THE ECONOMIC POTENTIAL OF UNMANNED AIRCRAFT IN AGRICULTURAL AND RURAL ELECTRIC COOPERATIVES

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Abstract: The Association of Unmanned Vehicle Systems International (AUVSI) predicts that 80% of the U.S. unmanned aerial vehicle (UAV) market will be in agricultural and rural areas where cooperatives have a strong presence. Agricultural cooperatives could use UAVs in crop scouting to provide timely high-resolution imagery of crop conditions. Rural electric cooperatives (RECs) could use UAVs to perform routine line inspection. Our research investigated the level of interest and awareness of these rural cooperatives towards UAVS and analyzed the feasibility of UAV adoption. Surveys were sent to Oklahoma grain and farm supply cooperatives and RECs. The survey investigated the knowledge of and interest in UAVs, and elicited information on crop scouting fees and costs, distribution line inspection costs and preventable line loss. The results indicated a low level of knowledge but a high level of interest in UAV technology. Modeling suggests that UAV applications could be feasible for both REC and agricultural cooperatives. Final regulations from the Federal Aviation Administration, particularly restrictions on line-of-sight operation and altitude appear to be a major impediment to UAV adoption. Our survey results suggest that REC applications would be particularly sensitive to the regulatory structure.

TABLE OF CONTENTS

Chapter	Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Background

The Association of Unmanned Vehicle Systems International (AUVSI) predicts that 80% of the United States' unmanned aerial vehicle (UAV) market will be in precision agriculture, encompassing remote sensing and precision application (AUVSI 2013). When the market is mature, AUVSI (2013) forecasts annual sales of approximately 150,000 units. Across all industries, AUVSI expects the UAV market to have a collective economic impact of over $82 billion between the ten year timespan of 2015 to 2025 and the creation in excess 103,000 new jobs (2013). In Oklahoma alone, a state that thrives on energy and agriculture, AUVSI predicts a $637 million economic impact, over $5.6 million dollars in tax revenue, and the addition of 805 jobs over that same ten year time span (2013). These estimates by AUVSI are based on forecasts derived from telephone interviews of 30 industry experts, existing UAV sales data from other countries, land ratios, and technology adoption literature (AUVSI 2013).

Leaders of agricultural cooperatives and rural electric cooperatives alike have noted this potential but may be unsure as to how this technology could lead to cost savings or revenue growth. Locally, Central Rural Electric Cooperative (CREC) in Stillwater, Oklahoma is exploring the use of autonomous UAVs. In partnership with Oklahoma State University's Unmanned Systems Research Institute (ESRI), their hope is to boost service reliability and mitigate risk of cooperative personnel (Meyers 2016).

Previous research indicates that UAVs, also referred to as unmanned aerial systems (UAS), could 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. Thus, the broad goal of this research is to investigate the economic feasibility of UAVs for farm supply and distribution rural electric cooperatives within the state of Oklahoma.

Impact of the Cooperative Firm

Cooperative firms are a unique type of corporation that distribute profits in proportion to the business volume of the user. This profit distribution is formally referred to as *patronage*. Inherently, members of the cooperative are also owners of the firm in which they patronize. This contrasts from investor-owned firms, where profits are allocated to shareholders who may or may not utilize the goods or services rendered by the firm in which they hold partial ownership in.

The member-owners of the two cooperative firms considered for this research, agricultural and rural electric cooperatives, often reside in rural locations with overlapping geographical service territory. Members of an agricultural cooperative could hypothetical also be members of an REC and vice-versa. Thus, this unique cooperative business model is important to both rural America and agriculture in terms of both access to goods and services and the rural economy.

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, Eversull and Ali (2014) with the United States Department of Agriculture (USDA) reported in their annual *Cooperative Statistics* publication that 2,186 agricultural cooperatives with over 2 million member-owners collectively generated over $246.1 billion in gross business volume. In addition, those same cooperatives provide over 136,000 fulltime jobs and 55,000 seasonal or temporary jobs in areas where employment may be limited (Eversull and Ali 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 (NRECA 2014). The National Rural Electric Cooperative Association reports that over 900 rural electric cooperatives (RECs) employed more than 70,000 people (2014) across the U.S. in 2014. Those same 900 cooperatives serve an estimated 42 million people and 18.5 million different establishments, including both homes, businesses, and industrial locations. These cooperatives are often the largest employer in the rural communities in which they operate.

RECs generate a relatively 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, according to the NRECA (2014) 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 presents challenges in efficiency, yet presents opportunities for research and improvement in developmental areas such as UAVs. Because they service more sparsely 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, interested in technologies that either allow themselves to operate more efficiently internally or those that add value at the farm level for members.

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 communication between the customer meter and the central system. According to Tweed (2015) with Green Tech Research, cooperatives are leading the electric utility industry in percentage of customers that have adopted smart metering.

UAVs as a Proposed Alternative

Because of these unique, yet interrelated, goals of these cooperative industries discussed 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. In a 2015 survey by Erickson and Widmar (2015) at Purdue University, 16% of the 261 crop input dealers surveyed signified that their firm utilized UAVs as a precision agriculture tool. Alternatively, satellite imagery was reportedly used by 51% of the respondents (Erickson and Widmar 2015).

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 in addition to visual inspection. However, those technologies are typically not practical in a financial sense 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 trained technician to inspect line more rapidly and the UAV could also be outfitted with near infrared cameras that could potentially detect line arcing and other problems which are not immediately obvious in visual inspection. In many areas, REC distribution lines are not accessible by roads. This necessitates the technician to walk the line or travel in an all-terrain-vehicle. UAV adoption could therefore also have advantages in worker safety. Although difficult to quantify in an economic sense, this could perhaps be the greatest reason for UAV adoption in RECs.

Research 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 (reduction in time) required to make UAVs a viable alternative for crop scouting within agricultural cooperatives, (2) determine the increased level of productivity (reduction in time) required to make UAVs a viable alternative for line inspection within rural electric cooperatives, and (3) to identify cooperative management's knowledge and perception of UAVs.

CHAPTER II

LITERATURE REVIEW

Overview

As a relatively new topic, little research exists in way of utilizing unmanned aircraft specifically in agricultural or rural electric cooperatives. Thus, most of the research outlined refers to more general UAV literature. Prior research shows that unmanned aircraft-based sensing is not only technically feasible, meaning it has the mechanical abilities to accomplish intended purposes, but can provide highly correlated data to ground-based observation. (Khot, et. al. 2015; Katrasnik, Pernus, Likar 2010). 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 research's more specific area of interest within cooperative firms.

UAVs in Agriculture

Dating back to as early as the 1950s, precision agriculture (PA) is a popularized management technique that has revolutionized the agriculture industry (Colewell 1956). One of those methods is remote sensing, defined by Barrett and Curtis (1976) as *"…the observation of a target by a device separated from it by some distance."* Previous academic research has explored the benefits and uses of satellite remote sensing in agriculture (Idso, et. al 1980; Tucker and Choudhury 1987). More recently, research such as Khot et. al (2015) explores using UAVs as a remote sensing tool.

While remote sensing is certainly a worthwhile area of exploration in UAV technology, this research will primarily focus on UAVs for crop scouting. A different PA method, 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. Using these inspections, a trained professional would assist in making recommendations on the application of inputs and other management decisions. By scouting crop fields, the producer (farmer) is able to make management decisions based on varying specific points within the crop field. However, one potential issue with manual crop scouting is that it is time consuming and relies on random sampling which may produce inaccuracies through human-error (Ehsani and Maja 2013).

Aside from manual crop scouting, other instruments are used as a part of precision agriculture routines. As technology such as variable rate machinery has risen into production agriculture, farm implements that accommodate for intra-field variation in input application, productivity may be improved at the farm level in certain instances. Thus, precision agriculture has the potential to become instrumental in improving crop yields and the overall efficiency and stewardship of farming.

Historically, precision agriculture has relied heavily on the use of global positioning systems (GPS) and satellite imagery. 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.

To compare UAVs to ground-based data, Khot, et al. (2015) conducted an assessment using winter wheat and potato fields. They analyzed data from the multispectral images acquired and compared the two methods by utilizing the Pearson correlation coefficient. Their results concluded a strong positive correlation between the two methods, which they concluded indicates unmanned aircraft data can be a suitable alternative for making management decisions in crop production and may reduce labor. This is important in the modeling assumptions to follow, as a cost reduction model is used to determine levels of feasibility.

Another study further exploring the relevance and feasibility of unmanned aircraft, 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 (2012), 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. For example non-cooperative entities such as Seattle, Washington based mega merchant Amazon.com, Inc. have created a buzz around the term "drone", referring to the polyonymous UAV (Huffington Post 2015). Freeman and Freeland (2015) allude to the hype and negative connotation surrounding the buzzword "drone." Their paper goes on to discuss policy, consumer expectations, and technology adoption. To further assess adoption and expectations of the cooperatives studied, survey results of Oklahoma agricultural cooperatives are included later in this research 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 of unmanned aircraft operation.

This research captures some of the affordability aspect of the UAV initial costs. However, due to the structure of cooperative firms it is anticipated that initial costs are less prohibitive in the decision-making process as these costs are taken on by the cooperative and spread out over the member-owners. Unlike Primicerio et. al (2012), this research assumes 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. Also differing, it is assumed that operators of the UAV will be trained individuals.

In terms of the uniqueness of the data produced by UAVS, the near-infrared 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.(2008) refer to this in their article assessing the sensor technology currently available in unmanned aircraft used in crop scouting of wheat fields. Like the majority of literature available, their assessment targets developing indices from images 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. (2015) further analyze the benefits and drawbacks of unmanned aircraft in precision agriculture (PA), versus using traditional manned aircraft and satellite imagery. Like others, these authors used the NDVI, further described later in this research, derived from near infrared 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 such as land value appraisal or record-keeping.

The research by Matese et al. (2015) continued by stating that UAVs, satellites, and manned aircraft all possess distinct advantages and disadvantages. The main differences include acquisition and processing costs, temporal and spatial resolution, coverage speed, and reliability (Matese et. al 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.

The formerly mentioned research does provide valuable information, but is inadequate in certain instances 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, it is assumed 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 analyzed in this research 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 (2005) 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. 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.

Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index, NDVI, is one of the most common indices used to monitor "greenness" or a plant's photosynthetic activity. This metric is often used by individuals with satellite or UAV imagery. Due to a heavy reliance upon this calculation, it is important to make a mention of it. NDVI is based on the principle that different surfaces reflect different types of light in distinct ways. Active vegetation, or healthy plants, absorb most of the red light and reflect a large portion of the near infrared light. Dissimilarly, dead or stressed vegetation reflects more red light and a smaller amount of near infrared light. Additionally, non-vegetative surfaces provide a more evenly distributed reflectance.

These differences in light interaction form the basis for the NDVI, which is calculated on a per-pixel basis from the red and near infrared bands from and image as

$$NDVI = \frac{(NIR-RED)}{(NIR+RED)},$$

where NIR refers to the near infrared bands and RED the red light bands (Anderson, Hanson, and Haas 1993). Values of the NDVI range from -1.0 to 1.0. Low values indicate low photosynthetic activity, while high values indicate a high level of photosynthetic activity.

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., et al. 2007). These vegetation related outages make up a large portion of the total outages. This affects overall cooperative profitability (Russell, B., 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). This implies that electric cooperatives are typically only inspecting lines on a routine basis and in cases of mechanical failure. 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 (2010) further describe some of the limitations of current inspection methods and propose the usage of automated systems such as automated helicopters. 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,and Likar 2010).

Although significantly less time-intensive, the authors go on to state that manned 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, but not necessarily economically, feasible. Their results show that UAVs provide at minimum the same accuracy as a manned helicopter at a foreseeable lower cost.

One of the proposed benefits of UAVs over traditional inspection methods is the reduction in inspection time. This reduction in time forms the basis of the rationale behind the ensuing cost-savings model proposed later in this research. 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 the 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 Literature

One of the biggest limitations in the unmanned aerial vehicle market is the lack of clear, definitive regulations. As such a dynamic and changing industry, regulations are still somewhat developmental and are seen by many as prohibitive to business usage. 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, by definition, 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 this 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). These “micro drones”, small and limited capability unmanned aircraft, SDG&E reported were purchased at a cost of around $6,000 for a pair of two (2015).

It is anticipated that current regulations would impede cooperatives on both ends of the spectrum from adopting the technology. Therefore, further discussion on regulatory matters and their impact is included later in the conclusions of this research. Additionally, results from a cooperative management survey conducted as an additional part of this research are included to show their perception and attitude towards current regulations.

CHAPTER III

METHODS AND PROCEDURES

Research Objectives

The overall objective of this research is to determine the potential effectiveness of unmanned aerial vehicles as a cost reducing method of crop scouting for agricultural cooperatives and line inspection for rural electric cooperatives. Although the industries potential purposes for using UAVs differ, a similar approach can be taken to investigate their potential within both categories of cooperative firms. The actual economic benefits of UAVs in these specific applications cannot be measured because the technologies have not yet been adopted in most cooperatives. The approach of this research is, therefore, to determine the level of productivity gains from using UAVs that would need to be obtained in order to make UAV adoption feasible for the two aforementioned cooperative industries. Specifically this research seeks to: (1) determine the increased level of productivity required to make UAVs a viable alternative for crop scouting within agricultural cooperatives and (2) determine the increased level of productivity required to make UAVs a viable alternative for line inspection within rural electric cooperatives. This research also will identify cooperative management's knowledge and perception of UAVs.

Previous research indicates that UAVs have the mechanical ability to perform both crop scouting and power line inspection effectively and that they are technically feasible (Zhang and Kovacs 2012; Katrasnik, Pernus, and Likar 2010). However, from a financial perspective, little research has been performed to determine the cost savings needed to justify making the investment. Additionally, research specific to their application within cooperative firms proves to be very limited as well. Both firms spend a considerable amount of employee labor and vehicular expense to perform inspection activities. While the electric cooperatives receive no direct cash inflow from inspecting, vegetation management programs (line inspection) comprise a $7-10 billion industry annually (Russell, Benner, Wischkaemper 2007). In addition, these vegetation management or inspecting practices mitigate costs as a part of a comprehensive risk-management plan. Therefore, cost savings alone could justify the initial investment in theory. Agricultural cooperatives, on the other hand, may generate revenue as some charge a nominal fee for crop scouting.

Methods Overview

In order to accomplish the objectives of this research outlined above, data from two surveys and secondary data sources obtained from the statewide associations of each cooperative industry, the Oklahoma Ag Cooperative Council (OACC) and the Oklahoma Association of Electric Cooperatives is employed. The survey data is used to model crop scouting activities at a typical Oklahoma grain and farm supply cooperative and to model line inspection activities at a typical Oklahoma distribution electric cooperative. The potential to invest in UAVs to reduce costs in those activities will be examined using an internal rate of return (IRR) model, which is a capital budgeting technique that is commonly used to determine the profitability of investing in a particular project or investment. IRR is closely related to the simpler concept of Net Present Value (NPV) which compares the initial investment amount to the present value of the future cash inflows or cash saving as this research uses. NPV is defined as:

(1) $$NPV = initial\ investment + \left[\frac{CF_1}{(1+r)^1}\right] + \left[\frac{CF_2}{(1+r)^2}\right] + \left[\frac{CF_3}{(1+r)^3}\right],$$

where t is the time at which cash flow CF_t occurs and r is the discount rate. The discount rate typically reflects the firms cost of capital or the potential rate of return from alternative investment opportunities. The discounting process is used to convert the future cash flows to their equivalent value at the time of the initial investment. This reflects the fact that a cash flow received in some future year is not a valuable as a cash flow received immediately. Put differently, there is some discounted amount of a future cash flow that could be invested at the opportunity cost of capital to yield the future cashflow.

IRR, a modification of the NPV equation, is the discount rate, *r*, such that yields a present values of zero for a particular initial investment and stream of future cash flows.

Data

A 16 question survey was distributed in person to managers of 29 Oklahoma agricultural cooperatives at an annual retreat of Oklahoma Ag Cooperative Council (OACC) members. The survey measured the quantity of acres scouted annually (if any), a self-ranking in knowledge of UAVs, interest in specific potential UAV benefits, and their interest level in further education. An 83% (24 cooperative managers) response rate was achieved in this survey. The total membership of OACC in 2014 consisted of 31 cooperatives which represents the vast majority of the total agricultural cooperative population in Oklahoma. Therefore, the survey and financial data provides a strong representation of Oklahoma agricultural cooperatives as a whole.

Similarly, a 16 question online survey was disseminated to managers of distribution rural electric cooperatives in Oklahoma using web-based software *Qualtrics*. 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 in Oklahoma, responses from 20 managers were received for a 71% response rate. Not unlike the agricultural cooperatives, the survey data encompasses the bulk of all Oklahoma distribution electric cooperatives as very few (if any) cooperatives choose not to be a part of OAEC.

Data collected from recent financial statements for both respective cooperative industries in year 2014 were collected from the statewide associations mentioned previously. This historical data gave us estimates on characteristics of the firm and were used to compile estimates that were used in the internal rate of return analysis below. Survey responses relating to crop scouting and line inspection activities are reported in Table 1 to follow.

Internal Rate of Return Analysis

Using data collected from the two 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 and is representative of the mean our survey respondents. The Internal Revenue Service standard business mileage rate for 2016 of $0.54 per mile was used as a proxy for vehicular operating expenses associated with current line inspection.

From those cost estimates and business volume levels derived from survey data and financial statements, the initial costs and annual cash flows were then constructed for a typical Oklahoma agricultural cooperative firm using equation two.

$$(2)\ CF_{agcoop,t} = (Annual\ Savings\ from\ \ Manual\ Scouting) - (wage * hours_{uav}) - (0.03 * Initial\ Investment) - Initial\ Investment + Salvage\ Value\ ,$$

where the *"Annual Savings of Manual Scouting"* is calculated as:

$$Annual\ Savings\ from\ Manual\ Scouting = (wage *\ hours_{traditional})\ ,$$

or simply the average wage surveyed multiplied by the average hours surveyed of traditional crop scouting.

An initial investment of $15,000, or the purchase price of a UAV, was assumed. It is also assumed that the cooperative will utilize it over a three year lifespan with a $3,000 salvage value realized as a positive cash inflow at the end of year three.

In equation two, the annual cash flow for agricultural was determined as follows: using the wage of $26.25 per hour developed from the mean wage across the cooperative sample data (shown below in Table 1), then it is multiplied by the average yearly hours of 1,026.33 to receive the total labor expenses incurred for the specified time period. Next, the same recorded mean wage ($26.25) is multiplied by the hours solved for indirectly using the target internal rate of return. This is the unknown solved for originally. Finally, we subtract the cost of maintenance and the initial investment (only relevant in time period 0) and add the salvage value, if any exists, in that time period. The maintenance costs are estimated as 3% of the purchase value (initial investment) of the unmanned aircraft. At a purchase price of $15,000, an annual $450 maintenance cost (before discounting) is expensed. This figure is deemed appropriate as in many UAV scenarios this would allow for the purchasing of two additional batteries per year and performing of minor repairs.

Table 1. Crop Scouting and Line Inspection Activities: Average of Survey Responses by Cooperative Firm Industry

Agricultural Cooperatives		Electric Cooperatives	
Item	Value	Item	Value
Acres Scouted (annual)	29,892.00	Line (miles)	3,995.60
Acres Scouted (ac/day)	1,165.00	Inspection Rate (mi/day)	53.50
Days of Scouting (per yr)	25.66	Annual Inspections (per mi)	1.65
Scouting (hrs/yr)	1,026.33	Total Miles Annually	6,592.74
Wages ($/hr)	$ (26.25)	Days Inspecting (days/yr)	123.23
Total Scouting Costs ($/yr)	$(26,941.16)	Hours Inspecting (hr/yr)	985.83
Total Costs ($/ac)	**$ (0.90)**	Average Wage	$ (26.74)
		Vehicle and Fuel ($/mi)	$ (0.54)
		Total Labor Costs (2 employees)	$(2,717.44)
		Total Vehicle Costs (yr)	$(3,560.08)
		Total Annual Costs ($/mi)	**$ (8.54)**

In the case of electrical distribution cooperatives the cash flows were modeled in a like manner (see equation 3). This cash flow equation differs from the above by simply adding in vehicular expenses on the job. During distribution line inspection, we assume the line will have to be driven to some extent in both UAV and foot patrol, due to the nature of the line of sight regulations imposed. These are captured by using the annual miles multiplied by the 2016 IRS mileage rate of $0.54 per mile. It's important to note that in both cash flow models, we do not consider the cost of transportation to and from the origin of the job location. Only expenses incurred on the job itself are accounted for.

$$(3)\ CF_{rec,t} = [Savings\ from\ Traditional\ Inspection] - [(wage * hours_{uav}) + (miles * IRS\ Mileage\ Rate) - (0.03 * Initial\ Investment) - Initial\ Investment + Salvage\ Value],$$

where $Savings\ from\ Traditional\ Inspection = (wage * hours_{traditional}) + (miles * IRS\ Mileage\ Rate)$, or simply the surveyed average wage in Table 1 multiplied times the average of the surveyed hours spent inspecting lines plus the product of the miles of line driven multiplied by the IRS Mileage Rate of $0.54.

The costs of *manual* inspection are attributed as a positive cash inflow to the cooperative, as the value they would normally spend on inspection or scouting is essentially a "savings" to the cooperative. With the exception of the $3,000 salvage value at the end of year 3 (t=3), this is the only "positive" cash flow in the cost-reduction model.

We assume a cost-reduction model is appropriate in both cooperative firms because electric cooperatives do not directly generate revenue from the inspection process, although it can result in significant savings. Similarly, the sample of agricultural cooperatives reported charging very little, if any, for their scouting services. Many offer this as an added "good-will" benefit to members. An example of the annual cash flows for time periods zero through three is outlined below, using the labor costs, mean annual hours scouting, initial investment, and salvage values. These cash flows can be inserted into the IRR formula, and then $hours_{uav}$ can be solved for as a single unknown, assuming that the variable is held constant across time periods. The result is the reduced maximum hours of scouting a UAV would have to provide for the same fixed acreage.

The same process of inputting the strings of annual cash flows into the internal rate of return equation, setting IRR equal to a fixed level, and solving for the unknown of hours results in the reduced hours a UAV would need to accomplish the line inspection process in. This process was completed six times at 5%, 10%, 15%, 20%, 25%, and 50% for each of the two cooperative firm industries. Detailed results can be seen in the appendix for the actual cash flow streams segmented by target internal rate of return. A summary of the percent reduction in time needed is provided later in the results section of this research.

Table 2. Annual Cash Flows for UAV Operations at an Agricultural Cooperative

t	Project Cash Flow
0	$CF_{agcoop,t=0} = (\$26.25 * 0) - (\$26.25 * 0) - \$15{,}000 + \$0$
1	$CF_{agcoop,t=1} = (\$26.25 * 1{,}026.33) - (\$26.25 * hours_{uav}) - (\$15{,}000 * 0.03) - \$0 + \$0$
2	$CF_{agcoop,t=2} = (\$26.25 * 1{,}026.33) - (\$26.25 * hours_{uav}) - (\$15{,}000 * 0.03) - \$0 + \$0$
3	$CF_{agcoop,t=3} = (\$26.25 * 1{,}026.33) - (\$26.25 * hours_{uav}) - (\$15{,}000 * 0.03) - \$0 + \$3{,}000$

Similarly, the REC cash flows can be further developed and described by the below strings of project cash flows from period zero through period three.

Table 3. Annual Cash Flows for UAV Operations at a Rural Electric Cooperative

t	Project Cash Flow
0	$CF_{rec,t=0} = [(\$26.74 * 0) + (0 * \$0.54)] - [(\$26.74 * 0) + (0 * \$0.54)] - \$15{,}000 + \$0$
1	$CF_{rec,t=1} = [(\$26.74 * 985.83) + (6592.74 * \$0.54)] - [(\$26.74 * hours_{uav}) + (6592.74 * \$0.54)] - (\$15{,}000 * 0.03) - \$0 + \$0$
2	$CF_{rec,t=2} = [(\$26.74 * 985.83) + (6592.74 * \$0.54)] - [(\$26.74 * hours_{uav}) + (6592.74 * \$0.54)] - (\$15{,}000 * 0.03) - \$0 + \$0$
3	$CF_{rec,t=3} = [(\$26.74 * 985.83) + (6592.74 * \$0.54)] - [(\$26.74 * hours_{uav}) + (6592.74 * \$0.54)] - (\$15{,}000 * 0.03) - \$0 + \$3{,}000$

CHAPTER IV

RESULTS AND DISCUSSION

Survey Knowledge and Interest Levels

On a 1-5 scale ranging from "No Knowledge" to "Advanced Knowledge" and the midpoint of three being "Moderate Knowledge", managers were asked to rank their personal understanding of unmanned aircraft. Surveys of both agricultural and rural electric cooperative managers revealed a generally low level of UAV knowledge, with both means below the moderate midpoint of three. Additionally, we can see that electric cooperatives recorded a slightly higher level of personal understanding than did the agricultural cooperatives Table 4.

Table 4. Survey Results of Cooperative Manager Knowledge of UAVs

	Ag	REC
Mean	2.23	2.7
Low	1	1
High	4	5
Std. Dev.	0.75	0.92
N	22	20

By viewing the histogram that follows in Figure 1, one coud further notice the majority of the survey respondents selected that they have "Very little" knowledge of unmanned aerial vehicles, with "Moderate" knowledge collectively being the second highest category. Only one respondent surveyed selected that he or she had "Advanced knowledge" of unmanned aircraft. This observation was a part of the REC managers surveyed. In summary, we see overall low knowledge levels, with REC managers selecting a slightly higher level of knowledge

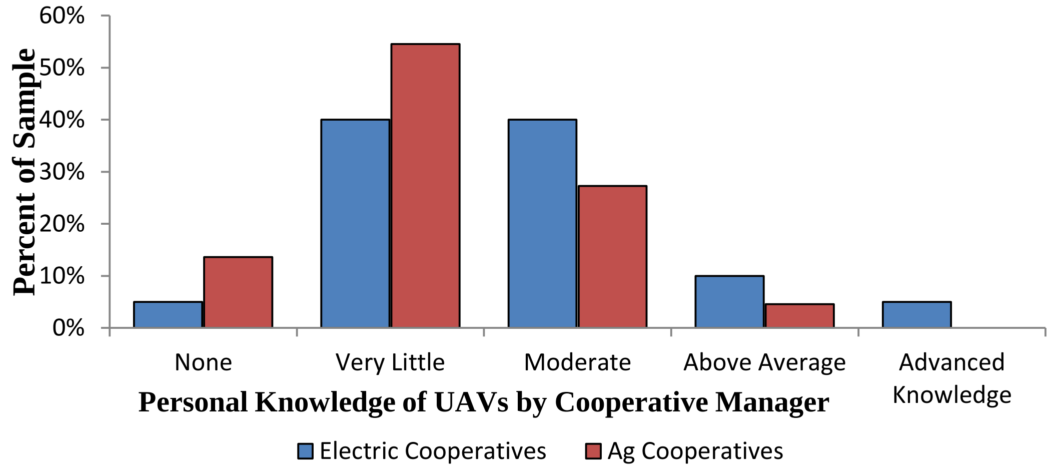

Figure 1. Histogram of Oklahoma Agricultural and Rural Electric Cooperative UAV Knowledge Survey

Despite the relatively low knowledge levels, management of both firms expressed significant interest in implementing UAV technology. On a scale of 0-10, with zero corresponding to "Not at all Interested" and ten being "Extremely Interested", mean responses recorded below show there is indeed interest in utilizing unmanned aircraft for both sets of cooperative firms. In general, both managers of each of the two respective cooperative industries appeared to have a moderate knowledge of UAVs as surveyed.

In Table 5 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. This is not surprising as literature by Russel et. al (2007) quantify the costly impact of vegetation on the electric utility industry, as mentioned previously. The lowest response was in identifying vegetation conditions. Perhaps this is of the least concern, due to most vegetation being relatively easy to identify with the human eye from a safe distance.

Table 5: Survey Results of Rural Electric Cooperative Managers' Interest in UAVs

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 scale from "Not at All Interested" to "Extremely Interested." Managers proved most interested in developing nitrogen recommendations, a costly but often very beneficial input, through this technology as seen in Table 6 below. By efficiently applying nitrogen, farmers could improve yields, reduce operating expenditures, and better manage their fields in a sustainable environment.

Table 6. Survey Results of Agricultural Cooperative Managers' Interest in UAVs

Description	N	Mean Response*
Assessing plant drought and stress	22	5.91
Site-Specific Imaging	22	5.23
Weed Pressure Estimation	22	6.59
Yield Estimation	22	6.48
Nitrogen Recommendations	22	7.16

* 0-10 Scale

Perceived Implications Due to Restrictions

Survey respondents from both groups were asked to rate their perceived unmanned aircraft effectiveness in crop scouting or powerline inspection, respective to their industry, with and without the current 400 feet of altitude limitation and line-of-sight requirements. The below results in Table 7 show that electric cooperatives are particularly sensitive to the flight requirements imposed by the FAA. This could be due to the fact that agricultural cooperatives would be operating unmanned aircraft in crop fields which are primarily open areas without obstruction or rugged terrain. Electric cooperatives, on the other hand, maintain line in various terrain and with numerous obstructions to impede foot and vehicle access. Additionally, line-of-sight may be obstructive due to the unpredictability and non-uniformity of the right-of-way in comparison to that of a crop field.

Table 7. Survey Results of Agricultural Cooperative and Rural Electric Cooperative Managers' Assessment of UAV Effectiveness With and Without Regulatory Restrictions

	Agricultural		Electric	
	Restricted	Unrestricted	Restricted	Unrestricted
Mean	4.32	5.68	6.00	6.90
SD	2.58	2.07	2.53	2.45
N	22.00	22.00	20.00	20.00

*0-10 Scale

IRR 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 agricultural 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, ranging on average from $1,200-$25,000.

Consumer quadcopters fixed with a basic camera can be purchased on the lower end of the spectrum (roughly $1,000-$2,000) and modified for crop scouting, although professional models complete with software packages for direct integration into variable rate farm equipment fall in the upper end of that range. Pricing data on professional models are not as readily available as the market is still somewhat limited in the number of firms producing and marketing UAVs.

Table 8. Estimated Efficiency Needed for Agricultural and Rural Electric Cooperatives to Achieve Target Internal Rate of Return Levels Based on Savings

Target IRR*	% Efficiency Improvement Required (Time)	
	Rural Electric	Ag
5.00%	9.50%	18.58%
10.00%	10.58%	20.69%
15.00%	11.68%	22.85%
20.00%	12.80%	25.04%
25.00%	13.94%	27.27%
50.00%	19.87%	38.89%

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

The six pre-determined IRR levels and the corresponding percentage reduction in line inspection or scouting time is displayed above in columns two and three. For actual time estimates (in minutes) and further details, see the appendix at the end of this paper.

At a selected target rate of 15%, nearly a 12% reduction in powerline inspection is needed. For agricultural cooperatives, the results show a reduction of roughly 23% in time spent scouting would be needed to achieve feasibility at a 15% IRR level. This is significantly higher efficiency gain relative to that needed in powerline inspection, although not surprisingly as manual crop scouting requires very few inputs besides the cost of labor. Additionally, the agricultural cooperatives need a significantly higher reduction to achieve those same IRR levels.

Below are partial results for per unit (acre or mile) costs. Based upon survey results, conventional crop scouting costs are estimated at $.90 per acre. Likewise, RECs surveyed resulted in a per-unit cost of $8.28 per mile inspected. At a target internal rate of return of 15%, a projected reduction of $.04 per acre for ag cooperatives is given. Similarly, at 15% RECs are projected to see a $.26 per mile inspected cost reduction. These estimates, of course, hinge on the validity of survey data and the technical ability of UAVs to achieve the time reduction in scouting needed to reach the target IRR rate. In the appendix of this paper, per-unit costs are outlined for all target IRR levels. Costs were computed by included depreciation of the UAV at $3,000 each year, as the purchase price is $15,000 and the salvage value at the end of year three is selected as $3,000. The remaining $12,000 of value is amortized over the three year useful life using straight line depreciation to attribute an equal value (cost) of the UAV to each of the three years.

Table 9. Per-Unit Costs of Crop Scouting and Line Inspection with and without Efficiency Gain Needed to Generate a IRR of 15% on UAV Investment

	AG ($/ac)			**REC ($/mi)**		
IRR	**Conventional**	**UAV**	**Δ**	**Conventional**	**UAV**	**Δ**
15%	$ 0.90	$ 0.86	$ 0.04	$ 8.54	$ 8.28	$ 0.26

Cooperative Application

In a typical analysis using an internal rate of return, the firm would simply select the project that yields the highest internal rate of return—*ceteris paribus*. However, we must remember the IRR levels were pre-determined in the six simulated scenarios. Therefore, the time spent inspecting becomes the variable of interest within the UAV project cash flows. Therefore, a different approach must be taken to evaluate and apply the information derived from this tool. From a technical or engineering standpoint, comparing actual UAV flight inspection data to traditional inspection methods to discover what percentage reduction is feasible would be highly beneficial for cooperative decision makers. Additionally, the comparison uses a simulated firm that represents the mean of each cooperative industry we analyzed. Cooperative firms should delve into financials and determine actual inspection costs per unit (mile of line or acre).

Additionally, an evaluation of the actual standard rate of inspection for their cooperative firm. Constraints on labor, vehicles, weather, or excessively difficult-to-access terrain will adjust estimates and modify the firm-specific results

Traditionally, cooperatives may select a relative standard rate which they must receive on investments of similar size. Typically this rate varies depending on the size, length, and risk of the investment. However, in choosing whether or not to invest in UAV technology, other factors should be considered. Previously mentioned intangibles such as employee safety, convenience, and additional detail of data all may add value to the investment that is not captured in the IRR.

Moreover, we assume that cooperative firms are not selecting from multiple projects and choosing the highest rate of return. We assume they indeed expect a nominal positive return to incentivize the physical action of investing in UAVs. However, that investment may be deemed “feasible” internally at a rate of return lower than projects which derive nearly all value from the actual rate of return alone and rarely consider indirect or implicit value. This concept is similar to comparing accounting profits to economic profits.

CHAPTER V

SUMMARY AND CONCLUSIONS

Conclusions

Knowledge and Education

With regards to education, rural electric cooperatives appeared to have a somewhat higher level of knowledge of this technology when compared to agricultural cooperatives. Both firms, however, displayed above-average interest levels. Greater knowledge levels in RECs may be attributed to the proposed improvement in safety of employees and members alike. Additionally, RECs are often larger in number of employees and therefore may have more employee labor devoted to research and development efforts. Efficiency improvement is a large part of REC operations. Perhaps some of the greatest benefits from UAVs may not be realized in a financial sense, especially from the rural electric cooperative standpoint of safety and convenience.

As a whole, managers of both rural electric and agricultural cooperatives responded with a relatively low level of UAV knowledge, yet an eminent interest in using them. Survey data indicated that there are, indeed, some barriers to adoption and skeptics of this growing technology are present even at the cooperative level. This display of apprehension is to be expected with any new technology.

Economic Viability

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 12% and

23%, respectively. UAV adoption is easier to justify at rural electric cooperatives, relative to agricultural cooperatives because current inspection practices are very labor intensive and incur large wage expenditures because of this. 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 and relax the efficiency requirements to achieve such levels. Additionally, UAVs should continue to develop in technological abilities and also become less cost-prohibitive as the market develops.

Future of Satellite Imagery Data

Improvement in satellite imagery could provide an alternative to UAV usage in precision agriculture. Satellite imagery has played an important role in the development of precision agriculture. It has been implemented in crop mapping, assessing plant health, and general land surveying/appraisal uses. However, they were historically constrained to large acreage samples due to poor spatial resolution of sensors. Present day satellite technology is increasing in quality. Satellites such as *QuickBird* provide higher spatial resolutions than antiquated models, yet still lack in frequency compared to unmanned aircraft (Wojtowicz, Wojtowicz, and Pierkarczyk 2016).

UAVs are currently considered as an attractive alternative to satellite imagery because satellite data is inferior in spatial and temporal resolution compared to most UAV imagery. One important limitation to satellite imagery is the limitation imposed by cloud cover. Impending cloud cover can distort and reduce the usefulness of images. Thus one caome UAV skeptics, however, view that satellite data, while lacking in spatial and temporal resolution compared to UAVs, are the future of precision agriculture and crop management. One important limitation to satellite imagery is the limitation imposed by cloud cover. Impending cloud cover can distort and reduce the usefulness of images. Thus one can assume a UAV would be advantageous in areas where cloud cover or other vision obstructing elements are present.

As time progresses, the new developments in satellite technology as it relates to precision agriculture could have implications on the adoption of UAVs as a precision agriculture tool for cooperatives.

Value beyond the IRR

Outside of the quality of data and the value it could provide to cooperatives and their members, it is important to note that sentiment may play a large role in the demand for UAVs—specifically in agriculture. Utility may be attained from a producer simply having a tangible video or image of their farms. Agricultural producers (cooperative member-owners) may be willing to pay a premium for aerial imaging of their crop fields, even if the value of the data itself generates little to no return. While sentiment may not be as important to electric cooperatives, there are certainly other psychological driven factors that affect the adoption and demand of unmanned aircraft. For some, the value may be obtained through possessing cutting-edge technology—especially one so popularized by modern media.

An interesting question for further research is: Does the data itself create additional value for the cooperative beyond the existing methods? In simpler terms, is there a quantifiable economic benefit from the increased spatial and temporal resolution? Although the cost reduction model doesn't address this, it is an important aspect of this topic. Can farmers, agricultural cooperative member-owners, find value in the increased frequency of imaging or the quality itself? With higher levels of detail, could a farmer actually make management decisions at a greater vantage point than before? It is intuitive that limitations and constraints exist on the mechanical side of precision agriculture that could impede the usefulness of additional detail beyond a certain point. Farm implements and their technology, such as variable-rate fertilizers, would have to be able to handle the additional level of detail in order to actually apply the increased information provided.

From an agricultural cooperative's standpoint, the cooperative's financial sustainability is inherently impacted by the financial health of the farmers who are member-owners of the cooperative. This is unique from privately owned grain elevators or agricultural feed, supply, and chemical companies. The greater reliance and symbiosis between the farm owner and the cooperative, which, again, acts as an extension of the farm-firm, creates unique incentives for each party. Cooperatives have a natural inclination to encourage and improve the quality and quantity of agricultural commodities produced. Greater grain volumes and improved quality can results in increased profits and price premiums when the physical commodity is marketed. If unmanned aircraft can provide means which the farmer can increase yields and improve the quality of the grain or commodity being harvested, both the cooperative and the farmer would benefit.

Additionally, farm supply cooperatives could see benefits from increased sales of crop inputs. If cooperative members (farmers) are monitoring their crops regularly, they may be more likely to purchase additional fertilizer, herbicides, fungicides, or other various farm inputs. Not only does the farmer improve efficiency in allocating those inputs through using UAVs as a precision agriculture tool, but the cooperative firm could benefit from the potential increase in sales.

On the other hand, could rural electric cooperatives realize quantifiable benefits from the data? Electric utilities don't experience the same growth and harvest period as farmers. Therefore, a RECs ability to make management decisions in the short-term may be increased over an agricultural cooperative. Perhaps the increased spatial and temporal resolutions create greater value in an REC application than an agricultural cooperative.

Societal Impacts

Some of the major concerns and reasons for strict rulings by the FAA are a result of potential effects on society. For example, privacy is often a top concern of the average American. When equipped with cameras, the everyday resident may have uncertainties about violation of personal privacy. Additionally, government and business entities may have proprietary information that could be sourced by way of an aerial vantage point. These are just a few typically voiced concerns.

Sustainability

Aside from negative societal impacts, there may be positive impacts realized to society through UAV inspection. Specifically in rural electric cooperatives, hundreds of miles of system power line are driven by at least one vehicle. This often requires the use of fossil fuels and raises questions of emissions.

Additionally, some interest exists in using UAVs to inspect wind turbines—an alternative source of renewable energy. While distribution cooperatives do not own generation capacity, it is somewhat relevant at the centralized level, or generation and transmission cooperatives. However, even most G&T cooperatives do not actually own the wind-turbines but merely purchase portions or the entire generation capacity from a third party. Still yet, cooperatives could perhaps use UAVs as an integral part of a comprehensive environmental sustainability plan. Furthermore, by improving the efficient allocation of resources as it relates to applying agricultural inputs and mitigating electrical outages, we can further increase cooperative sustainability efforts.

Limitations

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. As it stands, there are four requirements for cooperatives to implement UAVs. Those four requirements are: (1) cooperatives would need to apply for an exemption through either the Section 333 or Special Airworthiness Certificate, (2) obtain a certificate of authorization (COA), (3) register their aircraft with the FAA, and (4) have a licensed pilot with a FAA airman certificate.

As of early March 2016, Section 333 exemptions granted exceed 3,800. However, interest surpasses this number as the FAA website states they are experiencing processing delays due to a high volume of requests outstanding (FAA 2016).

Proposed Small UAS Rules

In hopes of a long term solution, the Department of Transportation's FAA has begun to draft the Small UAS Rule to accommodate present and future needs of the unmanned aircraft industry. This ruling would encompass the aircraft potentially used by cooperatives. Some of the notable portions of the proposed draft include: an aircraft weight of less than 55 lbs., visual line of sight, daylight only operation, and 500 feet of altitude maximum. Operator requirements would include: passing a knowledge-based exam administered by the FAA, vetting by the Transportation Security Administration, and obtaining an unmanned aircraft operator certificate with a small UAS rating, among others. As of June 21, 2016, Part 107 of the Small Unmanned Aircraft Rule above has been completed and will take effect August 1, 2016 (FAA 2016).

Not only do the rulings restrict or promote growth in this area for the overall UAV industry, but it also affects the way cooperatives could implement UAVs in their firm. In Figure 2 that follows, we display the results of our two survey respondent groups and their recorded responses on the perceived effectiveness of UAVs with and without current restrictions imposed by the FAA.

The survey data shows both groups do appear, on average, to see current federal regulations as inhibitive towards the effectiveness of unmanned aircraft in their respective industry. With the current Section 333 exemption requiring a licensed pilot for operation, it certainly restricts many cooperatives from being able to obtain necessary requirements to file for the exemption. With heavy restrictions one could anticipate cooperatives, both agricultural and electric, would pursue third-party crop scouting services to contract out the scouting/inspection, which is contrary to the model we propose in this research.

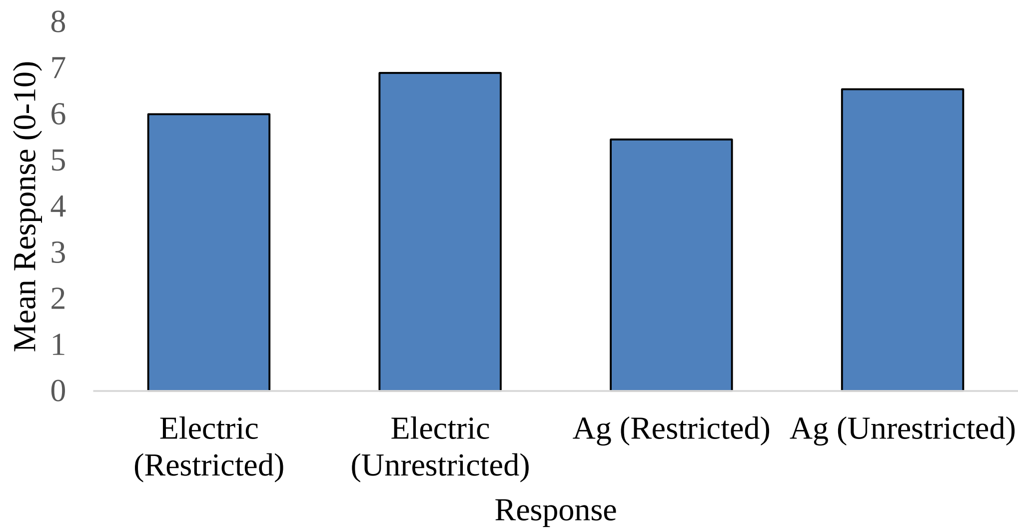

Figure 2. Perceived UAV Usefulness: With and Without 400 ft. and Line-of-Sight Restrictions Imposed for Agricultural and Rural Electric Cooperatives

Further Research

Data Ownership

One of the most deliberated issues in precision agriculture is often the question: *"Who owns the data?"* Is there value to a neighboring farm or electric utility that would create a competitive advantage? Furthermore, does having the data improve the ability to act and make value-added management decisions upon it? In an industry so deeply rooted on collaboration and growing together, cooperatives often find themselves very transparent and open to sharing information. Farm cooperatives may be able to used aggregated data and remove unique identifiers to benefit other members at the farm level. In the case of electric cooperatives where members are consumers, this would be less valuable. However, many distribution electric cooperatives collaborate with a "network" of RECs that are also served by their same centralized cooperative, or generation and transmission cooperative, from which they receive wholesale energy. While a blanket solution may not be obvious, there are benefits yet implications to the ownership and sharing of this geospatial data. Although UAVs could certainly provide a different source and level of data, cooperative industries already have and are collecting data. Thus, this is not a new issue but a reoccurrence of preexisting concern.

Empirical Inspection Data

To further test the feasibility of utilizing unmanned aircraft in cooperative firms, trial testing and monitoring of actual distribution line inspection and crop scouting times should be done to prove or disprove the validity of the reduction in time needed to achieve the targeted internal rates of return in the models. In addition to scouting and line inspection speed, addressing maintenance and repair costs, and the overall efficiency should be done. Furthermore, insight into the value of the additional detail of data could be analyzed to quantify other advantages in implementing UAV technology.

Final Remarks

As federal regulations and industry standards change, the potential of unmanned aircraft in agricultural and rural electric cooperatives continues to change likewise. Industry experts are hopeful that unmanned aircraft regulations are conducive to the business environment. Attempts of modernization of pre-existing rules, such as the Small UAS Rule mentioned previously indicate lawmakers are aware of the needs to accommodate industry utilization. Business leaders in agriculture and electric utilities, both cooperative and non-cooperative, are also hopeful for continued advancement in this area. However, some skepticism still exists on all sides. Amidst all of the hopeful industry leaders and critics of this technology, the data and research from this study and others show UAVs to be a promising opportunity for both agricultural and rural electric cooperatives to implement in their existing inspection routines and should continue to be evaluated as a financially viable opportunity.

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APPENDICES

Oklahoma State University Institutional Review Board

Date:	Wednesday, April 13, 2016
IRB Application No	AG1611
Proposal Title:	2016 cooperative UAV Survey
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved   Protocol Expires: 4/12/2019

Principal Investigator(s):

Justin Turner	Phil Kenkel
	516 Ag Hall
Stillwater, OK 74078	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1.Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms
2.Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3.Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4.Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

Projected Cash Flows from UAV Savings : Rural Electric Cooperative

		UAV						Traditional			
IRR	Year	UAV Expense	Wage	Hours*	Vehicular Expense	Wage	Hours*	Vehicular Expense	Salvage	NCF	NPV
5%	0	$ (15,000.00)	$26.74							$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$26.74	1784.42	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 4,556.80	$ 4,339.81
	2	$ (450.00)	$26.74	1784.42	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 4,556.80	$ 4,133.15
	3	$ (450.00)	$26.74	1784.42	$3560.08	$ 26.74	1971.66	$3,560.08	$ 3,000.00	$ 7,556.80	$ 6,527.85
10%	0	$ (15,000.00)	$26.74		$3560.08			$3,560.08		$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$26.74	1763.14	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 5,125.82	$ 4,659.84
	2	$ (450.00)	$26.74	1763.14	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 5,125.82	$ 4,236.22
	3	$ (450.00)	$26.74	1763.14	$3560.08	$ 26.74	1971.66	$3,560.08	$ 3,000.00	$ 8,125.82	$ 6,105.05
15%	0	$ (15,000.00)	$26.74		$3560.08			$3,560.08		$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$26.74	1741.44	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 5,706.08	$ 4,961.81
	2	$ (450.00)	$26.74	1741.44	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 5,706.08	$ 4,314.62
	3	$ (450.00)	$26.74	1741.44	$3560.08	$ 26.74	1971.66	$3,560.08	$ 3,000.00	$ 8,706.08	$ 5,724.39
20%	0	$ (15,000.00)	$26.74		$3560.08			$3,560.08		$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$26.74	1719.34	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 6,297.04	$ 5,247.53
	2	$ (450.00)	$26.74	1719.34	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 6,297.04	$ 4,372.94
	3	$ (450.00)	$26.74	1719.34	$3560.08	$ 26.74	1971.66	$3,560.08	$ 3,000.00	$ 9,297.04	$ 5,380.23
25%	0	$ (15,000.00)	$26.74		$3560.08			$3,560.08		$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$26.74	1696.86	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 6,898.15	$ 5,518.52
	2	$ (450.00)	$26.74	1696.86	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 6,898.15	$ 4,414.82
	3	$ (450.00)	$26.74	1696.86	$3560.08	$ 26.74	1971.66	$3,560.08	$ 3,000.00	$ 9,898.15	$ 5,067.85
50%	0	$ (15,000.00)	$26.74		$3560.08			$3,560.08		$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$26.74	1579.84	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 10,027.27	$ 6,684.84
	2	$ (450.00)	$26.74	1579.84	$3560.08	$ 26.74	1971.66	$3,560.08	$ -	$ 10,027.27	$ 4,456.56
	3	$ (450.00)	$26.74	1579.84	$3560.08	$ 26.74	1971.66	$3,560.08	$ 3,000.00	$ 13,027.27	$ 3,859.93

*Hours are total billable hours for two employees. Project hours should be total hours divided by 2

Projected Cash Flows From UAV Savings: Agricultural Cooperative

		UAV			Traditional				
IRR	Year	UAV Expense	Wage	Hours*	Wage	Hours	Salvage	NCF	NPV
5%	0	$ (15,000.00)						$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$ 26.25	835.61	$ 26.25	1026.33	$ -	$ 4,556.53	$ 4,339.55
	2	$ (450.00)	$ 26.25	835.61	$ 26.25	1026.33	$ -	$ 4,556.53	$ 4,132.90
	3	$ (450.00)	$ 26.25	835.61	$ 26.25	1026.33	$ 3,000.00	$ 7,556.53	$ 6,527.61
10%	0	$ (15,000.00)						$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$ 26.25	831.08	$ 26.25	1026.33	$ -	$ 5,125.44	$ 4,659.49
	2	$ (450.00)	$ 26.25	831.08	$ 26.25	1026.33	$ -	$ 5,125.44	$ 4,235.90
	3	$ (450.00)	$ 26.25	831.08	$ 26.25	1026.33	$ 3,000.00	$ 8,125.44	$ 6,104.76
15%	0	$ (15,000.00)						$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$ 26.25	808.97	$ 26.25	1026.33	$ -	$ 5,705.83	$ 4,961.59
	2	$ (450.00)	$ 26.25	808.97	$ 26.25	1026.33	$ -	$ 5,705.83	$ 4,314.42
	3	$ (450.00)	$ 26.25	808.97	$ 26.25	1026.33	$ 3,000.00	$ 8,705.83	$ 5,724.22
20%	0	$ (15,000.00)						$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$ 26.25	786.46	$ 26.25	1026.33	$ -	$ 6,296.71	$ 5,247.26
	2	$ (450.00)	$ 26.25	786.46	$ 26.25	1026.33	$ -	$ 6,296.71	$ 4,372.72
	3	$ (450.00)	$ 26.25	786.46	$ 26.25	1026.33	$ 3,000.00	$ 9,296.71	$ 5,380.04
25%	0	$ (15,000.00)						$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$ 26.25	763.57	$ 26.25	1026.33	$ -	$ 6,897.58	$ 5,518.06
	2	$ (450.00)	$ 26.25	763.57	$ 26.25	1026.33	$ -	$ 6,897.58	$ 4,414.45
	3	$ (450.00)	$ 26.25	763.57	$ 26.25	1026.33	$ 3,000.00	$ 9,897.58	$ 5,067.56
50%	0	$ (15,000.00)						$ (15,000.00)	$ (15,000.00)
	1	$ (450.00)	$ 26.25	644.38	$ 26.25	1026.33	$ -	$ 10,026.31	$ 6,684.21
	2	$ (450.00)	$ 26.25	644.38	$ 26.25	1026.33	$ -	$ 10,026.31	$ 4,456.14
	3	$ (450.00)	$ 26.25	644.38	$ 26.25	1026.33	$ 3,000.00	$ 13,026.31	$ 3,859.65

Time Spent Inspecting for RECs and Ag Cooperatives: Actual Versus Projected UAV (Minutes/unit)

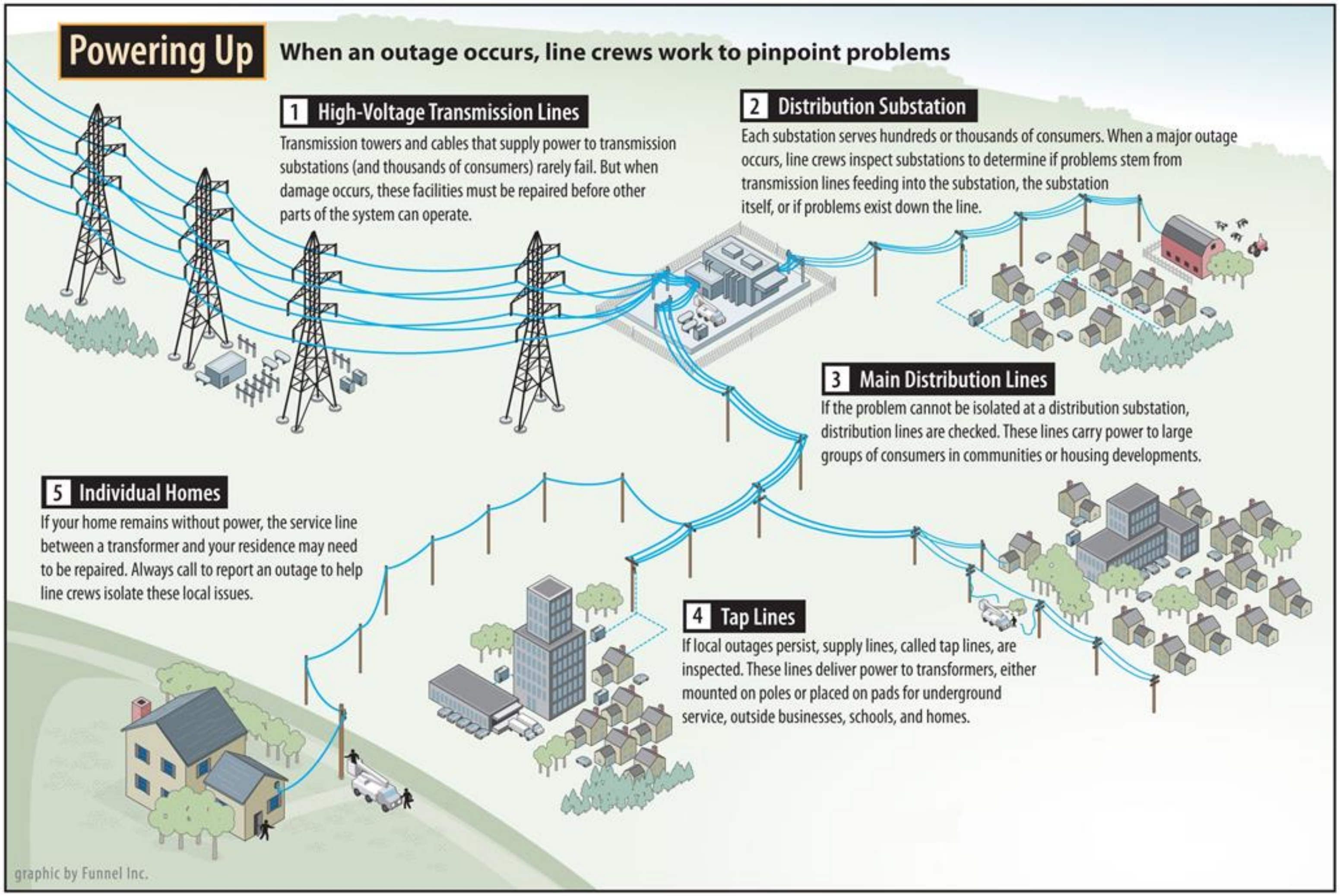
IRR	Minutes/Mile Line	Δ time	Minutes/Acre	Δ time
	REC		Ag	
Actual (from survey)	*8.97*		*2.06*	
5%	8.12	-9.50%	1.68	-18.58%
10%	8.02	-10.58%	1.63	-20.69%
15%	7.92	-11.68%	1.59	-22.85%
20%	7.82	-12.80%	1.54	-25.04%
25%	7.72	-13.94%	1.50	-27.27%
50%	7.19	-19.87%	1.26	-38.89%

Overview of Oklahoma Distribution REC Inspection Statistics

Description	N	Mean	Standard Deviation	Median	Min.	Max.
Miles of Line	20	3995.60	1708.78	3881.50	1500	8900
Inspection Rate (miles/day)	20	53.50	74.04	20	4	300
Annual Inspections	20	1.65	1.23	1	0	5

Oklahoma Distribution REC Knowledge and Awareness Survey Results

Description	N	Mean	Standard Deviation	Median	Min.	Max.
Personal UAV Knowledge (Perceived)	20	2.70	0.92	3	1	5
Perception of UAV Effectiveness in Line Inspection (Restricted)*	20	6.00	2.53	6	1	10
Perception of UAV Effectiveness in Line Inspection (Unrestricted)	20	6.90	2.45	7	1	10



Overview of Electric Power System from Generation to Consumer (Funnel, Inc. 2015)

Per-Unit Costs of Inspection for Agricultural and Rural Electric Cooperatives (Conventional versus Projected UAV Costs)

	AG ($/ac)		REC ($/mi)	
IRR	**Conventional**	**UAV**	**Conventional**	**UAV**
0.05	$ 0.90	$ 0.88	$ 8.54	$ 8.45
0.1	$ 0.90	$ 0.88	$ 8.54	$ 8.37
0.15	$ 0.90	$ 0.86	$ 8.54	$ 8.28
0.2	$ 0.90	$ 0.84	$ 8.54	$ 8.19
0.25	$ 0.90	$ 0.82	$ 8.54	$ 8.10
0.5	$ 0.90	$ 0.71	$ 8.54	$ 7.62

VITA

Justin Michael Turner

Candidate for the Degree of

Master of Science

Thesis: THE ECONOMIC POTENTIAL OF UNMANNED AIRCRAFT IN AGRICULTURAL AND RURAL ELECTRIC COOPERATIVES

Major Field: Agricultural Economics

Biographical:

Education:

Completed the requirements for the Bachelor of Science in your Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in 2014.

Experience:

Graduate Research Assistant
Department of Agricultural Economics
Oklahoma State University
Stillwater, OK