error.

With a recent rise in availability of commercial unmanned aircraft, agricultural cooperatives could potentially utilize UAVs as a precision agriculture technique to scout crops and obtain high resolution imagery, data, and information relative to pre-existing methods such as satellite imaging or manual crop scouting. This would be offered as a service to members (farmers) of agricultural cooperatives, much like existing crop scouting practices.

In their recent study, Zhang and Kovacs analyzed using small UAVs as a low cost alternative to more traditional precision agriculture methods (2012). Their research concluded that UAVs possess many benefits as a method of capturing geospatial data for precision agriculture, but high costs and unknown reliability may cause a lack of interest at the farm level. However in the four year gap between our research and that of Zhang and Kovacs, significant advancements in unmanned aircraft and sensing technologies have occurred. Furthermore, a different level of awareness is expected to exist as consumer “drones” have been popularized by the media. Mainstream non-ag entities such as Seattle, Washington based merchant Amazon.com, Inc. have created a buzz around the term “drone”, referring to the polyonymous UAV (Huffington Post 2015). In response, survey results of Oklahoma agricultural cooperatives are included later in this paper to capture the awareness and interest levels of cooperative management.

Other research performed on Italian vineyards concluded that utilizing unmanned aircraft unmanned aircraft could significant improve sustainability, efficiency of inputs due to variable rate mapping, and improve overall profits for farmers (Primicerio et. al 2012). Like many common precision agriculture imagery techniques, they utilized the Normalized Difference Vegetation Index (NDVI) which indicates plants photosynthetic activity or simply “greenness.” Other notable research conclusions included the significance of affordability and the simplicity and autonomy of unmanned aircraft operation.

Our research does capture some of the affordability aspect of the UAV initial costs. However, due to the structure of cooperative firms we anticipate initial costs to be less prohibitive as these costs are taken on by the cooperative and spread out over the member-owners. We also assume that simplicity is not a determining factor in this study as agricultural-specific UAVs are now more prominent and refined than primitive, less-specialized models in 2012. Additionally, we assume that operators of the UAV will be trained individuals.

In terms of the uniqueness of the data produced by UAVS, the multispectral imaging produced by UAVs is typically of much higher quality than that of other imaging counterparts. The push for close-proximity measurements stems from the low spatial resolution and infrequency of temporal-data that satellite imagery currently provides in precision agriculture.

Lelong et al. refer to this in their article assessing the sensor technology currently available in unmanned aircraft used in crop scouting of wheat fields (2008). Like the majority of literature available, their assessment targets capturing indices such as Normalized Difference Vegetation Index (NDVI), Soil-adjusted Vegetation Index (SAVI), Green Normalized Difference Vegetation Index (GNDVI), and Greenness Index (GI) to provide quantitative insight on plant health and progress through derived Leaf Area Indexing and Nitrogen Uptake maps. They concluded that cost-effective UAVs are indeed relevant and provide enough precision to continue research efforts.

Matese et al.further analyze the benefits and drawbacks of unmanned aircraft in precision agriculture (PA), versus using traditional manned aircraft and satellite imagery (2015). Like others, these authors used the NDVI derived from multispectral images to provide a basis in which to compare consistently across PA methods. They allude to the fact that satellite imagery can map large areas of cropland but does not always provide sufficient quality data for PA applications. Some issues with satellite imagery include low resolution (both spatial and temporal), coarse imagery. Therefore, satellite data may work in certain instances, but isn't always beneficial in an intra-season crop scouting sense. However, it can be beneficial for many other applications in agriculture.

The research by Matese et al. continued by stating that UAVs, satellites, and manned aircraft all possess distinct advantages and disadvantages (2015). The main differences include acquisition and processing costs, temporal and spatial resolution, coverage speed, and reliability (2015). Uniquely, these researchers performed a break-even analysis between UAVs, satellites, and manned aircraft imaging. Their analysis took the position of acquiring these images from a third-party expert, therefore ignoring initial costs taken on by the owner. However, pricing data would indicate that UAVs would rank among the lowest of the three alternatives in initial costs. Their results concluded that an area of slightly greater than five hectares (or 12.36 acres) was the break-even point of the three imaging alternatives. Beyond this point to at least 50 hectares (123.56 acres), satellite and manned aircraft were more economically efficient.

That research does provide valuable information, but is inadequate in certain areas for American production agriculture. Firstly, most U.S. crop producers exceed the five to 50 hectares this study encompasses. As these mechanisms are used over a larger acreage base, we assume different marginal operating costs of data acquisition for the next acre. Secondly, this research assumes a third party owning the UAV or other imaging device. If the cooperative is the owner and operator of the UAV, acquisition and processing fees should differ from those of a third-party contractor. Therefore, further research must be done to extend this thought process to the cooperative business model we analyze to reflect both ownership of the UAV and the larger acreage covered.

Although not specific to UAVs but certainly relevant to precision agriculture and agriculture sensing, several articles outline the use of other autonomous (robotic-type) vehicles in precision agriculture applications. One example by Pedersen, et. al performs a feasibility study of using autonomous vehicles equipped with sensor technology to determine the cost-effectiveness of this alternative in croup scouting, weeding, and grass cutting on golf courses (2005). Although the construction of this autonomous vehicle differs from that of a UAV, the authors estimated a 20% reduction in robotic scouting costs over traditional methods. Additionally, the ability to produce weed maps created an anticipated 30-75% reduction in herbicide application costs, due to the ability to provide optimized variable-rate applications. It is anticipated that many of those estimates would be somewhat relevant in production of other agricultural crops. This provides additional validation for the further research of other autonomous vehicles (i.e. UAVs) in agriculture.

UAVs in Electric Utility Inspection

Power line and right-of-way inspection is performed routinely by cooperatives as both a preventative measure within a vegetation management program and as a method of assessing damage in transmission and distribution power lines. In high voltage transmission lines, the North American Electric Reliability Corporation (NERC) ensures both cooperative and non-cooperative electric utilities adhere to specified vegetation management guidelines to ensure overall grid reliability. Additionally, most cooperatives have their own protocol for inspection of lines and right-of-way. Traditional methods of inspection include visual inspection by trained linemen and helicopter-aided inspection. With the increase in available technology, research indicates that UAVs could perform many of these same tasks with added benefits.

Maintenance, repairs, and system interruptions make up a large portion of many cooperatives' budgets. Vegetation management programs, the maintenance of trees and other vegetation along the right-of-way, are estimated to comprise a $7-10 billion industry annually (Russell, B. Don, et al. 2007.) These vegetation related outages make up a large portion of the total outages. This affects overall cooperative profitability (Russell, B. Don, et al. 2007.) Common issues in overhead power lines due to both vegetation and non-vegetation related incidents are cracks in insulators and corrosion or wind-induced damage to conductors, among many others (Aggarwal et. al 2000).

Because electric cooperatives often have a large portion of their infrastructure located in rural, difficult terrain, vegetation is often a significant concern for safety of both employees and residents. Although difficult to quantify, this is perhaps the greatest benefit of using UAVs in REC. Additionally, the increased vegetation provides higher likelihood of costly power outages. In states such as Oklahoma, adverse weather conditions often increase the amount of fallen trees which could potentially be identified before they enter the right-of-way by unmanned aircraft.

One of the primary issues with current inspection methods is that they are typically performed based upon a specified time, rather than need-based (Russell et al. 2007). Therefore, inefficiencies occur that could potentially be mitigated by the autonomy, speed, and low cost of unmanned aircraft compared to current practices (Li et al 2008). This would minimize the downtime, improve overall inspection speed, and ensure efficient use of labor and capital resources.

Katrasnik, Pernus, and Likar further describe some of the limitations of current inspection methods and propose the usage of automated systems such as automated helicopters (2010). Although regarded as relatively accurate for seeing surface level issues, some of the listed disadvantages of foot patrol (visual inspection) include: slow speed of inspection, monotony, subjectivity, and difficulty of noticing non-surface level issues (Katrasnik, Pernus, Likar 2010).

Although significantly less time-intensive, the authors go on to state that helicopter inspection is not typically as accurate and is far more expensive than foot patrolling. This formed the basis of their rationale behind researching both a flying (UAV) and climbing robot, which they deemed technically feasible. Their results show that UAVs provide at minimum the same accuracy as a manned helicopter at a lower cost.

One of the proposed benefits of UAVs over traditional inspection methods is the reduction in inspection time. A group of researchers in China proposed using a combination of fixed and rotary winged UAVs reduced inspection time and improved efficiency (Deng, et. al

2014). As our survey data shows later in this research, speed and timeliness of repairs are important to rural electric cooperative managers and, intuitively, cooperative members. An approach of utilizing a multi-platform team of unmanned aircraft and operators may have additional benefits over utilizing a singular UAV in this sense and should be considered when adopting UAV technology into a cooperative's inspection protocol.

Regulatory and other Limitations

One of the biggest limitations in the unmanned aerial vehicle market is the lack of clear, definitive regulations. Currently, the Federal Aviation Administration (FAA) classifies UAVs into three categories: public operations (government), civil operations (non-government), and model (hobbyist) aircraft (FAA 2016). Hobbyists must fly below an altitude of 400 feet, within line-of-sight, and must not generate an economic benefit from flying the aircraft. These model aircraft must be registered by the FAA for a nominal fee.

Outside of hobbyist aircraft, an exemption must be made. For public operations, this means a certificate of authorization (COA) must be issued. For civil operations, the most common exemption is the Section 333 Exemption--this would commonly apply to entities within our study. Additionally, civil operations can apply for a special airworthiness certificate (FAA 2016).

While much hypothetical research has been done proving their technical relevance, little known field testing of UAVs in electric utilities has been done. This is largely due to strict governing of unmanned aerial vehicles in the United States. However, in June of 2014, the FAA granted a Special Airworthy Certificate to the California investor-owned-utility San Diego Gas and Electric for UAV research purposes (SDG&E 2015).

This exemption is the first of its kind given to a utility company for research and testing. Using a relatively small UAV of 16 inches in diameter and under one pound in weight, SDG&E states that UAVs present numerous benefits to day to day operations in their energy firm. Five of those outlined explicitly were: advantages in inspection ability, enhanced safety, timeliness of power restoration, situational awareness for employees, and improved environmental protection (SDG&E 2015).

Objectives

The broad objective of this research is to determine the potential effectiveness of unmanned aerial vehicles as a method of crop scouting for agricultural cooperatives and line inspection for rural electric cooperatives. Specific objectives include: (1) determine the increased level of productivity required to make UAVs a viable alternative for crop scouting within agricultural cooperatives, (2) determine the increased level of productivity required to make UAVs a viable alternative for line inspection within rural electric cooperatives, (3) identify cooperative management's knowledge and perception of UAVs, and (4) determine which potential UAV uses appeal to management of each cooperative industry most.

Methods and Procedures

Surveys

A16-question surveyed was distributed in person to managers of 29 Oklahoma agricultural cooperatives at an annual retreat of Oklahoma Ag Cooperative Council members. This survey measured the quantity of acres scouted annually (if any), knowledge of UAVs, interest in specific potential UAV benefits, and the interest level in further education. An 83% (24 cooperatives) response rate was achieved in this survey.

Similarly, a 16-question online survey was disseminated to managers of distribution rural electric cooperatives in Oklahoma. Question types paralleled those in the agricultural cooperative survey with industry-specific questions differing. Managers' level of understanding, interest, and scope of their current inspection protocol was assessed in this survey. Out of the 28 transmission cooperatives, responses from 20 managers were received for a 71% response rate.

Efficiency Analysis

Using data collected from the surveys, annual costs of crop scouting and annual costs of line inspection were estimated using mean information from the survey respondents. Wage data was used from the statewide associations of each respective cooperative industry. The Internal Revenue Service mileage rate for 2016 of $0.54 per mile was used to capture vehicular costs. From those cost estimates and business volume levels, annual cash flows were then constructed using a $15,000 UAV over a three year lifespan with a $3,000 salvage value. Six target IRR values were selected and the level of efficiency improvement (% time reduction) needed to reach those IRR levels was solved for using Equation 1 below

$$Equation\ 1: 0 = \sum_{t=0}^{n} \frac{CF_t}{(1+IRR)^t} \ ,$$

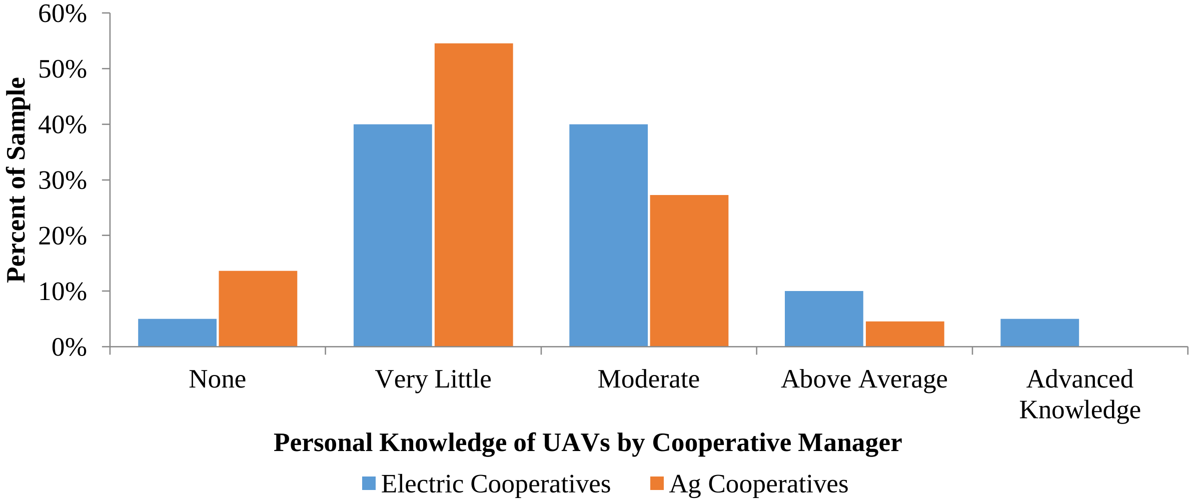
where t is the time at which cash flow CF_t occurs. IRR can further be defined as the rate of return such that the sum of the present values of all cash flows equals zero.

Results

Survey Knowledge and Interest Levels

Surveys of both agricultural and rural electric cooperative managers revealed a generally low level of UAV knowledge, with electric cooperatives responding at a slightly higher level of understanding than the agricultural cooperatives (Figure 1).

Figure 1. Oklahoma Ag and Electric Cooperative Surveys: UAV Knowledge



Despite the relatively low knowledge levels, management of both firms showed significant interest in this technology. In Figure 2 below, mean responses from a 0-10 scale with corresponding values of "Not at All Interested" to "Extremely Interested." are reported for electric cooperative managers on six potential UAV uses. Accessing difficult terrain ranked as the highest mean interest amongst the respondents.

Figure 2: Rural Electric Cooperative UAV Interest Levels

Description	N	Mean Response*
Accessing Difficult Terrain	18	6.33
Locating "Problem Areas"	18	6.06
Site-Specific Inspection	18	6.06
Thermal Imaging	18	5.78
High Resolution Still/Video Imagery	18	5.67
Identifying Vegetation Conditions	18	5.17

*0-10 Scale

Not unlike the electric cooperatives, agricultural cooperatives were provided with a similar set of questions which elicited interest levels of management. Five potential uses were outlined on a five-point scale from “Not at All Interested” to “Extremely Interested.” Managers proved most interested in estimating weed-pressure through this technology as seen in Figure 3 below.

Figure 3. Agricultural Cooperative UAV Interest Levels

Description	N	Mean Response*
Assessing plant drought and stress	22	3.36
Site-Specific Imaging	22	3.09
Weed Pressure Estimation	22	3.63
Yield Estimation	22	3.59
Nitrogen Recommendations	22	3.86

* 1-5 Scale

Efficiency Analysis Results

Using mean cost and business volume data for Oklahoma agricultural and electric cooperatives surveyed, the target internal rate of return levels were achieved by solving for the time reduction needed. Figure 4 depicts the time reduction needed for both REC and ag cooperatives. A lifespan of three years was chosen as UAV technology is rapidly improving, as are the needs of cooperative firms. An initial investment of $15,000 was chosen as a wide range of UAV costs exists in the marketplace.

Figure 4. Estimated Internal Rate of Return on UAV Investment for REC and Ag Cooperatives

Target IRR*	% Efficiency Improvement Required (Time)	
	Rural Electric	Agricultural
5.00%	8.64%	16.60%
10.00%	9.72%	18.68%
15.00%	10.82%	20.79%
20.00%	11.94%	22.94%
25.00%	13.08%	25.13%
50.00%	19.02%	36.53%

*Assuming Initial Investment: $15,000 Salvage Value (end of year 3): $3,000

Conclusion

As a whole, managers of both rural electric and agricultural cooperatives have a relatively low level of UAV knowledge, yet an eminent interest in using them. Survey data show that there are, indeed, some barriers to adoption and skeptics of this growing technology. Modeling suggests that financially UAVs could be a viable option at an IRR of 15% if they improved efficiency levels in RECs and agricultural cooperatives by approximately 11% and 21%, respectively. Rural electric cooperatives find it easier to justify the cost saving model as current inspection practices are very labor intensive. Agricultural cooperatives would need a higher level of efficiency from UAVs to justify the model. By increasing fee-based scouting volume, agricultural cooperatives may be able to improve feasibility levels. Further research and field testing could be done to extend on this idea.

With regards to education, rural electric cooperatives appeared to have a somewhat higher level of knowledge and interest in adopting this technology. This may be attributed to the proposed improvement in safety of employees and members alike. Some of the greatest benefits from UAVs may not be realized in a financial sense.

Finally, limitations on usage persist as the FAA continues strict regulation on the industry. Regulatory impacts could hinder or accelerate progress in this area of interest and should be analyzed as FAA rulings continue to develop and are modified.

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