JOURNAL OF UNMANNED AERIAL SYSTEMS

PEER-REVIEWED PAPER

PERCEPTIONS OF PROGRAM LEADERS ON THE USE OF UNMANNED AIRCRAFT SYSTEMS FOR FOREST HEALTH MANAGEMENT

Danny R. Zimmerman, Ph.D.
Northeastern Area Aviation Officer, State & Private Forestry, U.S. Forest Service

Helen Zaikina-Montgomery, Ph.D.
Director, Graduate School, Northcentral University

Abstract

Forests are a significant resource to the national economy in terms of forest-related products, environmental impact, and recreation. The US Forest Service manages federally owned national forests and collaborates to provide assistance to states and private individuals in management of state and private forests. Wildland fires and insect and disease outbreaks threaten the health of the forests in the US. The Forest Service is tasked with monitoring forest health and aerial surveys contribute extensively to the achievement of this goal. However, these surveys are time-consuming and expensive. Given the current need to decrease government budgets, the organization is challenged to provide adequate forest surveillance, while at the same time lowering cost. The addition of unmanned aircraft system (UAS) technology could be part of the solution to this problem. Recent studies suggest UAS technology can be used to provide quality data collection regarding forest health at a lower cost than traditional methods. In order to introduce this new technology within such a large organization, management support would be needed. This descriptive qualitative case study explored the attitudes of key forest health personnel on the concept of UAS technology through informal conversational interviews. Diffusion of innovations theory was used to guide the research process. The participants included forest health program managers and data collectors from all nine geographic regions of the United States that are managed by the Forest Service. The researcher explored their knowledge of UAS technology and its potential use in improving forest health surveillance within their programs, as well as their attitude regarding this innovation. Seventeen themes were identified including overall acceptance of the technology, reasons for favorability and concerns about the technology, overall knowledge level as well as educational needs, uncertainty of cost effect, and overall belief that this technology will improve data quality. The results added to the current limited literature regarding implementation of new technology in a government organization. Implications of using UAS technology in forest health management are presented regarding privacy, educational needs, budgets, and effects on cost and quality. Recommendations are presented for future research.

Background

The Forest Service, an agency that falls under the direction of the US Department of Agriculture (USDA), is an organization comprised of personnel who manage large areas of forested public lands ("About us," 2011) and interface with states and private landowners to provide support in the management of forests ("State and Private Forestry," 2010). The Forest Service manages 193 million acres of national forests and grasslands in the United States, including 155 national forests and 20 grasslands ("About us," 2011). The mission of the organization is to sustain the health, diversity, and productivity of the forests and grasslands in order for these resources to be able to meet the needs of the present and future generations ("Mission," 2008).

The value of the public forest resources to the US national economy is significant with respect to forest-related products, environmental impact, and recreation ("USDA Forest Service Strategic Plan FY 2007-2012," 2007). National forests, especially in the west, are a significant source of the nation's water supply with the estimated annual value of water flowing from national forests of $3.7 billion (Kimbell, 2010). Recreation on the national forests and grasslands contributes an estimated $14 billion per year to the nation's economy ("National visitor use monitoring results," 2010). A key challenge to the organization is to protect the resources contained in national forests ("Forest Health," 2011). Since 1990, concerns have increased due to weather extremes, severity of wildland fires, and insect and disease outbreaks that threaten the health of the forests and disrupt ecosystems ("National roadmap," 2010). Between 65 and 82 million acres of national forests and grasslands need some type of restoration (USDA-Forest Service, 2012). This fact emphasizes the need to increase the pace and scale of restoration (USDA-Forest Service, 2012). These facts only strengthen the idea that there is not only a need to restore, but to protect the undamaged areas and monitor the progress of the ongoing restoration. This task will be accomplished through forest surveillance.

Surveillance of forest health is monitored by means of formal surveys of the land (Carnegie, Cant, & Eldridge, 2008). The Forest Health Protection program is devoted to monitoring forest health ("Programs," 2011). The program provides technical assistance on forest health matters, especially related to disturbance agents such as pests, pathogens, and invasive plants that threaten forest resources. The most efficient and cost-effective technique related to invasive species is the prevention of their establishment and spreading within a forest area ("Forest Health Protection," 2011). The forests in the United States are monitored to obtain information over time about the health of the forest in order to determine if there are detrimental changes or improvements (Bennett & Tkacz, 2008). In order to achieve this goal, it is necessary to obtain views of large areas of land. Aerial surveys are used in surveillance as a method to determine the status of forest health (Woodall, Morin, Steinman, & Perry, 2010) and have played a key role in facilitating the goal of forest health management, from the perspective of forest health and fire management ("Aerial Application," 2009). Therefore, the use of aircraft contributes to achieving the mission of the Forest Service by providing access to large areas of land. The high resolution images that are needed for forestry are costly and difficult to obtain by either satellite or traditional airborne data collection using pilots and technicians (Grenzdorffer, Engle, & Teichert, 2008). Despite the benefits of aerial support for forest health monitoring, these programs are often targets for cost-cutting (Becker, 2004).

As with any government agency, the Forest Service is tasked with decreasing operational costs ("Budget," 2011). The Budget for FY 2012 contained a three percent reduction for Forest Health Management-Federal Lands ("FY 2012 budget justification," 2011). The cost related to using aerial support for forest surveillance adds to the organizational budget (Rasker, 2010). However, a recent survey involving attitudes of managers suggested that Forest Service wildfire managers consistently ranked the cost of their efforts as the least important factor in their decision-making process (Wibbenmeyer, Hand, & Calkin, 2012).

The addition of unmanned aircraft system (UAS) technology could be one key part of the solution in reducing cost and improving forest health management, as well as other programs such as fire, wildlife, and timber management. The organizational change involved to implement this innovative technology would be facilitated by the support of management within the forest health programs, as well as by employees who will use the technology within the organization (Fernandez & Rainey, 2006). However, organizational change and acceptance of new technology can be difficult to achieve (Chew, Cheng, & Petrovic-Lazarevic, 2006).

Currently, about one-third of the US is forested making it the fourth largest forest estate in the world and the Forest Service manages about 25 percent of those forested lands (Blay & Dombeck, 2013). The agency is organized into nine geographical regions illustrated in Figure 1 and each region has a forest health program manager and at least one individual who collects forest health data ("About us," 2011).

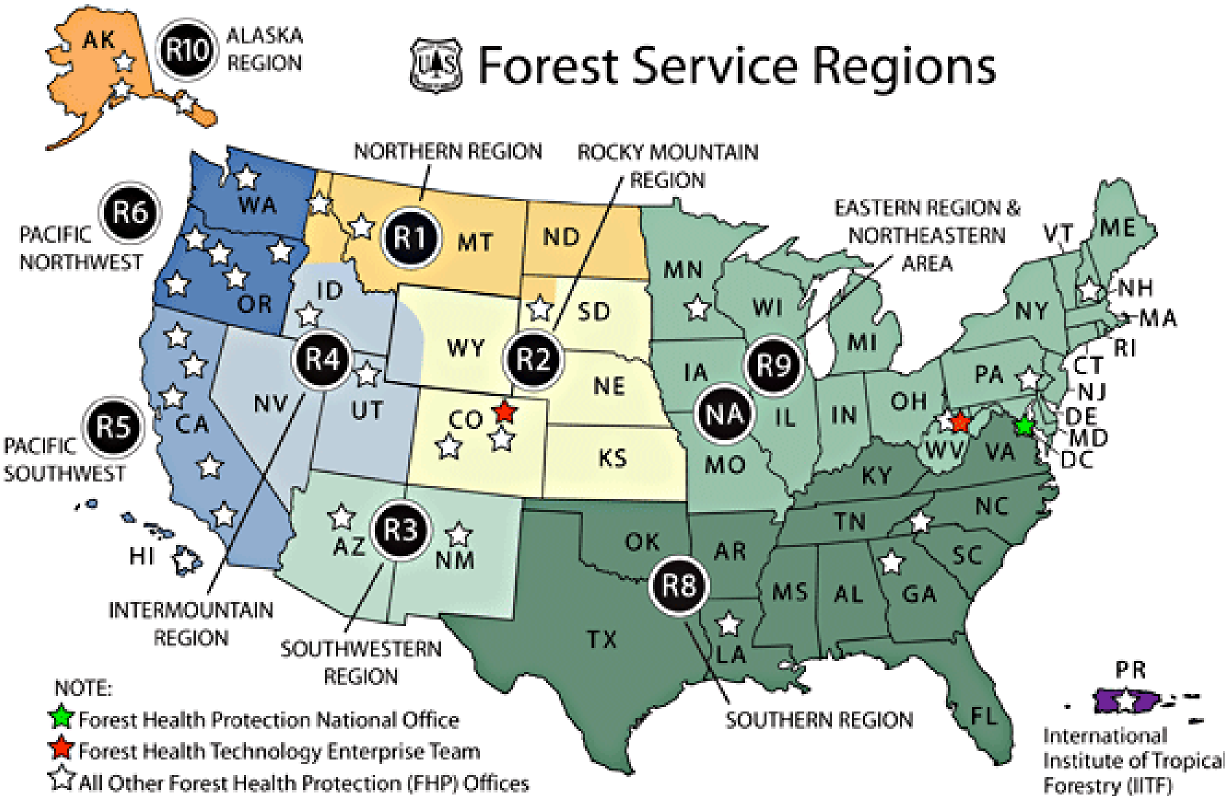

Figure 1. Regions of the US Forest Service

This figure illustrates the nine regions of the US Forest Service including Northern Region (R1), Rocky Mountain Region (R2), Southwestern Region (R3), Intermountain Region (R4), Pacific Southwest Region (R5), Pacific Northwest Region (R6), (note there is no R7), Southern Region (R8), Eastern Region (R9), and Alaska Region (R10) presented at http://www.fs.fed.us/foresthealth/resources/images/FS_regions.gif

Statement of the Problem

The Forest Service is challenged to provide forest health management at a lower cost. Forest Service aviation needs, which play a large role in forest health surveillance and fire management, have been assessed many times; however, the conclusions of these studies in terms of type, quantity, and cost differ (Bracmort, 2013). Even the most recent of these studies (Keating et al., 2012) does not consider UAS technology, despite the fact that studies suggest that UAS technology has the potential to provide effective surveillance to maintain forest health, while at the same time allowing for a reduction in cost (Grenzdorffer, Engle, & Teichert, 2008; Marenchino, 2008; McCormack, 2008; & Meszaros, 2011). Regulations were expected to be in place by 2020 to govern UAS operations ("Unmanned Aircraft Systems," 2008), but with the "Small UAS Notice of Proposed Rulemaking" having gone forward in February (Federal Aviation Administration, 2015), this is now more likely to be in 2016 or 2017, at least for small UASs (those under 55 pounds). The introduction of UAS technology has the potential to be part of the solution to improve forest health surveillance; however, the acceptance of this new technology will involve change. Because managers are very influential in promoting organizational change (Ryan, Williams, Charles, & Waterhouse, 2008), the attitude of program managers about UAS technology and their understanding of its potential use in their programs is crucial. At the same time, the implementer will be the individual who will actually put the innovation to use (Rogers, 2003) and therefore, data collectors also play a significant role in acceptance of this new technology. Because the perceptions of key forest health personnel about UAS technology are unknown, the need for a qualitative study exploring the attitudes and knowledge of these individuals about the use of UAS technology has emerged.

Purpose of the Study

The purpose of this descriptive qualitative case study was to explore the attitudes of the forest health program managers and data collectors about the use of UAS technology and their knowledge level of this technology in relation to their programs.

Theoretical Framework

The Diffusion of Innovation Theory (Rogers, 2003) was used as the theoretical framework. This research falls under the category of organizational behavior as it involves members of the organization to implement a new innovation as part of the standard practice. However, it also involves social psychology in that individual and cultural factors affect the acceptance of innovations (Tolba & Mourad, 2011). The Diffusion of Innovation Theory has its roots in social psychology. The history of conceptual and empirical study of this theory is extensive and the robustness of the theory is the result of studies that have been conducted from many disciplines and fields (Dearing, 2009). Rogers' theory is appropriate for investigating the adoption of new technology and, in fact, Rogers often used the words technology and innovation interchangeably (Sahin, 2006). The current use of the theory is evident in research involving acceptance of new technology (Blau & Hameiri, 2010; Casanovas, 2010; Greenhalgh et al,, 2008; Peslak, Ceccucci, & Sendall, 2010; Tolba & Mourad, 2011; & Vaccaro, Ahlawat, & Cohn, 2010).

Rogers (2003) developed the theory in an effort to understand what factors influence a person's willingness to accept or reject new technology. The theory was developed in terms of the social context in which individuals exist. The four main elements of the theory are the innovation itself, communication channels, time, and the social system. The guiding principle is that in the process of diffusion, the innovation is communicated through channels over time within a social system (Sahin, 2006). The assumption of the theory is that in any given sample of individuals or organization faced with accepting new technology, this process will occur.

According to Dearing (2009), diffusion of innovation theory is evolving into a science of dissemination driven by new technologies and needs of government agencies. Dearing believes this science is being shaped by researchers in various fields of study, including forestry. Dearing also pointed out that the adopter of the innovation is not necessarily the one who will use it. The implementer will actually put the innovation to use.

The social system in Rogers' theory may be represented by an organization. According to Rogers, the individual and the social system in which they exist may be affected by the innovation. In a literature review regarding the adoption of online education in universities by Casanovas (2010) concluded that the organizational culture will influence whether the innovation is accepted.

This study was guided by the Diffusion of Innovation Theory because adopting UAS technology represents a change for individuals as well as organizational change. Within the context of the theory, the program managers represent the adopters, the data collectors the implementers, and the Forest Service the social system.

There are five main diffusion characteristics that influence the rate of adoption including relative advantage, observability, compatibility, complexity, and trialability (Rogers, 2003). The presence of these five factors is consistent with faster adoption of the innovation. Rogers stressed that adopting a new innovation is difficult and that the theory of diffusion will continually evolve over time. In a study by Vacaro, Ahlawat, and Cohen (2010) regarding adoption of the Apple iPhone, the researchers contributed to the theory by extending the list of diffusion characteristics to include cost, uncertainty, social relevance, and marketing design.

The model postulates that in any given sample, the subjects will fall into one of five adopter categories illustrated in Figure 2. Few (16%) are in the innovator and early adopter category, the majority (68%) falls into the early and late majority, and the final 16% fall into the laggard category (Rogers, 2003). The theory enables the researcher to predict that in the group of managers and data collectors, there will be individuals who will represent characteristics of each of these groups in a similar distribution.

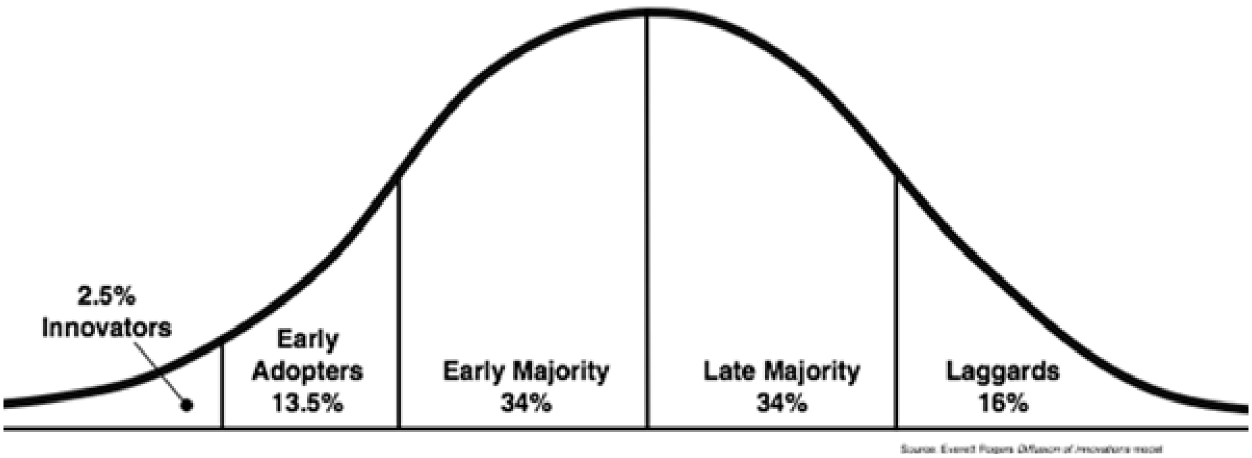

Figure 2. Bell-curve distribution for Roger’s Diffusion of Innovation Theory

This figure illustrates the distribution of the five categories for any given sample.

Many studies suggest that UAS technology can provide quality data for forest health surveillance at a lower cost; however, there is an unanswered question whether individuals, such as program managers and data collectors, in the Forest Service would accept the technology. Therefore, the use of a theory related to diffusion of innovation of new technology was appropriate for this study.

Research Questions

The purpose of this descriptive qualitative case study was to explore the attitudes of the forest health program managers and data collectors about the use of UAS technology and their knowledge level of this technology in relation to their programs. The central research question was what perceptions do program leaders have on the use of Unmanned Aircraft Systems in their Forest Health Management programs? The five research questions that guided the inquiry are listed below.

Q1. What is the attitude of managers and data collectors regarding the future use of UAS technology in their programs?

Q2. What reasons exist to contribute to the attitude of the managers and data collectors about future use of UAS technology in their programs?

Q3. What is the knowledge level of managers and data collectors regarding how UAS technology would be used in their forest health programs?

Q4. What is the level of understanding that managers and data collectors have regarding how UAS technology would affect the cost of their forest health programs?

Q5. What is the level of understanding of managers and data collectors about how UAS technology might affect the quality of data collected through aerial surveillance?

Research Methods and Design

In this descriptive qualitative case study the attitudes of forest health program managers and data collectors were explored regarding the use of UAS technology in their programs. This was done in order to examine their inherent knowledge of the technology and its potential use in improving forest health surveillance with an emphasis on increasing the quality of the data collected and lowering the cost of the program. To accomplish this objective, interviews using open-ended questions were conducted with program personnel in order to gather the data. This interview technique is used when the researcher is principally interested in descriptive, explanatory or exploratory appraisal in order to obtain subjective data, such as attitudes (Patton, 2002).

A qualitative design was appropriate for this study because the attitude of program managers and data collectors about the concept of UAS technology is unknown. A case study is used to capture the complexities of a single case; however, the single case can be made up of multiple cases (Yin, 2014; Patton, 2002). In this research, the multiple-case study design was used in which multiple cases (18 interviewees) contributed to the overall qualitative data. The reason this design was chosen is that, unlike single case design, multiple-case design provides the possibility of direct replication and a strong start to theoretical replication which will strengthen the findings (Yin, 2014). The researcher was able to maintain the personnel consistency of manager and data collector as the interviewees, while at the same time, providing the diversity within the sample consisting of personnel from all nine regions of the country. The multiple interviews served as the case of analysis studied. The qualitative analysis centered on the presentation of thematic analysis across the cases (Patton, 2002). The justification for choosing an interview approach for this particular study was based on the fact that both the participants and the researcher would have the ability to take the interview in a variety of directions for the purposes of data collection. The open-ended questions used within the study were primarily guided by the research questions established by the researcher and Diffusion of Innovation Theory. The interview style was informal conversational interviewing. The research questions were directed at how the managers view UAS technology and how much they know about its potential use in their programs. A pilot study was conducted in order to test this entire process on two individuals not involved with this research. One individual works as a wildland fire training officer and the second individual is a program manager for the Forest Service state fire assistance program. Institutional Review Board (IRB) approval from Northcentral University (NCU) was obtained for the pilot study alone and then later obtained for the core study.

Population

The population in this research study included individuals who are responsible for forest health protection within the Forest Service. This group includes those individuals in management positions related to the forest health program as well as those individuals who carry out assessments and data collection. Forest health oversight is influenced by decisions made by high level leaders in the Forest Service to program managers in each region to those individuals who actually collect data regarding forest health. This population was appropriate for the study because it is the attitude of these individuals about the value of UAS technology that will determine if it will be used, since these individuals will be most affected by its use.

Sample

The purposive, convenience sample (Marshall, 1996) was pre-determined by the regions of the Forest Service and consisted of 18 participants. The sample consisted of the one program manager and one data collector from each of the nine geographic regions. There is some word of caution on even using the term "sample" within a case study (Yin, 2014), since the use of the term may mislead others to think the case comes from a larger population of like cases. The researcher did not wish to imply that assumption. This sample was chosen because it represents the nine regions nation-wide and included those individuals with the closest involvement with forest health activities.

Recruitment consisted of the researcher contacting the managers and data collectors from each of the nine regions. These regions were already established and identified as well as the individuals who serve in these positions. All 18 individuals were invited to participate in the study and were informed that participation was voluntary.

Materials/Instruments

The interview questions were guided by the Diffusion of Innovation Theory. The concepts of the theory were used to develop the questions in relation to the five research questions. These questions were derived from the researchers' desire to explore attitudes and knowledge level of managers and data collectors about the use of UAS technology in their programs. There were a total of 10 interview questions. Each participant was allowed as much time as was needed to answer the questions. Prior to full study data collection, the interview instrument was pilot tested with two individuals who are in similar positions as the full study participants in the Forest Service, but were not a part of the full study sample. One individual works as a wildland fire training officer and the second individual is a program manager for the Forest Service State Fire Assistance Program. Based on the results of the pilot study and input from the reviewers, the researcher made revisions to the interview questions. The researcher revised the interview to include open-ended questions with follow-up questions to eliminate the possibility of simple yes or no answers. The questions also reflected a greater clarification asking the participants to explain their knowledge of UAS technology. Based on reviewer input, a question regarding aerial surveys was added as well as a question regarding safety. The question related to a timeframe when the Forest Service could be ready for implementation of UAS technology in forest health was changed to allow for an open-ended answer rather than the specific year. Finally, a way of debriefing participants was added by asking them if they had any questions about the study.

Data Collection, Processing, and Analysis

There were six steps in the data collection process. (1) Each participant completed an informed consent form. (2) The researcher conducted one interview with each individual by telephone. (3) One hour was allotted for each interview. (4) Because the questions were open-ended, each interviewee also had an opportunity to ask questions or take the interview in a different direction in order to share his or her ideas regarding the topic. (5) If any program manager would have been uncomfortable with this method, other data collection accommodations would have been made, such as traveling to meet with that individual personally; however, this situation did not occur. (6) With the permission of the participants, the interviews were digitally recorded. If the participant would have been uncomfortable with the interview being recorded, the researcher would have taken detailed notes from the interview. However, this situation did not occur.

After the data was collected, the digitally recorded interviews were transcribed by an individual not affiliated with the study. The transcribed data was reviewed manually by the researcher and two professional colleagues not involved in the research project.

Thematic analysis was used to identfy themes. This process is a form of pattern recognition achieved by careful reading and re-reading of the data in order to identify emerging themes (Fereday & Muir-Cochrane, 2006; Patton, 2002). The three evaluators manually reviewed the data separately, but in the same manner. Having multiple evaluators review the transcripts enabled the different individuals to form themes from the data (Golafshani, 2003) and served as a form of investigator triangulation in an effort to balance the subjective influences of individuals (Jupp, 2006). Each reviewer received paper copies of the transcribed interviews and was instructed to manually review the data using coding, sifting, sorting, and identifying themes (Lichtman, 2013). As such, it was expected that by utilizing the process of reading and re-reading the data, emerging themes within the collected data sets could be identified. For example, the assigned code of [decreased risk to personnel] was present in all 18 responses regarding potential benefit of UAS technology. Thematic analysis can help the researcher to demonstrate rigor (Fereday & Muir-Cochrane, 2006), an important factor in conducting case study research (Yin, 2014). When research is performed in a rigorous manner it can lead to more effective practices than decisions based mainly on intuition, personal preferences, or common sense (Anderson, Lievens, Van Dam, & Ryan, 2004). With such an analysis, the findings were obtained in an unbiased manner.

The reviewers identified categories and themes derived from the data, and identified the main common themes. It is based on this information that the researcher utilized the data garnered through the interviews, along with data from the literature review, in order to develop a sufficient platform from which effective, and above all accurate, conclusions were created.

Results

A total of 18 individuals were invited to participate in the study and all accepted. The sample consisted of the one program manager and one data collector from each of the nine regions of the Forest Service for a total of 18 participants. The demographics of the sample are presented in Table 1. The average age of the program managers was 54 (M=54.89, SD=6.41) and 46 (M=46.00, SD=7.53) for the data collectors. Eight of the nine program managers and seven of the nine data collectors were male. Of the nine program managers, eight were caucasian and one was African American. Eight of the nine data collectors were caucasian and one was Native American. Of the nine program managers two had a bachelor's degree, five a master's degree, and two a doctoral degree. Of the nine data collectors one had some college, four had a bachelor's degree and four had a master's degree. The mean years of service for the program managers and data collectors was 26 (M=26.39, SD=12.15) and 17 (M=17.33, SD=7.95), respectively.

Table 1

Demographics of Sample

Characteristics	Subgroup	Program Manager (n=9)	Data Collector (n=9)
Age	M (SD)	54.9 (6.4)	46.0 (7.5)
	Range	42-62 yrs	37-57 yrs
Years Service	M (SD)	26.4 (12.15)	17.3 (7.95)
Gender	Female	1	2
	Male	8	7
Race/Ethnicity	African American	1	0
	Asian American	0	0
	Caucasian	8	8
	Hispanic	0	0
	Native American	0	1
	Other	0	0
Education	High School	0	0
	Some College	0	1
	Associate Degree	0	0
	Bachelor's Degree	2	4
	Master's Degree	5	4
	Doctoral Degree	2	0

Seventeen themes were identified illustrated in Figure 3 including overall acceptance of the technology, reasons for favorability and concerns about the technology, overall knowledge level as well as educational needs, uncertainty of cost effect, and overall belief that this technology will improve data quality.

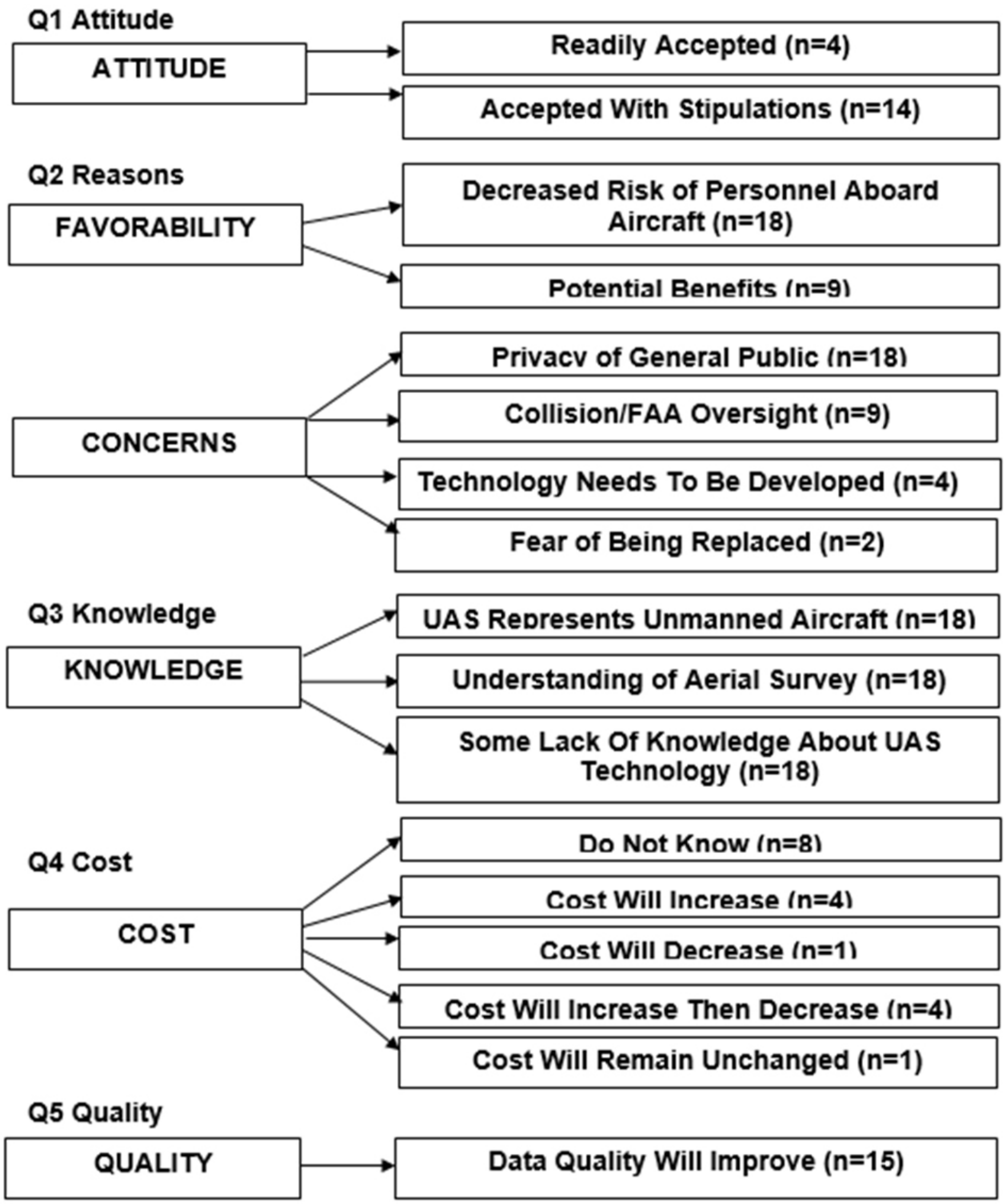

Figure 3. Flowchart created by the author illustrating the 17 themes identified through data analysis in relation to the five research questions.

Accepted with stipulations. While several participants expressed that the technology would be readily accepted, most participants expressed that UAS technology would be accepted with stipulations including the development of a communications plan, a training plan, a strategy for implementation, and organization-wide policies. This information will be especially helpful to those individuals within the organization planning education and training of personnel on UAS technology.

Most of the participants categorized themselves on the early adoption side of Rogers' Theory. This factor is important because, according to the theory, the adopter will make the decision whether to invest in the innovation (Rogers, 2003). Fifteen of the 18 participants placed themselves in the category of innovator, early adopter, or early majority. Support for UAS technology at the level of the managers is a good predictor of its acceptance within the organization. The literature supports the fact that organizations must be innovative to adapt to changing circumstances (Yukl & Lepsinger, 2004) and in the public sector, such as the Forest Service, organizational change requires support of top level civil servants (Fernandex & Rainey, 2006).

Table 2

Categories of Participants within Roger's Theory

Categories	Program Managers (n=9)	Data Collectors (n=9)
Innovators	3	3
Early Adopters	4	2
Early Majority	1	2
Late Majority	1	0
Laggards	0	2

Decreased risk of personnel aboard aircraft. All the study participants expressed that UAS technology would improve safety simply by keeping personnel out of the air. One of the many benefits of UAS technology is less risk in flight compared to traditional manned aircraft (Martinsanz, 2012).

Potential benefits. Most participants expressed that UAS technology will benefit their programs. The literature supports the participants belief and contains multiple sources that suggest UAS technology will improve surveillance over large areas of land, whether that be for forest health monitoring (Ollero & Merino, 2004), inspecting forestry operations (Grenzdorffer, Engel, & Teichert, 2008), glacier monitoring (Whitehead, 2010), avalanche control (McCormack, 2008), natural disaster monitoring ((Al-Tahir, Arthur, & Davis, 2011), forest fire monitoring (Everaerts, 2008), and collecting low-altitude imagery over difficult areas (Jones, Pearlstine, & Percival, 2006).

Privacy of general public. All participants expressed that the use of UAS technology will create privacy concerns for the public. Several addressed the big brother concept and that some members of the public will worry that they are being watched by the government. Some stated that this may be more prevalent in certain areas of the country than others. The literature supports the fact that civil liberty and privacy groups have concerns about misuse of UAS technology and limited oversight by the FAA in this regard (Elias, 2012). Many participants in this study expressed that a proactive approach by the organization would be best when implementing UAS technology into their programs and regions. This important data finding can be very useful to the organization in planning a proactive approach to public education of UAS technology in its forest health program.

Collision/FAA oversight. Several participants expressed concern that UASs may collide mid-air with other aircraft. Many participants also expressed not only the need for FAA oversight, but that they want the direction and guidance of the FAA regulations. Participants pointed out that the Forest Service is an organization in which personnel are familiar with rules and regulations and they want similar guidance to address the use of the new technology. The FAA is working closely with the UAS community to develop standards including how UASs will sense and avoid other aircraft. Part of this effort is the UAS Traffic Management (UTM) system, being led by NASA for the FAA so that small UAVs and other aerial platforms can co-exist, especially in airspace that will primarily be used by UAVs (National Aeronautics and Space Administration, 2015.)

Technology needs to be developed. Several participants stated they believed UAS technology will need to be further developed before it could be useful in their programs. One researcher found that despite the advancing use of UAS technology in photogrammetry, the availability of these systems is limited and development is needed in relation to the sensors and the Global Positioning System (GPS) unit of the guidance system (Meszaros, 2011). However, as manufacturers become aware of the requirements needed for UASs to complete aerial survey images, the way will be paved for UAS technology development in this area (Grenzdorffer, Engel, & Teichert, 2008).

Fear of being replaced. Two participants expressed concern that they may be replaced by this new technology. They enjoy flying and they do not want to see that part of their job eliminated. However, the literature supports the fact that UAS technology will not eliminate jobs; a UAS is not without a pilot and in many cases, there may be more crew members needed than with traditional aircraft (Everaerts, 2008).

Some lack of knowledge about UAS technology. While all participants had a clear understanding of aerial surveys and UAS technology in general, most expressed that they do not know enough about it to know how it will affect their Forest Health programs. Under the Diffusion of innovation Theory, the first of the five stages of acceptance of new technology is knowledge; there must be knowledge and understanding of the concept in order to achieve acceptance (Rogers, 2003).

Desire for multiple methods of learning. Most participants expressed that they want to learn more about UAS technology and that they want to have multiple methods of training in order to gain that knowledge. This information can be very beneficial for leaders within the organization as they plan education programs for learning about UAS technology.

Cost-benefit uncertainty. Participants had a wide range of responses related to the potential cost benefit of UAS technology in their programs. All participants expressed their opinion of what would happen with cost; however, most all participants stated that they did not really know for certain how the new technology would affect their program costs. The literature suggests that aerial surveying can be conducted using UAS technology in forestry and can provide the same high quality data as conventional methods at a much lower cost (Grenzdorffer, Engle, & Teichert, 2008; Marenchino, 2008; Rango et al,, 2009; Wallace, Lucieer, Watson, & Turner, 2012; & Whitehead, 2010).

Improved quality. All participants expressed the belief that UAS technology would improve the quality of data collected in their programs. This belief is related to the fact that the data would be more standardized, human subjectivity would be removed, and interpretation would be more objective. The literature supports the participants' belief that conducting forestry surveillance using UAS technology will improve quality of the data (Lu, Li, & Tang, 2010; & Lucieer, Robinson, & Turner, 2010).

Evaluation of Findings

Q1. What is the attitude of managers and data collectors regarding the future use of UAS technology in their programs?

The overall attitude of the participants was positive regarding the future use of UAS technology in their programs. However, only a few participants stated that the technology would be readily accepted. The majority of participants said the technology would be accepted with stipulations including the development of a communication plan, training plan, strategy for implementation, and an organization-wide policy.

Participant Ma stated:

> "I feel pretty positive about the technology. I'd really be a champion if we're going to this new technology."

Nearly all participants felt safety would be improved simply by keeping personnel out of the air.

Participant Ma stated:

> "I don't have much of a safety concern about using the drones. . . . . the safety aspect I see is protecting the lives of our pilots and spotters who go up into the air on this monitoring for hundreds of hours every summer season."

All of the participants addressed the belief that public privacy concerns will be an issue, the concept of big brother watching over the public, the need for a social license to use this technology, and the need to be proactive in educating the public.

Participant Ma stated:

> "I think we'll need some social license to do this work . . . and I think it's our responsibility to do that."

Q2. What reasons exist to contribute to the attitude of the managers and data collectors about future use of UAS technology in their programs?

The overall attitude was positive and one might postulate that the participants felt this way because many placed themselves in the early innovator category and that they believe the organization will benefit from this new technology. The participants offered positive reasons in favor of the technology including decreased risk to personnel and potential benefits. They also offered concerns that contributed to their attitude. These reasons included concerns for privacy of the general public, for collision and need for FAA oversight, for the need for technology development, and for fear of being replaced in their jobs by the technology.

Q3. What is the knowledge level of managers and data collectors regarding how UAS technology would be used in their forest health programs?

While all participants knew what UAS technology meant in terms of the aircraft being unmanned and had an understanding of aerial survey, most expressed at some point in the interview that they do not know enough about the technology, especially in relation to how it can be used to benefit their forest health programs.

Q4. What is the level of understanding that managers and data collectors have regarding how UAS technology would affect the cost of their forest health programs?

Many participants simply did not know how the technology would affect the cost of their program and data collection. However, many discussed how they thought it might influence cost, whether that would be to increase, decrease, increase over time, or remain unchanged.

Q5. What is the level of understanding of managers and data collectors about how UAS technology might affect the quality of data collected through aerial surveillance?

Most participants felt the quality of data would improve. The benefit of computer technology was compared to that of the human eye as being more precise and accurate. The benefit of the ability to review the data multiple times from the UAS recorded data was also addressed. Currently, when aerial surveys are completed, the person performing that survey interprets the observations and completes a sketch map. This action involves the observation of that individual and interpretation to be placed on a map. There is no opportunity to repeat that view. If this activity were to be completed with the use of UAS technology, the imagery could be captured by a single image, continuous imaging, or videography, depending on the type of sensor used. This raw data will not contain individual subjectivity of interpretation and would provide historical data that would be available for unlimited review by many individuals at unlimited time-points.

Participant Ma stated:

> "Well, of course you could remove some human error. You can't take your eyes off the target and I would think drones would not. And even human beings could look to the ground, even professionals, and think they see damage this year, when it was really damage from last year. So I do think there's some opportunity to avoid those skips in detection . . . . and maybe avoid some of the errors in professional judgment."

Summary

The Forest Service is a conservation organization that has existed for more than a century (Williams, 2000) that faces many challenges in a changing global community with the complexities of public opinion, ecosystem management, and declining budgets (Kennedy & Quigley, 1998) to continue its mission to care for the land. The benefits of forests to the nation and the global ecosystem are significant in terms of clean air and water, recreation, renewable resources, and jobs (USDA-Forest Service, 2012). Research supports the use of aerial surveys to assess forest health (Woodall, Morin, Steinman, & Perry, 2010). The role of the Forest Service in managing the health of 193 million acres of forest and grass lands through surveillance by aerial photography and mapping carries risk and high cost (Becker, 2004; & Carnegie, Cant, & Eldridge, 2008). Budget cuts and flat existing budgets threaten the ability of the Forest Service to adequately monitor forest health (Becker, 2004). UAS technology is one tool that may provide the possibility of monitoring large areas of land, including forests, as a safer, cost-saving alternative to traditional manned aircraft (Grenzdorffer, Engel, & Teichert, 2008), especially with the ability it provides to fly at low altitudes (Everaerts, 2008). In order to use this tool, the Forest Service would have to accept this new technology. Organizational change, especially within the public sector, can be difficult (Fernandez & Rainey, 2006). The introduction of a major innovation within an organization can cause resistence to that change, even from the leaders (Yukl & Lepsinger, 2004). Top-management support and committment are crucial in bringing about change within an organization (Fernandez & Rainey, 2006). Perceptions of managers is a key element in an organization to support change and innovation, as well as effective communication and employee attitudes (Chew, Cheng, & Petrovic-Lazarevic, 2006). The use of Rogers' Diffusion of Innovation Theory (2003) can be helpful in determining the adoption process of new technology.

Implications

The results of this research study have contributed to the understanding of attitudes and knowledge level of managers and data collectors, or potential users, regarding UAS technology within the Forest Service. Knowing the attitudes and perceptions provides individuals planning to introduce this new technology with a foundation on which to build the innovation process. The results of this study show that key personnel who will be responsible for initiating this technology have a basic understanding of the technology and a desire to learn more, are favorable to its use in their program, have knowledge of some of the potential problems such as public concern for privacy, believe in taking proactive steps to minimize these problems, and believe that the technology can improve cost and quality of data necessary for their forest health programs.

Limitations include the fact that despite the participants representing managers and data collectors from all nine national regions of the Forest Service, the results from this small sample cannot be generalized to other populations, especially those individuals representing non-government organizations (Fernandez & Rainey, 2006).

Additionally, one of the interview questions asked the participants to place themselves into one of Rogers' categories regarding acceptance of innovation. Both the researcher and the external reviewers pointed out that this question was confusing and difficult to interpret. However, most particpants expanded enough on their answer that the researcher and the external reviewers were able to determine the appropriate category into which the participants placed themselves.

Recommendations

Several recommendations emerged from this study including the need for a proactive plan for public education about UAS technology concerning privacy issues, the need for multiple methods of education and training of personnel to introduce the new technology, the need for education of personnel on what research has been completed regarding UAS technology and forest management, the effect this technology will have on current budgets, potential personnel needs regarding the use of this new technology, and education on how the technology can improve cost and quality of data.

Most all of the 18 participants expressed that the public will have concerns about unmanned aircraft flying over private and public property. Many felt that the Forest Service will need to have a proactive plan to educate the public prior to the implication of UAS technology.

Participant Ma stated:

> "I think we would have to approach it very gently and gradually and have a public awareness campaign; maybe even a demonstration. I would want to work with our communications professionals and see how we did roll this out publically and develop some support."

All of the 18 participants told how they would like to learn about UAS technology. There were multiple methods mentioned including webinars, videos, field demonstration, hands-on training, experience-sharing by others, classroom, and written material. Most participants said they would like to receive the education by more than one method.

Participant Db stated:

> "A good place to discuss this with folks nationally would be at an aerial survey working group meeting; have this be a discussion item with an individual presenting who really knew the ins and outs, the regulatory, and some of the practical applications. Then have follow-up discussion with the group."

Participant Dc stated:

> "I tend to do better if something is presented to me in a classroom style setting, where I'm introduced to it and I learn all the functions and how to operate it."

Participant De stated:

> "I would be interested in testing it out in a kind of hands-on manner. Actually going out with a UAS and checking out, you know doing a little mock survey and seeing what type of data we get out of it. . . . I would also like to see how other people are using it and using the data, both in forest heath and in related fields."

Participant Df stated:

> "I guess I would like to see an application for webinars to cover general topics and how people are using UAS in the forest health arena, And then I would like to see some practical, hands-on application type data – to be able to kind of kick the tires with it a little bit just to see what it can do and how it can be used in the program and then, as a last phase, share our experience with others in the field to see if this technology would be useful or applicable to other programs."

Participant Di stated:

> "Well, by using it. I think that's the best way for us to learn is to just get out and do it in a limited sense."

Participant Mb stated:

> "I think some hands-on examples of maybe even some case studies specific to forest health issues and how they were resolved . . . . I believe maybe results of case studies presented in a workshop-type of format where people could ask questions would probably be kind of an ideal way to market it."

Participant Me stated:

> "Certainly materials that can be read are very good, videos that demonstrate how the technology is used or how it can be used would be great . . . eventually some form of hands-on demonstration or training to learn about it."

Participant Mf stated:

> "I would wish to learn from pilot testing in certain regions, different cover types of vegetation to see how the mapping turned out under different scenarios."

Many study participants also expressed the desire to know what research has already been done with UAS technology in relation to forest management. This information can be very helpful in the program planning for the introduction of UAS technology. The programs planned will need to include multiple learning methods and a thorough coverage of what research has been done with UAS technology, both within the Forest Service and in private orgainzations, in relation to forest health management.

The implementation of this new technology will most likely affect the allocation of current budgets. When the FAA has the regulations in place that will enable the organization to implement the use of UAS technology, funds will need to be allocated to purchase the UASs. The decision will need to be made as to whether there will be a pilot use of the technology or whether it will be simultaneously used in multiple areas of the country.

Participant Ma stated:

> "Honestly, if the Forest Service was looking for a region to give it a test drive, I'd be willing to raise my hand."

The implementation of this technology will also require management of these changes within the organization. It will need to be decided if existing managers can adequately handle the implentation of such a change. Perhaps there will be a need for one person to provide oversight of the program on a national basis.

Finally, the study participants had beliefs about how UAS technology will affect the cost and quality of data in their programs. While all participants had ideas on how the technology will affect cost, most were not sure and admitted to only guessing about its effect. The literature supports the fact that UAS technology can reduce cost on surveillance of large areas of forested lands (Grenzdorffer, Engle, & Teichert, 2008; Marenchino, 2008; Rango et al., 2009; Wallace, Lucieer, Watson, & Turner, 2012; & Whitehead, 2010) and this information will need to be included in the training programs offered.

While most participants expressed the belief that UAS technology would improve the quality of their data, they were not certain about this prediction. Research has shown that this technology can provide improved quality of data collection for forest health monitoring over large areas of forested lands (Casbeer, Kingston, Beard, & McLain, 2005; Everaerts, 2008; Grenzdorffer, Engel, & Teichert, 2008; Jones, Pearlstine, & Percival, 2006; Lu, Li, & Tang, 2010; Marenchino, 2008; McCormack, 2008; Meszaros, 2011; & Morris, 2007) and this information will need to be included in the training programs offered.

Recommendations for future reseach include the possibility of other quantitative and qualitative studies involving other samples and other questions. A potentially beneficial quantitative study design may include comparison of existing cost of data collection by manned aircraft vs. collection of the same data using UAS technology. This same study design could be used to compare quality of data. A potential qualitative study could involve interviews or questionnaires of members of the public on privacy concerns, especially land owners near the sites of aerial surveys. Additional questions that could be asked may include the nature of their privacy concerns, whether these concerns do not exist with manned aircraft surveys, and would they be willing to pay higher taxes to maintain the traditional methods of aerial surveys of public forest lands.

Conclusions

In conclusion, the results of this study have added to the literature regarding implementing new technology into a government organization. The literature contains fewer references on organizational change in the public sector (Fernandez & Rainey, 2006). The perceptions of managers is a key element in an organization to support change and innovation, as well as effective communication and employee attitudes (Chew, Cheng, & Petrovic-Lazarevic, 2006). The perceptions identified in this study of managers and data collectors who will use the technology are crucial information to be used in planning the technological innovation of UAS technology within the Forest Service to assist with forest health and, ultimately, ecosystem management.

References

About us. (2011). US Forest Service: *About us.* Retrieved from http://www.fs.fed.us/aboutus/

Aerial application. (2009). US Department of Agriculture – Forest Service. *Aerial application Forest Health Protection Aviation Program.* Retrieved from http://www.fs.fed.us/foresthealth/aviation/aerialapplication.shtml

Al-Tahir, R., Arthur, M., & Davis, D. (2011). *Low cost aerial mapping alternatives for natural disasters in the Caribbean*. Paper presented at the FIG Working Week 2011: Bridging the Gap between Cultures, Marrakech, Morocco.

Anderson, N., Lievens, F., Van Dam, K., & Ryan, A. M. (2004). Future perspectives on employee selection: Key directions for future research and practice. *Applied Psychology: An International Review,* 53(4), 487-501.

Becker, R. (2004). Program areas: Aerial vegetation survey. Retrieved from http://www.fs.fed.us/t-d/programs/im/aerial/index.shtml

Bennett, D. D., & Tkacz, B. M. (2008). Forest health monitoring in the United States: A program overview. *Australian Forestry*, 71(3), 223-228.

Blau, I., & Hameiri, M. (2010). Implementing technological change at schools: The impact of online communication with families on teacher interactions through learning management system. *International Journal of E-Learning and Learning Objectives, 6*. 245-257.

Blay, N., & Dombeck, M. (2013). The integration of forest science and climate change policy to safeguard biodiversity in a changing climate. In J. F. Brodie, E. Post, & D. F. Doak (Eds.), *Wildlife conservation in a changing climate* (p. 371). Chicago: University of Chicago Press.

Bracmort, K. (2013). *Wildfire management: Federal funding and related statistics.* (CRS Report R43077). Washington, DC: Congressional Research Service.

Budget (2011). USDA Forest Service Fiscal Year 2012 Budget. Retrieved from http://www.fs.fed.us/aboutus/budget/

Carnegie, A. J., Cant, R. G., & Eldridge, R. H. (2008). Forest health surveillance in New South Wales, Australia. *Australian Forestry, 71*(3), 164-176.

Casanovas, I. (2010). Exploring the current theoretical background about adoption until institutionalization of online education in universities: Needs for further research. *Electronic Journal of e-Learning. 8*(2). 73-84.

Casbeer, D. W., Kingston, D. B., Beard, R. W., McLain, T. W., Li, S.M., & Mehra, R. (2005). Cooperative forest fire surveillance using a team of small unmanned air vehicles. *International Journal of Systems Science, 00*(00). 1-18.

Chew, M. M. M., Cheng, J. S. L., & Petrovic-Lazarevic, S. (2006). Manager's role in implementing organizational change: Case of the restaurant industry in Melbourne. *Journal of Global Businesss and Technology, 2*(1), 58-67.

Dearing, J. W. (2009). Applying Diffusion of Innovation Theory to intervention development. *National Institute of Health.* 19(5). 503-518.

Elias, B. (2012). *Pilotless drones: Background and considerations for congress regarding unmanned aircraft operations in the national airspace system*. (CRS Report R42718). Washington, DC: Congressional Research Service.

Everaerts, J. (2008). The used of unmanned aerial vehicles (UAVS) for remote sensing and mapping. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 37(B1), 1187-1191.

Federal Aviation Administration. (2015). *Small UAS notice of proposal rulemaking* (NPRM). Retrieved from https://www.faa.gov/uas/nprm/

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods, 5*(1), Article. Retrieved March 15, 2012 from http://www.ualberta.ca/~iiqm/backissues/5_1/pdf/fereday.pdf

Fernandez, S., & Rainey, H. G. (2006). Managing successful organizational change in the public sector. *Public Administration Review*, 66(2), 168-176.

Forest Health (2011). Forest Health Protection Aviation Program. Retrieved from http://www.fs.fed.us/foresthealth/aviation/

Forest Health Protection. (2011). Forest Health Management. Retrieved from http://www.na.fs.fed.us/fhp/fh/

FY 2012 Budget justification. (2011). US Department of Agriculture – Forest Service. *Overview of FY 2012 budget justification*. Retrieved from http://www.fs.fed.us/aboutus/budget/2012/justification/FY2012-USDA-Forest-Service-overview.pdf

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. *The Qualitative Report*, 8(4) 597-607. Retrieved from http://www.nova.edu/ssss/QR/QR8-4/golafshani.pdf

Greenhalgh, T., Stramer, K., Brantan, T., Byrne, E., Mohammad, Y., & Russell, J. (2008). Introduction of shared electronic records: multi-site case study using diffusion of innovation theory. *British Medical Journal*, 337(a1786), 1-12.

Grenzdorffer, G. J., Engel, A., & Teichert, B. (2008). The photogrammetric potential of low-cost UAVs in forestry and agriculture. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. 37(B1), 1207-1214.

Johnson, E. W., & Wittwer, D. (2006). Aerial detection surveys in the United States. In: C. Aguirre-Bravo, P.J. Pellicane, D.P. Burns, and S. Draggan, (Eds.), *Monitoring Science and Technology Symposium: Unifying Knowledge for Sustainability in the Western Hemisphere Proceedings RMRS-P-42CD* (pp. 809-811). Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Jones, G. P., Pearlstine, L.G., & Percival, H. F. (2006). An assessment of small unmanned aerial vehicles for wildlife research. *Wildlife Society Bulletin.* 34(3), 750-758.

Jupp, V. (2006). *The Sage dictionary of social research methods.* Thousand Oaks, CA: Sage Publications.

Keating, E. G., Morral, A. R., Price, C. C., Woods, D., Norton, D. M., Panis, C., Saltzman, E., & Sanchez, R. (2012). Air attack agains wildfires: Understanding U.S. Forest Service requirement for large aircraft. Retrieved from http://www.rand.org/content/dam/rand/pubs/monographs/2012/RAND_MG1234.pdf

Kennedy, J. J., & Quigley, T. M. (1998). Evolution of the USDA Forest Service organizational culture and adaptation issues in embracing an ecosystem management paradigm. *Landscape and Urban Planning* 40, 113-122.Lu, H., Li, Y., & Tang, M. (2010). Study of the method of rapid land information inspection based on UAV images. *Journal of Southwest Jiaotong University*. 270-274.

Kimbell, G. (2010). *USDA Forest Service water and wilderness briefing paper.* Retrieved from https://www.wilderness.net/NWPS/documents/FS/Chiefs-Long-water.pdf

Lichtman, M. (2013). *Qualitative research in education: A user's guide* (3rd ed.). Thousand Oaks, CA: SAGE Publications, Inc.

Lu, H., Li, Y., & Tang, M. (2010). Study of the method of rapid land information inspection based on UAV images. *Journal of Southwest Jiaotong University*. 270-274.

Lucieer, A., Robinson, S. A., & Turner, D. (2010). *Using an unmanned aerial vehicle (UAV) for high-resolution mapping of Antarctic moss beds.* Paper presented at the 15th Australasian Remote Sensing & Photogrammetry Conference. Alice Springs, Australia.

Marenchino, D. (2008). *Low-cost UAV for the environmental emergency management: Photogrammetric procedures for rapid mapping activities* (Doctoral dissertation). Retrieved from http://www.dirap.unipa.it/autec/uploads/YvC2c2qgRDbdutX5naRU3d39daXs4m3TGvKKnZR5.pdf

Marshall, M. N. (1996). Sampling for qualitative research. *Family practice*,13(6), 522-526.

Martinsanz, G. P. (2012). Unmanned aerial vehicles (UAVs) based remote sensing [Special issue]. *Remote Sensing*. Retrieved from http://www.gim-international.com/issues/articles/id1601-Unmanned_Aerial_Vehicles_for_Glaciological_Studies.html

McCormack, E. D. (2008). *The use of small unmanned aircraft by the Washington State Department of Transportation* (Agreement T4118, Task 04). Seattle: Washington State Department of Transportation.

Meszaros, J. (2011). Aerial surveying UAV based on open-source hardware and software. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 38*(C22), 1-5.

Mission. (2008). US Forest Service. *About us* – mission. Retrieved from http://www.fs.fed.us/aboutus/mission.shtml

Morris, J. (2007). Trial by fire: U.S. civil agencies eye UAVs for fire fighting, global warming research. *Aviation Week & Space Technology*, 167(6), 55-56.

National Aeronautics and Space Administration. (2015). *Unmanned Aerial System (UAS) Traffic Management (UTM): Enabling civilian low-altitude airspace and unmanned aerial system operations.* Retrieved from http://utm.arc.nasa.gov/index.shtml

National roadmap. (2010). United States Forest Service. *National roadmap for responding to climate change.* Retrieved from http://www.fs.fed.us/climatechange/pdf/roadmap.pdf

National visitor use monitoring results. (2010). *National visitor monitoring results – USDA Forest Service, National Summary Report.* Retrieved from http://www.fs.fed.us/recreation/programs/nvum/nvum_national_summary_fy2009.pdf

Ollero, A., & Merino, L. (2004). *Control and perception techniques for aerial robotics.* Annual Reviews in Control 28. 167-178.

Patton, M. Q. (2002). *Qualitative research & evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Peslak, A., Ceccucci, W., & Sendall, P. (2010). *An empirical study of social networking behavior using diffusion of innovation theory.* Paper presented at the Conference of Information System Applied Research, Nashville, TN.

Programs. (2011). US Forest Service. *National offices and programs*. Retrieved from http://www.fs.fed.us/aboutus/national.shtml

Rango, A., Laliberte, A., Steele, C., Herrick, J. E., Bestelmeyer. B. Schmugge, T., Roanhorse, A., & Jenkins, V. (2006). Using unmanned aerial vehicles for rangelands. *Environmental Practice* 8(3). 159-168.

Rango, A., Laliberte, A., Steele, C., Herrick, J. E., Wingers, C., Havstad, K., Steele, C., & Browning, D. (2009). Unmanned aerial vehicle-based remote sensing for rangeland assessment, monitoring, and management. *Journal of Applied Remote Sensing*. 3(033542). 1-15.

Rasker, R. (2010). Curbing wildfires' cost: Ten ways to control the cost of fighting fires in the wildland-urban interface and to keep people safer. Western Perspective: Insight and Analysis. Retrieved from http://www.headwatersnews.org/p.HeadwatersEconomics010610.html

Rogers, E. M. (2003). *The diffusion of innovation* (5th ed.). New York: Free Press.

Ryan, N. F., Williams, T. A., Charles, M. B., & Waterhouse, J. M. (2008). Top-down organizational change in an Australian Government agency. *Journal of Public Sector Management*, 21(1), 26-44.

Sahin, I. (2006). Detailed review of Rogers' Diffusion of Innovation Theory and educational technology-related studies based on Rogers' Theory. *The Turkish Online Journal of Educational Technology*. 5(2), 14-23.

State and Private Forestry. (2010). State and Private Forestry: Connecting forestry to people. Retrieved from http://www.fs.fed.us/spf/

Tolba, A. H., & Mourad, M. (2011). Individual and cultural factors affecting diffusion of innovation. *Journal of International Business and Cultural Studies*, 1-16.

Unmanned Aircraft Systems. (2008). *Unmanned aircraft systems: Federal actions needed to ensure safety and expand their potential uses within the national airspace system.* (GAO Report 08-511). Washington, DC: United States Government Accountability Office.

USDA Forest Service Strategic Plan FY 2007-2012. (2007). *USDA Forest Service Strategic Plan FY 2007-2012.* (FS-880). Retrieved from http://www.fs.fed.us/publications/strategic/fs-sp-fy07-12.pdf

USDA-Forest Service. (2012). *Increasing the pace of restoration and job creation on our national forests.* Retrieved from http://www.fs.fed.us/sites/default/files/media/types/publication/field_pdf/increasing-pace-restoration-job-creation-2012.pdf

Vaccaro, V. L., Ahlawat, S., & Cohn, D. Y. (2010). Diffusion of innovation, marketing strategies, and global consumer values for a high technology product. *International Journal of Business Strategy.* 10(3), 1-10.

Wallace, L., Lucieer, A., Watson, C., & Turner, D. (2012). Development of a UAV-LiDAR System with application to forest inventory. *Remote Sensing*, 4, 1519-1543.

Whitehead, K. (2010). Unmanned aerial vehicles for glaciological studies. *GIM International, 24*(10). Retrieved from http://www.gim-international.com/issues/articles/id1601-Unmanned_Aerial_Vehicles_for_Glaciological_Studies.html

Wibbenmeyer, M., Hand, M., & Calkin, D. (2012). *Preliminary results from a survey of U.S. Forest Service wildfire managers' attitudes toward aviation personnel exposure and risk.* (Research Note RMRS-RN-50WWW). Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Williams, G. W., (2000). The USDA Forest Service: The first century. Washington, DC: United States Department of Agriculture.

Woodall, C. W., Morin, R. S., Steinman, J. R., & Perry, C. H. (2010). Comparing evaluations of forest health based on aerial surveys and field inventories: Oak forests in the Northern United States, Ecological Indicators, 10, 713-718.

Yin, R. K. (2014). *Case study research: Design and methods*. (5th ed.). Thousand Oaks, CA: SAGE Publications, Inc.

Yukl, G. & Lepsinger, R. (2004). Flexible leadership: Creating value by balancing multiple challenges and choices. San Francisco: Jossey-Bass.