

**A Review and Prospects on the Use of Unmanned Aerial Systems (UAS) in Precision
Agriculture for the Mid-Atlantic United States**

Aaron Scott Thompson

Major Project/ Report submitted to the faculty of the Virginia Polytechnic Institute and State
University in partial fulfillment of the requirements for the degree of

Online Master of Agricultural and Life Sciences
In
Agribusiness

Committee Chair: Dr. Dixie Watts Dalton,
Associate Professor of Practice
Department of Agricultural and Applied Economics, Virginia Tech

Committee Member: Dr. Matthew Holt, Dean
Agriculture & Applied Economics
College of Agriculture and Life Sciences, Clemson University

Committee Member: Dr. Jonathan Phillips, Adjunct Instructor
Agricultural & Applied Economics, Virginia Tech

Date of Submission – 11/12/2024

Keywords: Drone, UAS, Precision Agriculture

**A Review and Prospects on the Use of Unmanned Aerial Systems (UAS) in Precision Agriculture for the
Mid-Atlantic United States**

Aaron Thompson Online Master of Agricultural & Life Sciences

Abstract:

This case study is a comprehensive evaluation of the level of adoption for precision agriculture Unmanned Aerial Systems, (UAS) in farming activities in the Mid-Atlantic United States. For context, the Federal Aviation Administration (FAA) defines Unmanned Aircraft Systems (UAS) as an aircraft that is operated without the possibility of direct human intervention from within or on the aircraft. The term UAS encompasses the unmanned aircraft (UA) (commonly referred to as drones), the controller on the ground, and the communication link between them. This system allows for the operation and navigation of unmanned aircraft. Since the turn of the 19th Century, industrialized agriculture has advanced globally at a rate that is hard to imagine. This advancement has been highly accelerated since the dawn of the digital era. Part of that digital technology advancement has come in the form of UAS. UAS provide a scalable technology platform to accomplish improved efficiency for individual agricultural work functions such as crop/herd monitoring and precision spraying solutions. This case study assesses the integration levels of agricultural UAS operations, specifically within smaller farms, orchards, and vineyards, across the Mid-Atlantic compared to the rest of the United States.

The primary objective of the study is to evaluate the extent to which UAS integration in the Mid-Atlantic United States has been effective, as well as to identify barriers that have caused Mid-Atlantic UAS implementation rates to be lower than those of the Western United States. Using qualitative in-field interviews and quantitative data analysis, the study examines the effect of UAS technology on crop/herd management, pest management, irrigation management, and overall farm productivity.

Finally, this case study examines the financial impact of incorporating agricultural UAS into the average-sized Mid-Atlantic farm versus maintaining standard practices. The analysis compares outcomes when hiring a drone service versus purchasing and implementing a drone program internally. Economic implications of drones on net-profit and expenses for a representative 200-acre soybean farm are projected utilizing a University of Tennessee enterprise budget (Appendix A) and RStudio visualizations (Appendix B). The study also examines legal and regulatory components around drones utilized in agriculture, such as airspace restrictions, data/general privacy, and Federal Aviation Administration (FAA) policy compliance.

This case study revealed practical contributions of drone technology for Mid-Atlantic agriculture allowing farmers, policy makers and other stakeholders to make informed decisions about the uses and expansion of UAS in agricultural operations.

Table of Contents

Introduction	4
Literature Review	7
Project Methodology and Design.....	15
Qualitative Survey.....	16
Quantitative Conceptual Analysis.....	18
Financial Formulas and Calculations.....	19
Summary of Outcomes, Discussions and Recommendations.....	25
Conclusion.....	26
References.....	27
Appendix	31

Introduction

The Mid-Atlantic produces a wide array of agricultural products due to its unique geography that spans from the mountainous west to the flat coastal lands. For the purposes of this study, the Mid-Atlantic includes the states of Maryland, Virginia, West Virginia, the Carolinas, and extending to parts of Eastern Kentucky and Tennessee. This region is a major agricultural producer with commodities ranging from crops, including tobacco, corn, soybeans, and wheat, to livestock and aquaculture. These diverse farming operations are driven by the different topography, soil types and climate, which make this region distinctive from the traditional Mid-western United States concept of farming. For example, historically, tobacco and cotton were the dominate cash crops; however, by the late twentieth century, corn and soybeans became the dominant non-livestock commodities, benefiting from the region's fertile soil and productive growing conditions. This diverse, market-driven agricultural adaptation is one unique feature of the Mid-Atlantic's versatile agriculture industry.

Though the diverse agricultural industry in the Mid-Atlantic is influential on a global scale, the region still faces numerous difficulties. For example, farming operations throughout the Mid-Atlantic face economic challenges because of volatile commodity markets which can have a significant impact on the region's farming operations. Inelastic commodities are also significantly affected by the forces of supply and demand at the global level, as well as the macroeconomic influence of government trade policies. This volatility has an amplified impact on Mid-Atlantic farming operations as many producers are smaller in scale compared to Western United States operations. The squeeze of rising cost of inputs like seeds, fertilizers, pesticides, equipment, and low profit margins leave farmers with a thin profit margin in many cases. These market instabilities have made it difficult for smaller Mid-Atlantic farmers to target cost-saving opportunities.

Another constraint that highly impacts Mid-Atlantic farms is a shortage of labor. While labor shortages are a national agricultural industry struggle, it is particularly felt in areas like the Mid-Atlantic. Such shortages cause operations to increasingly rely on migrant labor which introduces further layers of cost and legal complications that are strictly enforced by the U.S. Department of Labor. Considering this two-fold reality and given the high-intensity physical labor performed on farms, for relatively low wages, finding stable farm labor proves to be a constant, cost-intensive challenge for farming operations. This challenge is perhaps seen most acutely in seasonal labor, with farmers having to time staffing with planting/harvesting schedules. It causes delays and increased costs and usage of mechanization, which is

more difficult to adopt for highly diverse smaller Mid-Atlantic farming operations compared to larger Midwestern operations specializing in row crops.

Sustainable practices in farming have become an area of focus in recent years due to mounting legal and social pressure on agriculture, aimed at reducing the exploitation of natural resources and reducing environmental impact. Farming operations have addressed this in many ways to include crop rotation, no till farming, integrated pest management, organic farming, precision or smart farming, and silvopasture. This is another aspect where transitioning to these practices can create a challenge for Mid-Atlantic operations due to high initial costs, the need for education and training, potential changes in productivity, and/or a long-term break-even point. Mid-Atlantic farmers must also work within very complicated regulatory systems to farm environmentally responsibly while staying abreast of changing environmental regulations, labor laws and food safety practices, just to name a few. Federal and state policy changes, as well as macro and micro market conditions, affect how farming is practiced. Complying with these regulations can take time, effort, energy, and significant investments in technology and people.

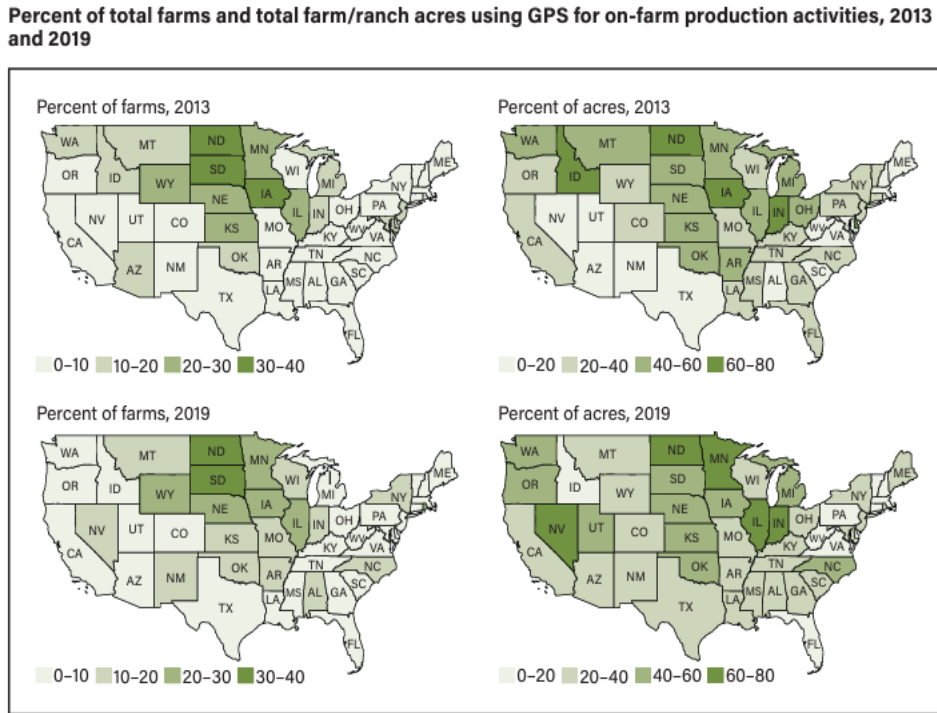
Over the last century, technological and machinery improvements in the agricultural industry have been slowly reducing the number of human laborers needed in an operation. That advancement has improved production, efficiency and safety while decreasing operational labor costs. Industries which tend to require more human capital like agriculture found a much-needed boost thanks to significant technological advancements ranging from tractor development to hydroseeding and even artificial intelligence (AI) and machine learning (ML). The integration of technology in farming has been accelerated by the evolution of mass production processes and has boosted the standardization of large field management; this has been further refined with modern technological support like crop imaging and data analytics. This mechanization along with the availability of bulk quantities of fertilizer, pesticides, and other input items have enabled higher yields and bigger farms and reduced some of the human capital requirements.

Some of the operational challenges can and have been addressed through technological advancements. Agricultural technology such as soil health monitoring and irrigation innovations with drones are on the rise. They allow resource use to be optimized, crop yields to be increased, livestock management to be more effective, and overall farm productivity to be improved to assist sustainability and profitability. Although technological innovation addresses numerous challenges for farmers, access to these technologies remains challenging among small-scale, resource-limited Mid-Atlantic operations.

The lack of general access to technology coupled with perceptions of complexity have hindered adoption for operations east of the Mississippi River, particularly in the Mid-Atlantic region. Equitable access to these technologies and information is critical for the Mid-Atlantic to remain competitive in agriculture.

The overall usage of GPS-based equipment, including autonomous ground-based and ariel-based platforms, is depicted as a percent of farmland and a percent of farm acres. Figure 1 shows the increased usage of GPS-based technology in the United States between 2013-2019, McFadden et al. (2023). While the Mid-Atlantic states in this study did see an increase in the usage of agriculture-based GPS technology during this period, the rate of adoption falls well below the pace seen in the Mid and upper Midwestern United States.

Figure 1: Percentage of Total Farms using GPS: 2013 & 2019



Source: McFadden *et al.* (2023): “Note: The top panels depict the percent of each State’s total farms and total farm/ranchland, respectively, in 2013, with operators who indicated they used GPS for on-farm production activities. Similarly, the bottom panel depicts these percentages for year 2019. Data are not available for Alaska and Hawaii. Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, 2013 and 2019 Agricultural Resource Management Survey (ARMS).”

The many recent digital advancements in agriculture have created the age of precision farming, (PF). The PF era started in earnest in the 1980s and expanded in the 1990s in the form of data collection and analysis of crops, soils, and yields, helping farmers to make strategic decisions based on such data. This in turn gave operations the top-level, aggregated data needed to make targeted yield decisions. The

PF age provided farmers the opportunity to start making more data-driven decisions which was previously very difficult to do. These data now incorporate more real-time aggregate information that moves decision-making from a more reactive posture to a more proactive one. Previously, the time-consuming process of manual data collection and analysis would lead to reactionary crop management decisions. Since PF is a scalable tool, it can be applied to operations of any size and therefore, provides a huge amount of value in the forms of input resource optimization (watering, fertilizer and pesticide application, and waste reduction), increased crop resiliency and yields for better quality produce, and cost savings which all improve farm profitability. So why has PF not been adopted as quickly as was hoped?

Literature Review

The agricultural technological boon in recent decades has led to increased productivity, efficiency, profitability and safety while also minimizing human error and application waste. However, some of that technology has not been widely adopted in parts of the United States like the Mid-Atlantic. For example, McFadden et al. (2023) shed a possible light on the lack of UAS adoption compared to other smart technology options. Drones, though less commonly used in digital agriculture (DA) compared to other technologies like Variable Rate Technology (VRT) or yield monitors, have more predictable replacement costs. This is because agriculture UAS are more prone to catastrophic damage that renders them unusable. Replacement costs for drones include the platform itself, onboard cameras, and communication devices which can amount to tens of thousands of dollars depending on the platform and payload. Minor crashes may only require propeller replacements, but catastrophic damage often necessitates purchasing new equipment. Though the catastrophic loss of a UAS is likely less expensive than the total loss of a tractor, the ripple effect of a UAS crash (FAA investigation, collateral damage, etc.) may be another cultural barrier to entry for many smaller farming operations. In addition to the physical risks, subscription-based fees (data storage, security and software), manufacturer-specific technology, and various service providers are additional cost factors that farming operations must weigh when considering the implementation of smart technology. Rarely do operations utilize the same equipment manufacturer across the fleet which makes UAS adoption slower given the scarcity of service providers available in the market today (McFadden et al. 2023).

Though there are numerous examples of smart technology in global precision agriculture, drones provide a wide array of solutions at scale for farming operations. Lim, et al. (2021) and Zhang and Kovacs (2012) have underscored the promise of UAS photogrammetry, demonstrated the capacity

of low-cost UAS to gather the level of spatial resolution needed to manage plots effectively, and concluded that UAS have immense potential for close-range aerial imaging for precision agriculture in both forestry and traditional agriculture. UAS produce a variety of tangible benefits to users such as high-resolution, accurate imagery and topographic mapping. Coupled with software such as Pix4D, the detailed imagery can be analyzed alongside weather data to measure crop health, speculate the conditions in the fields, and highlight the areas needing attention. Such detailed information can be (and has been) used to better target applications of input resources including water, fertilizers and pesticides to maximize resource application efficiency and performance. Additionally, UAS usage in precision agriculture enhances the farm's ability to detect emerging problems such as pest and weed outbreaks and disease, making it possible to react quickly, precisely, and more proactively to prevent widespread damage thereby reducing the risk of greater crop loss. The development and implementation of scalable UAS technology is a breakthrough advancement for sustainable and efficient agriculture. This type of innovation is a critical opportunity for smaller farming operations to remain competitive in their respective markets.

In the United States, research on the adoption of precision agricultural technologies, such as UAS, has shown notable regional differences. Findings from studies by McFadden et al. (2023) and Rodriguez III (2023) reveal that the Mid-Atlantic region exhibits slower adoption rates of these technologies compared to the more rapidly advancing Midwestern states. The sluggish warming toward UAS technology in the Mid-Atlantic can likely be attributed to a range of socio-economic and geographical factors. Some of the compounding regional factors found in the Mid-Atlantic are the greater concentration of highly populated areas adjacent to farmland, more high-traffic air travel corridors over farmland, and a higher density of military installations in the region which play a role in restrictions for UAS flight and observation operations.

The Mid-Atlantic region encompasses a diverse geographic landscape ranging from coastal plains to mountains, and dense urban areas. While this unique geography provides a wide array of agricultural capabilities, it also adds some additional challenges for implementing UAS in farming. Farm size and the type of crops grown also have an important role in how this technology is integrated into crop management practices. Smaller, family-owned farming operations constitute much of the Mid-Atlantic agricultural landscape with broilers (chicken) and cow/calf operations being the top commodities in the region of this study. Though UAS can be used in livestock operations, generally the technology has been more widely adopted with crop farming. Since soybeans and corn have a smaller

market share in the Mid Atlantic, this could be another indicator why UAS adoption falls behind the Midwestern family farms. A study by Finger et al. (2019) discuss the wider economic and geographical relationship associated with precision agriculture and suggest that regions with large farms typically seen in the Midwest and western United States are expected to consider and implement this technology as it helps to avoid scale inefficiencies that can affect large farming operations. This point is further supported by McFadden et al. (2023) and Rodriguez III (2023) in the collective economic drivers of fleet acquisition and implementation, and software and data management costs that affect technology adoption. Similarly, Velusamy et al. (2021) discuss the operational hurdles farmers face when implementing UAS in precision agriculture by echoing the high initial cost of purchasing advanced UAS systems, the need for specialized training to maintain these technologies, and the skills needed to integrate and analyze UAS data with existing farm management systems. Beyond that, the ever-changing regulatory environment, between regions, can pose additional challenges for farmers planning to adopt UAS technology.

Smaller farms and those in remote areas could see the cost of technological features required for UAS to be barrier to entry (Rodriguez III, 2023). Velusamy et al. (2021) emphasize that the technological readiness of a region plays a crucial role in the adoption rates of UAS in agriculture. Understandably, regions with better infrastructure, such as high-speed internet connectivity and access to technical support services, are more likely to see higher adoption rates. Conversely, areas lacking these resources may struggle with the implementation of UAS technology, despite its potential benefits. This disparity suggests that targeted investments in infrastructure and education are essential to promote the effective use of UAS in precision agriculture. Given that many of the rural areas in the Mid-Atlantic region lack cohesive technological readiness, it is no surprise that UAS and precision agriculture practices have been slowly adopted. Comparatively, Lee et al. (2021) studied the global adoption of precision agriculture and highlighted the importance of socio-economic conditions, regional economic status, education, and technology in the context of the adoption of new precision agriculture practices. This finding is consistent with the socio-economic constraints reported in the Mid-Atlantic region by McFadden et al. (2023) and Rodriguez III (2023).

Adopting UAS in agriculture has major economic implications the trough the required investment; however, this technology can provide revenue benefits as well as substantial savings in overhead costs. Quan et al. (2023) provide a detailed analysis of the economic impacts of UAS in pesticide application among Chinese grain farmers, where the use of UAS led to a marked increase in

revenue. The average revenue increased approximately \$175.53-\$197.50 per acre while an average reduction of 5.83 to 6.40 hours per acre in the time spent on pesticide application was achieved. These findings are particularly relevant to the Mid-Atlantic region of the United States, where similar agricultural practices and comparable economic conditions suggest that UAS adoption could yield comparable economic benefits (Quan et al., 2023).

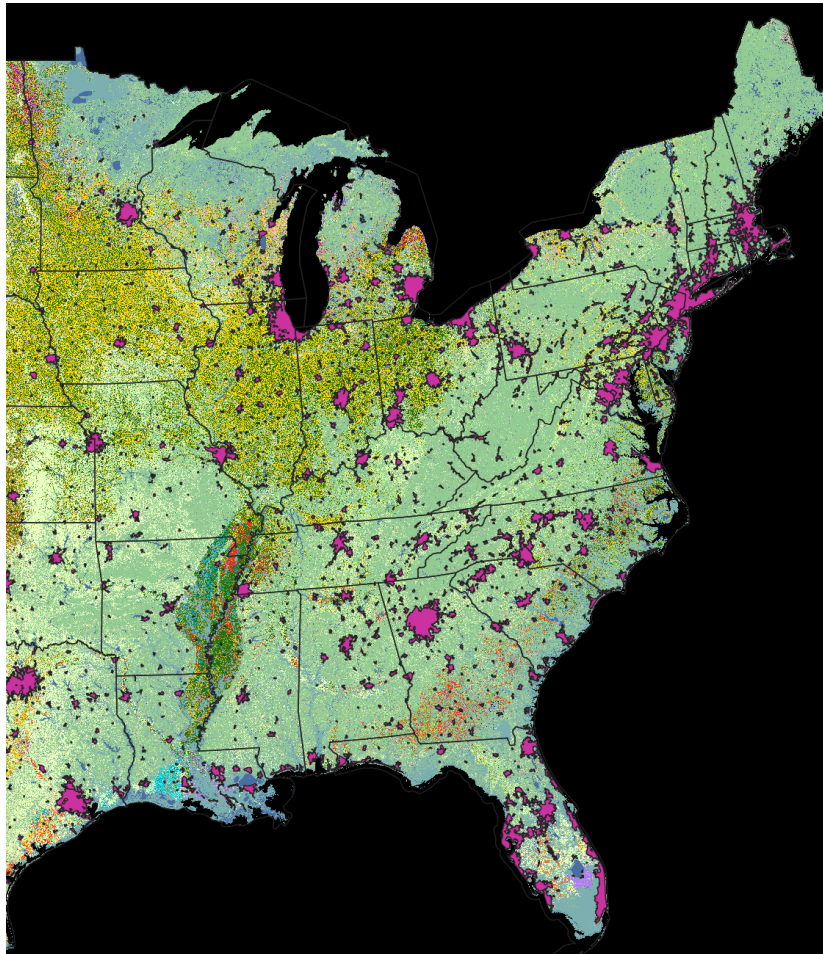
In addition to the direct economic benefits observed in crop management, Turner (2016) discusses the other ways agricultural operations are leveraging UAS technology. The discussion focuses on the role UAS play in monitoring and maintaining white fleets and rural electric infrastructure. White fleets (the fleet of systems and machinery used for various agricultural tasks) can be efficiently monitored using UAS to ensure they are operating optimally and safely. This real-time monitoring can reduce machinery downtime and maintenance costs, while allowing farmers to be more proactive in effectively planning the white fleet employment. Similarly, UAS can inspect rural electric infrastructure, both above ground and some underground, such as power lines and transformers, more safely and quickly than traditional manned flight methods. By identifying degradation issues, UAS play a critical role in preventing power outages and ensuring the reliability of electrical services in rural areas. Though indirectly related to agriculture, this is an important consideration when measuring the technological readiness of a Mid-Atlantic area. This dual use of UAS technology can help to improve the efficiency of agricultural operations, leading to broader economic benefits for rural communities that depend on farming operations for growth. Turner's model of economic benefits extends beyond simple cost savings, encompassing improvements in operational efficiency and safety, which are critical for sustainable rural development. This model can be adapted to Mid-Atlantic farms, where UAS could serve multiple roles, from precision agriculture to infrastructure management, thereby maximizing their economic impact (Turner, 2016). Additionally, Khanal et al. (2020) highlight the versatile applications of remote sensing in agriculture, which include crop monitoring, disease detection, and yield prediction, all contributing to potential enhanced yields and economic growth for operations. These applications reinforce some of the versatility and transformative potential of UAS technology and their ability to bring real-time data and analysis to decision-makers in agriculture (Khanal et al., 2020).

The regional regulatory confines around drones in agriculture has significant influence on producer adoption and the application potential throughout regions like the Mid-Atlantic United States. Stöcker et al. (2017) provide a comprehensive review of UAS regulations, highlighting that the photogrammetric potential of UAS in agriculture can often be underutilized due to stringent state and

local laws. These regulations, which are primarily focused on safety and privacy concerns, can impose severe limitations on how UAS are deployed in agricultural settings. For example, restrictions on flight altitude, proximity to urban areas, and airspace classification can restrict the operational flexibility necessary for effective agricultural management (Stöcker et al., 2017). This is particularly important in the Mid-Atlantic where there is a large mix of dense population areas adjacent to agricultural operations.

Figure 2 depicts a map overlay created in the QGIS program of the proximity of U.S. Census designated urban areas (magenta regions) to the U.S. Geological Survey (USGS) designated farmland areas (green, yellow, red and blue regions). The East Coast (including the Mid-Atlantic region) is characterized by high population densities and significant urbanization pressures, particularly in metropolitan corridors like the area that stretches from Boston to Washington, D.C. This region has experienced rapid urban expansion into previously rural and agricultural zones. The high demand for housing, infrastructure, and commercial development in these densely populated areas has resulted in the conversion of large swathes of farmland into urban land uses. For instance, farmland adjacent to urban areas on the East Coast is increasingly being developed into residential and commercial spaces, leading to a significant loss of agricultural land. Studies indicate that up to 34% of the agricultural land affected by urban expansion in this region has been converted into urban areas, reflecting the intense pressure on farmland (Xie et al., 2023).

Figure 2: Map Overlay: Urban Concentrations Adjacent to Farmland Eastern U.S. (2020)



Source: Graphic created by the author using USGS Global Croplands data and US Census Bureau (Geography Division) TIGER/LINE 2020 Urban Area Shapefiles. Map overlay created in QGIS.

The proximity of many East Coast cities to prime agricultural lands exacerbates this issue. As cities grow, they often encroach upon these farmlands, leading to their fragmentation and conversion into urban areas. This not only reduces the amount of land available for agriculture but also disrupts local ecosystems, increases the urban heat island effect, and contributes to environmental degradation. Additionally, the high cost of land in these regions makes it economically viable for landowners to sell agricultural land for development, further accelerating the rate of farmland conversion (Xie & Kovacs, 2023).

In contrast, the Midwest, with its vast expanses of agricultural land, faces different dynamics. While urban sprawl is also a concern in the Midwest, particularly around major cities like Chicago, Minneapolis, and Detroit, the region's lower population density and larger agricultural base provide a buffer against the immediate pressures faced by the East Coast. The Midwest has historically been the

agricultural heartland of the United States, with extensive tracts of farmland dedicated to crops like corn, soybeans, and wheat.

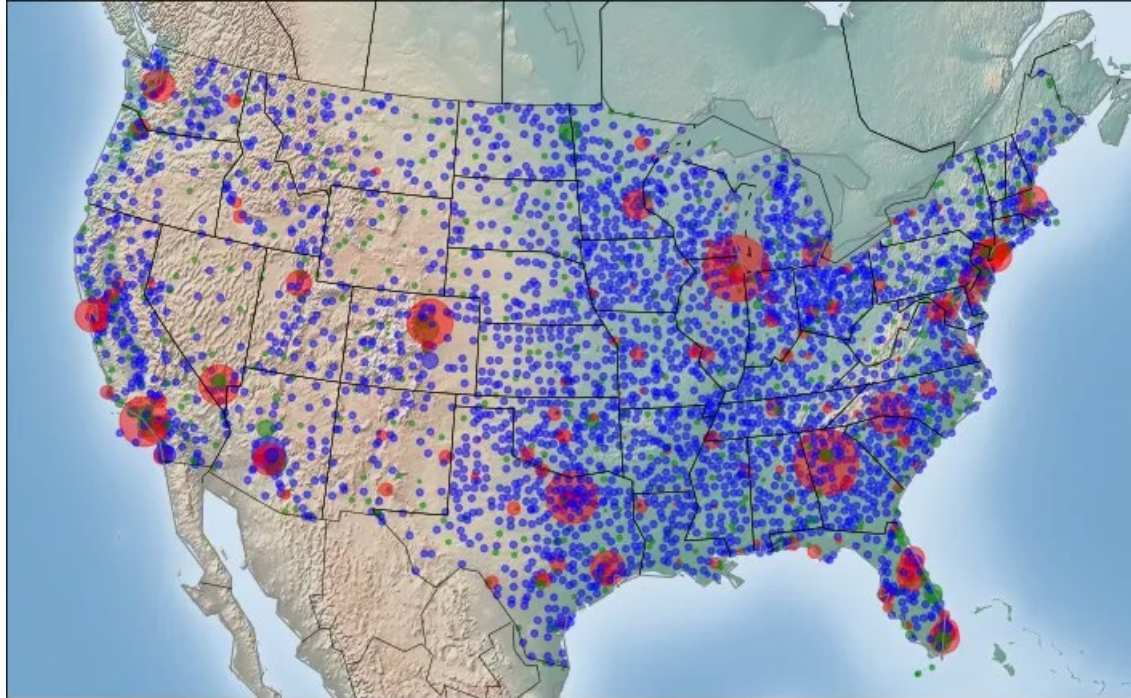
The photogrammetric capabilities of UAS, which involve capturing detailed aerial imagery and creating precise three-dimensional digital models of agricultural landscapes, offer significant benefits for precision farming as they enhance crop monitoring, soil analysis, irrigation management, and pest control by providing high-resolution, real-time data (Zhang & Kovacs, 2012; Turner, Lucieer, & Watson, 2012). However, regulatory constraints often impede the full realization of these benefits. For instance, restrictions on flight altitude limit the coverage area and the resolution of the images that can be captured, thereby reducing the effectiveness of UAS-based monitoring. This very issue impacts the possible UAS implementation for farming operations in the Mid-Atlantic region.

According to the Federal Aviation Administration (FAA), *Plane & Pilot Magazine*, and *MilitaryBases.com*, the East Coast of the United States has a higher airport and military installation density compared to the Midwest. The East Coast has 2.0 military installations and/or airports per 1,000 square miles compared to 0.61 per 1,000 square miles in the Midwest. The difference in military installation and airport density shows that it is much more likely that UAS operators will be flying near restricted airspace in the Mid-Atlantic versus the Midwest United States. Flight restrictions in these areas can also change with no prior notification, particularly around military installations. Sudden changes in airspace around military bases has a ripple effect on civilian flight operations as well, which can manifest in the form of rerouting, holding patterns and activation of previously unused airspace. This is a key consideration especially when operating near high-traffic airports as the flight operations in those areas are top priority behind military airspace usage, FAA Airport Data and Information Portal (n.d). *Plane & Pilot Magazine* (2023), *MilitaryBases.com*, (n.d) (Appendix C).

Figure 3 is a visual representation of all FAA registered public airports in the lower continental United States in 2019. The blue points represent small, local airports, while the green and red points represent medium regional, and large hub airports respectively. The size of the large red radii points corresponds with the number of takeoffs and landings from those airports. While large hub airports (airports people are most familiar with) account for the fewest number of public airports in the United States, they inversely account for the highest number of air operations in the country (Boynton, 2020). The graphic makes it clear that the highest concentration of large airport air traffic operations happens on the East Coast, and particularly within the Mid-Atlantic region. This difference in air traffic

underscores the need for additional flight planning considerations for Mid-Atlantic farmers that want to implement UAS technology into their operations.

Figure 3: Every FAA Public Airport with Air Operations Radii (2019)



Source: Boynton, B. (2020). Title of the webpage. "The Plethora of Airports that You Don't See", Medium, retrieved from: <https://medium.com/@bboynton97/the-plethora-of-airports-that-you-dont-see-cf89e375019d> 2024.

In addition to restricted flight paths near airports and military installations, flight laws often prohibit UAS operations near urban areas due to the privacy invasion risk. On the East Coast, this can be particularly challenging for farms located near urban sprawl areas as obtaining the necessary flight permits can become complex when flying near populated areas. While the Midwestern United States is not immune from this challenge, the rate of urban expansion on the East Coast and Southeastern United States has far outpaced the Midwest due to population growth and economic opportunities according to the Urban Institute (2024) and McDade (2012). The rapid population growth and urban expansion continues to threaten the long-term viability of many Mid-Atlantic farms. As a result, considering the use of agricultural UAS likely becomes a much lower business priority for farmers facing urban encroachment.

As a counter to this school of thought, Stöcker et al. (2017) argue that while these concerns are valid, the current regulatory frameworks need to evolve to balance safety and privacy with the operational needs of agricultural UAS applications. They suggest that more flexible regulations could

enable the agricultural sector to fully harness the photogrammetric potential of UAS. For example, implementing tiered regulations based on the risk profile of different UAS operations could allow for more relaxed rules in low-risk rural areas compared to urban settings. Additionally, advancing technologies such as geofencing and automated collision avoidance systems could mitigate safety risks, thereby justifying regulatory relaxation. However, addressing these regulatory challenges requires a nuanced approach that safeguards safety and privacy without unduly restricting the innovative applications of UAS technology in Mid-Atlantic agriculture.

Similarly, Freeman and Freeland (2014) point out the political and technological restrictions that U.S. regulations place on the use of UAS in agriculture. Regulatory hurdles not only delay the implementation of UAS technologies but also add significant costs to compliance, which can be prohibitive for small to medium-sized farm operations. This can be especially problematic in the Mid-Atlantic where farms are typically fragmented among smaller parcels and interwoven with urban developments. Farmers in this area must navigate through a myriad of FAA and local regulations that can be drastically different from one state to the next. The disjointed regulation leads to confusion and frustration which hinders farmers' ability to adopt UAS technology effectively (Freeman and Freeland, 2014). The impact of these regulations is further explored by Rodriguez III (2023), who provides a case study on the adoption of drones in the United States agricultural aircraft sector. This study indicates that while UAS offer substantial benefits for crop monitoring and pest management, regulatory barriers often lead to underinvestment in UAS technologies by the agricultural sector. The study suggests that more adaptive regulatory frameworks could support the safe integration of UAS while also promoting their wider use in agriculture, thus helping Mid-Atlantic farmers overcome some of the current challenges and harness the full potential of UAS technology in enhancing agricultural productivity and sustainability (Rodriguez III, 2023).

Project Methodology and Design

This study utilizes a conceptual framework design to evaluate the adoption and economic impact of UAS technology in agriculture, specifically within the Mid-Atlantic region. Employing a mixed-method approach, the study combines qualitative insights from an in-person survey of three representative farm operations- Saunders Brothers, Inc., Glenview Farms, and Hagan Cattle Company—with a quantitative analysis of a representative 200-acre soybean farm's profitability, projected over a ten-year period (2024-2034). The qualitative component explores the attitudes and concerns of farm

operators regarding UAS adoption, while the quantitative analysis models the financial implications of integrating UAS technology into precision agriculture compared to maintaining traditional farming methods.

The data collection involved both primary and secondary sources. The primary data were gathered through direct interviews with farm operators in the Mid-Atlantic region, offering a unique perspective on the barriers and opportunities related to UAS adoption. The secondary data, used for the quantitative analysis, were derived from enterprise budgets, current commodity prices, and average cost changes with respect to UAS implementation. By blending these methodologies, the study provides a comprehensive view of both the qualitative barriers and quantitative benefits of UAS adoption in precision farming.

Qualitative Survey

An in-person survey was conducted with three regional farming operations to gain a better understanding of the tactical perspective around agricultural UAS awareness. The farms were represented by Jim Saunders, Executive Vice President of Saunders Brothers, Inc. (survey conducted on April 2, 2024), Ronnie Sharpe, owner of Glenview Farms (survey conducted on April 13, 2024), and Matt Hagan, owner of Hagan Cattle Company (survey conducted on March 29, 2024).

Saunders Brothers, Inc. is a family-owned agricultural operation located in Piney River, Virginia, near the foothills of the Blue Ridge Mountains. Established in 1915, the business has grown to include a 100-acre wholesale nursery, a 160-acre orchard, and additional field production areas. Saunders Brothers, Inc. specializes in container production of a wide variety of plants, as well as producing tree-ripened peaches, apples, and other fruits. They cater primarily to garden centers, landscapers, and wholesalers throughout the mid-Atlantic region. The company prides itself on its family values and commitment to quality and customer service.

Hagan Cattle Company is a Christiansburg, Virginia, cattle operation known for its focus on producing high-quality beef cattle. The company is a first-generation beef cattle operation that began in 2015. With nearly 1,000 acres, Hagan Cattle Company prides itself on ethical and sustainable cattle operations, while providing agritourism opportunities through pick-your-own produce and retail sales via an online presence and at regional locations.

Glenview Farms is a small beef cattle operation located in Louisa, Virginia. Founded in 2001, the operation rents roughly 180 acres of land with about eighty-five head of cattle that are owned by the company. This small, independent operation is focused on providing high quality beef options in the local area with a plan to grow modestly through land that can be owned in the future. This operation is currently a part-time operation with family members holding full-time jobs (Appendices D, E, F).

Overall, the three operations revealed a cautious approach towards adopting UAS technology. Each farm expresses a lack of awareness and a lack of relevant information as significant barriers to venturing into that area of precision farming. Saunders Brothers, Inc., with its 350-acre operation, acknowledges potential uses in its nursery and orchard areas but remains hesitant due to uncertainty about costs and regulatory frameworks. Glenview Farms, which operates 180 acres for cattle farming, shares similar concerns and believes that UAS technology might primarily benefit larger farms rather than small-scale operations like theirs.

All three farms cite multiple concerns regarding UAS adoption, including initial investment costs, return on investment, and regulatory uncertainty. None have conducted trials or experiments with drones, reflecting a general skepticism about the tangible benefits of such technology in their specific businesses. Hagan Cattle Company, managing about 1,000 acres for various agricultural products, also highlights the lack of local support and technical assistance as significant obstacles. Despite recognizing the potential efficiency gains, they stress the need for more accessible information and affordable service providers to consider agriculture drones as a viable investment.

The potential for UAS technology to improve agricultural efficiency is acknowledged by all three farmers, but the farms emphasize the necessity of support and training to integrate it effectively. Saunders Brothers, Inc. expresses interest in educational workshops, while Glenview Farms and Hagan Cattle Company suggest that external service providers would be essential due to their current limitations in expertise and resources. Overall, the responses indicate that, while there is a cautious interest in UAS technology, substantial informational and logistical barriers must be addressed to foster broader adoption in the Mid-Atlantic agricultural sector.

During a drone data analytics workshop at the Virginia Tech Tidewater Agricultural Research and Extension Center (AREC) on April 22, 2024, Dr. Abhilash Kumar Chandel, Assistant Professor of Precision Agriculture Technologies and Data Management at Virginia Tech, lent his perspective on why agriculture UAS adoption in the Mid-Atlantic region has lagged behind other areas in the United States. He noted

that one of the critical steps that has been habitually overlooked is the improvement of information dissemination and training around UAS technology. He mentioned that one of the ways this can be achieved is through targeted educational programs, workshops, and hands-on training sessions for community practitioners that demonstrate the practical benefits of UAS technology. These initiatives should involve partnerships between universities, private sector companies, and local governments to leverage resources and expertise to build a multi-faceted communication plan within the region. Dr. Chandel also emphasized the necessity of presenting information in an accessible manner to non-technical practitioners. With this approach, potential users are not alienated but rather are encouraged to explore and adopt UAS technology. Moreover, creating robust community networks and peer learning platforms can facilitate knowledge sharing and support among farmers, helping to bridge the information gap and foster a culture of innovation in agriculture (Appendix G)

Dr. Chandel also discussed infrastructure readiness as an equally crucial friction point. The lack of reliable internet and cell service in the remote areas of the Mid-Atlantic poses a significant challenge to UAS adoption. Investment in infrastructure improvements is essential to ensure that farmers have the necessary connectivity to utilize UAS technology effectively. Additionally, financial barriers such as the high cost of UAS must be tackled for the region to really engage with the technology. Developing affordable UAS solutions and providing subsidies or financial assistance can make this technology more accessible to farmers that otherwise would be pushed away from the capability. By addressing these specific challenges through a collaborative and comprehensive strategy, the adoption of UAS technology in the Mid-Atlantic region can be enhanced, leading to more efficient, sustainable, and productive agricultural practices.

Quantitative Conceptual Analysis

The Mid-Atlantic region, characterized by its diverse agricultural practices ranging from small-scale orchards and vineyards to large grain and livestock farms, serves as the focal point for this study. This area offers a unique blend of agricultural environments, making it an ideal setting for evaluating the integration of UAS technology in various farming operations. For this study, a 200-acre soybean farm was chosen as a representative farm for analysis, since soybeans are the top revenue-generating crop in many Mid-Atlantic states. This conceptual analysis compares the projected profitability of a 200-acre soybean farm over a ten-year period (2024-2034) when either hiring or purchasing an agricultural drone UAS program for precision agriculture compared to maintaining a standard non-precision approach. The

baseline farm data were derived from the 2024 Soybean, No-Till, Non-Irrigated Enterprise Budget from the University of Tennessee Extension agency and was adjusted for the 200-acre soybean farm analysis.

This calculation uses a \$10.70 per bushel soybean price from mid July 2024, with an initial yield of 55 bushels per acre for an initial revenue of \$588.50 per acre. This paper acknowledges the volatility of global commodity prices; however, for illustrative purposes, it keeps the price standardized, while factoring in a steady assumed inflationary target rate of 2% per year for all calculations. The analysis estimates the fixed and variable cost savings of 20% based on the Quan et al., 2023 study of UAS impact on rice crops. The hired drone service was based on \$15 per acre input cost. The purchased drone program was based on an initial cost of \$15,000 (national average cost for a mid-range agriculture drone), an annual maintenance cost of \$5 per acre, and a 5-year straight line depreciation period for the platform with no salvage value. The general accepted accounting practice (GAAP) of fully depreciating the UAS in five years, but utilizing the system for the full decade was incorporated. The expected yield improvement for both drone scenarios is estimated at 5%.

Financial Formulas and Calculations

Several financial formulas were employed to assess the profitability of the soybean farm under different scenarios:

1. **Basic Future Value:** $FV = PV \times (1+i)^n$
 - a. Assuming an average annual inflation rate of 2%
 - b. FV = future value
 - c. PV = present value
 - d. i = inflation rate
 - e. n = number of years
2. **FV as Adjusted Revenue:** Initial Revenue per Acre \times Total Acres \times (1+Inflation Rate)
 - a. Initial Revenue per Acre: \$588.50
 - b. Total Acres: 200
 - c. Inflation Rate: 2% per year
 - d. Years: n= 0 to 10
 - e. Example Year 2: Adjusted Revenue Year 2= 55bu \times 200 \times \$10.70ppbu \times $(1+0.02)^1 = \$120,054$
3. **FV as Adjusted Variable Expenses:** Initial Variable Expenses per Acre \times Total Acres \times (1+i)ⁿ
 - a. Initial Variable Expenses per Acre: \$305.89

- b. Example Year 2: Adjusted Variable Expenses Year 2= $\$305.89 \times 200 \times (1+0.02)^1 = \$62,402$
- 4. **FV as Adjusted Fixed Expenses:** Initial Fixed Expenses per Acre \times Total Acres $\times (1+i)^n$
 - a. Initial Fixed Expenses per Acre: \$273.28
 - b. Adjusted Fixed Expenses Year 2= $\$273.28 \times 200 \times (1+0.02)^1 = \$55,749$
- 5. **Non-UAS Net Profit:** Adjusted Revenue $-($ Adjusted Variable Expenses $+$ Adjusted Fixed Expenses)
 - a. Example Year 2: Net Profit Year 2= $\$120,054 - (\$62,402 + \$55,749) = \$1,903$
- 6. **Hiring UAS Net Profit:** 5% Yield Improvement $-$ Adjusted Hiring Cost
 - a. Hiring Cost per Acre: $\$15 \times 200 \text{ acres} = \$3,000$
 - b. 5% Yield Improvement: Original 55 bushels per acre $\times 200 \text{ acres} \times 1.05$ (5% yield increase) = 11,550 total bushels. 5% Yield increase= 11,550 bushels for 200 acres.
 - c. Baseline Hiring UAS Gross Revenue: $55 \text{bu} \times 200 \text{ac} \times \$10.70 \text{ppbu} \times 1.05$ (5% yield increase) = \$123,585
 - d. Example Year 2: Hiring Net Profit Year 2 = $\$123,585 \times (1+0.02)^1$ (2% inflation) $-$ \$52,321 (after 20% variable cost reduction) $+$ \$55,749 (fixed cost includes \$3000 cost of hiring UAS for 200ac analysis) $=$ \$17,986.33
- 7. **Purchasing UAS Net Profit:**
 - a. Additional Revenue from Yield Improvement $-$ (Adjusted Depreciation $+$ Adjusted Maintenance Cost)
 - b. Purchase Cost for UAS: \$15,000
 - c. Depreciation Period: 5 years
 - d. Annual Straight-Line Depreciation: $\$15,000 / 5 \text{ years} = \$3,000$ depreciation per year
 - e. Annual UAV Maintenance Cost: \$1,000
 - f. Example Year 2 (After initial purchase): Purchasing UAS Net Profit = $\$123,585 \times 1.05$ (5% increase) $\times (1+0.02)^1$ (2% inflation) $-$ \$50,721 (fixed cost) $+$ \$68,749 (variable cost includes \$15,000 initial purchase $-$ \$3,000 for 1 year of depreciation) $=$ \$6,586.33
 - g. Example Year 6 after UAS is fully depreciated: Purchasing UAS Net Profit = $\$136,448 - \$60,345$ (fixed cost) $+$ \$54,836 (variable cost includes full depreciated UAS system, includes \$1,000 yearly maintenance costs) $=$ \$20,267

In Figure 4, the analysis of implementing drone services in a 200-acre soybean farm demonstrates that both hiring and purchasing options can contribute significantly to enhancing farm profitability through input cost efficiency improvements despite a 2% inflation rate through the years.

Over the decade, both hiring and purchasing UAS capability yield immediate net positive results to profitability, though purchasing a UAS program raises the initial total expenses. The total expenses soon drop below the standard projection due to asset depreciation and variable cost reduction (Figure 5), making it a competitive alternative in the end. It is important to note that the general industry standard lifespan of an agriculture UAS is approximately five years, which aligns with the general accepted accounting practice (GAAP) of straight-line depreciation. This has been factored into the total expense calculations, with the assumption that the UAS asset would be kept beyond full depreciation. The UAS platform does maintain a \$1,000 maintenance cost that includes aspects like: parts, software licenses and updates, and FAA remote pilot license renewals (Appendix H).

Hiring an agriculture drone service shows a higher net profit primarily due to the avoidance of substantial upfront capital expenditures that would be incurred by purchasing and maintaining a UAS program. The lower entry cost makes it easier for the farm to adopt the technology without heavily impacting cash flow, allowing for immediate operational improvements, such as better pest management, optimized irrigation, and more precise fertilizer application. These improvements lead to an estimated yield increase of 5%, translating into additional revenue per acre. For this analysis, the calculations do not account for drone service price fluctuations but do account for 2% annual inflation.

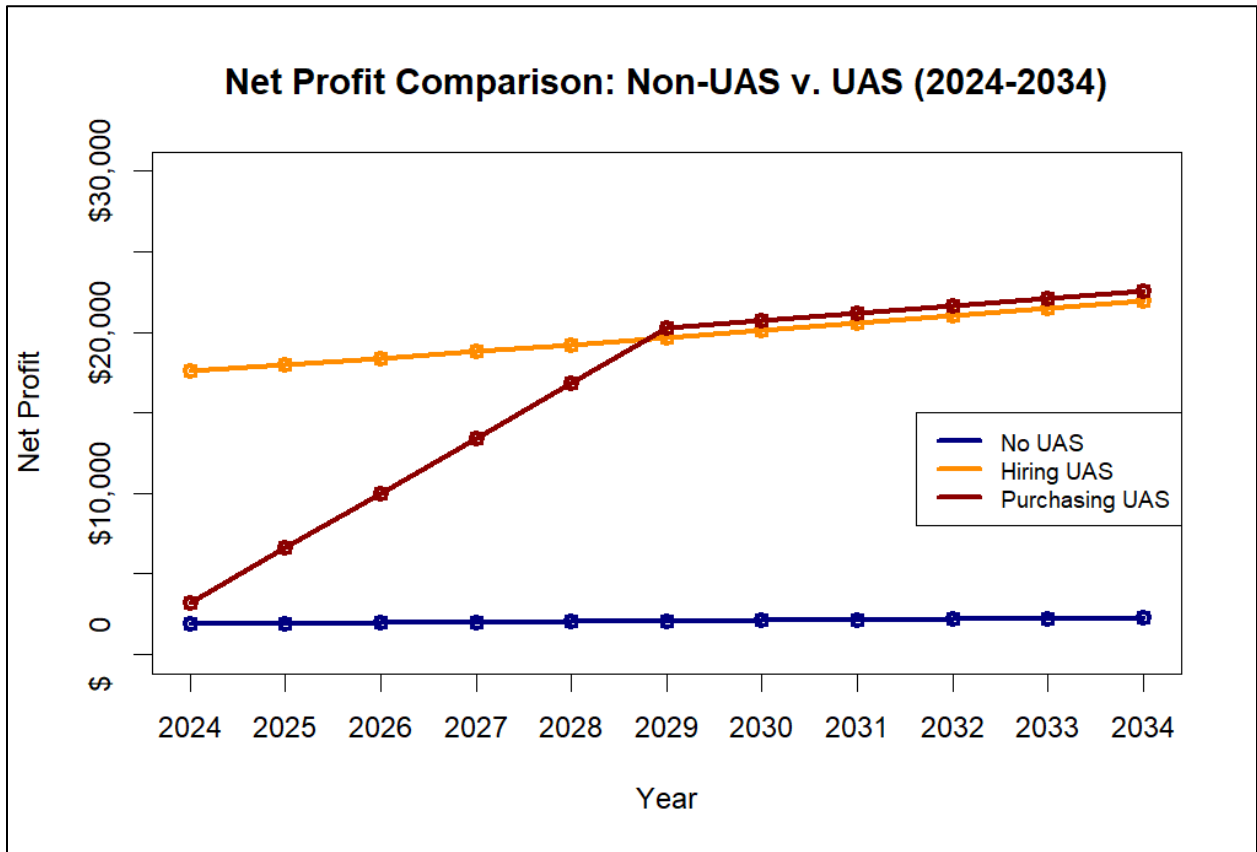
When comparing the net profit outcomes for each option throughout the decade, distinct differences emerge when considering options for implementing UAS into farming. The non-UAS option yields a modest net profit increase, starting at around \$1,866 in 2024 and gradually rising to \$2,020 by 2034. The slow growth can be attributed to inflation without significant operational changes. In contrast, hiring a UAS service provider yields a substantial improvement, where net profits start at \$17,587 in 2024 and increase to \$19,234 by 2034. This option benefits from the 5% yield increase and a 20% reduction in variable costs through targeted UAS crop analysis. Even after accounting for the price of hiring a UAS service provider, the profit significantly outweighs not using a UAS. Purchasing a UAS initially has higher upfront costs, particularly in 2024 with the \$15,000 purchase of the complete UAS and all associated software. This initial cost leads to a net profit of \$3,187 in 2024; however, the profitability quickly rises as the UAS becomes fully depreciated by year six. At this point, the net profit reaches \$40,061 in 2030 and keeps a steady pace through 2034. Purchasing the UAS offers long-term gains, especially after the depreciation phase, making it a highly advantageous choice over time if the initial cost of the system can be incurred by a farm.

The total expense comparison for each option highlights the different cost structures associated with the use of UAS compared to not using the capability. For the non-UAS option, expenses remain the

highest due to the lack of efficiency improvements, starting at \$115,834 in 2024 and climbing steadily to \$125,382 by 2034. Hiring a UAS service provider incurs the additional \$3,000 annual cost for hiring; however the farm benefits from reduced variable expenses, resulting in lower overall costs. Total expenses for this option begin at \$105,998 in 2024 and rise to \$114,538 by 2034, reflecting a more controlled expense growth. Purchasing a UAS shows a unique pattern: its total expenses are higher in 2024 due to the \$15,000 purchase, but they decrease steadily over time as the UAS reaches fully depreciation. By 2034, total expenses in this scenario stabilize around \$116,938.

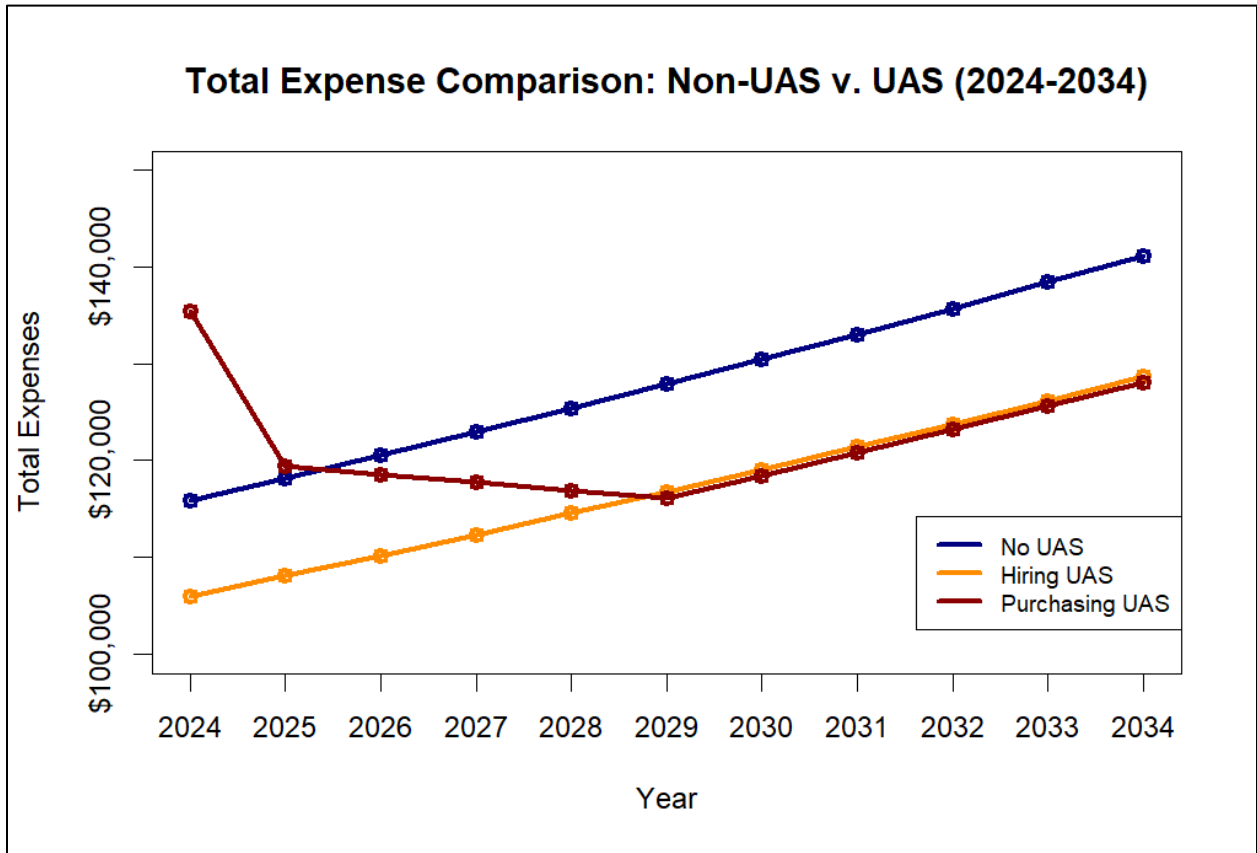
While both options provide a net positive impact on profitability for a 200-acre soybean farm, the recommendation for a ten-year projection would be to utilize a drone service due to its likely more predictable cost (charged by rate per acre), less risk from the farm owner's perspective, and flexibility with using it as needed while reducing the wear and tear on the land and on farm equipment. For farming operations that are over 200 acres, or that have more profitable crops, purchasing a drone package may be the better option over a ten-year period as the upfront cost may not be as impactful while yielding slightly higher profits (all variable remaining equal). For larger operations, purchasing a drone system may have a bigger impact on traditional machine maintenance costs due to field spot maintenance versus full-field treatments.

Figure 4: 10-Year Net Profitability Projection- 200 Acre Mid-Atlantic Soybean Farm



Source: Graphic created by the author. Adapted from the University of Tennessee Enterprise Budget for no-till, non-irrigated soybean farm. Baseline data was projected for 200-acre farm for 10 years in RStudio for graphical representation.

Figure 5: 10-Year Total Expense Projection- 200 Acre Mid-Atlantic Soybean Farm



Source: Graphic created by the author. Adapted from the University of Tennessee Enterprise Budget for no-till, non-irrigated soybean farm. Baseline data was projected for 200-acre farm for 10 years in RStudio for graphical representation.

Summary of Outcomes, Discussions and Recommendations

The integration of agricultural UAS into farming operations presents a significant opportunity for enhancing productivity, efficiency, and profitability in the Mid-Atlantic United States. This region, characterized by diverse agricultural practices and smaller farm sizes compared to the Midwest, faces unique challenges such as a varying range of climate and growing conditions, diverse terrain, rural technological infrastructure gaps and stringent UAS regulatory frameworks given the dense population areas closer to the coast. However, with widely disseminated information, training and support, these barriers can be overcome, and Mid-Atlantic farmers can benefit from the immense capabilities that agriculture UAS technology provides.

This project's analysis, including three qualitative in-field interviews, reveals that a wide knowledge and engagement gap exists among farm owners regarding agricultural UAS capabilities, services and the costs associated with such an endeavor. This gap will only widen with time if the effort to interact with farmers does not become more involved and engaging. The simulation of an average-sized Mid-Atlantic soybean farm highlighted the net income and expense differences when comparing hiring agriculture drone services versus purchasing a drone program and not using a UAS. Purchasing or hiring an agriculture drone service poses a significant investment consideration for the average Mid-Atlantic farming operation. Through a combination of grants, financing and tax credits, lawmakers in conjunction with private industry leaders can make it a feasible capability worth exploring.

Beyond financial considerations, UAS enhance operational efficiency and productivity through precise monitoring and management of agricultural inputs. This is no different for the Mid-Atlantic region, however the lag in adoption is complex and multi-faceted. Cultural, geographical, financial and regulatory challenges are amplified in the Mid-Atlantic as it is not primarily an agrarian region like those found in the Midwestern United States. Smaller and family-owned operations may find it difficult to employ advanced technology due to the cost and regulatory implications such organizations would have to endure. This is why a multi-faceted approach to these challenges is necessary, and it should be delivered through community engagement involving private firms and university cooperative extension networks.

The multi-faceted approach would cover four key areas: information and training, focused infrastructure investment, financial support and UAS regulatory flexibility.

1. **Information and Training:** Implement targeted educational programs and hands-on training sessions in collaboration with universities, private sector companies, local governments and

extension offices. These initiatives should focus on demonstrating the practical benefits of UAS technology and providing accessible information to potential practitioners.

2. **Focused Infrastructure Investment:** Continue to improve internet and cell service infrastructure in rural areas to ensure farmers have the necessary connectivity to utilize UAS technology effectively. This is crucial for the successful implementation of all precision agriculture practices.
3. **Financial Support:** Develop affordable UAS solutions and provide subsidies or financial assistance to make this technology accessible to small and medium-sized farms. This can be achieved through government programs and partnerships with financial institutions and non-profits.
4. **Regulatory Adaptation:** Mid-Atlantic agriculture government liaisons need to advocate for more flexible regulations that balance safety and privacy with the operational needs of agricultural UAS applications. Implementing tiered regulations based on the risk profile of different UAS operations could facilitate broader adoption and reduce the barrier to entry. These regulations need to consider farmers in rural settings as well as urban fringe areas.

Conclusion

While agricultural UAS technology is not necessarily new, it has rapidly gained popularity in the last twenty years. Most of the technology adoption is coming from larger farming operations in the Midwestern United States, which outpaces the Mid-Atlantic region significantly, despite the Mid-Atlantic having a large agricultural sector that could benefit from such a capability. This project provided insight into why that may be the case. Given the feedback from practitioners and an expert in the field, coupled with a profitability impact simulation for UAS integration, it becomes clear that the issues facing the Mid-Atlantic farming community regarding UAS adoption are complex, layered and potentially expensive. Many of the Mid-Atlantic barriers to this capability can be greatly reduced through an integrated training and awareness approach led by university extension offices, the private sector and local lawmakers. This effort would have to be executed in a consistent manner that builds relationship and trust among farmers, private firms, universities, financial institutions and lawmakers in a way that provides a path for Mid-Atlantic farmers to experience the benefits of agricultural UAS. This will be a critical point to help Mid-Atlantic agriculture remain competitive, profitable and sustainable into the future.

References

Aubert, B. A., Schroeder, A., & Grimaudo, J. (2012). IT as Enabler of Sustainable Farming: An Empirical Analysis of Farmers' Adoption Decision of Precision Agriculture Technology. *Decision Support Systems*, 54(1), 510-520.

Behjati, M., Seyfi, A., & Sadeghpour, S. (2021). LoRa Communications as an Enabler for Internet of Drones Towards Large-Scale Livestock Monitoring in Rural Farms. *Sensors*, 21(15), 5044.

Boynton, B. (2020). The Plethora of Airports That You Don't See. Medium.

<https://medium.com/@bboynton97/the-plethora-of-airports-that-you-dont-see-cf89e375019d>

Chandel, A. K., PhD. (2024, April 22). Assistant Professor and Extension Specialist: Precision Agriculture Technologies and Data Management, Virginia Tech. In-person discussion.

Chandel, A. K., PhD. (2024, April 22). Assistant Professor and Extension Specialist: Precision Agriculture Technologies and Data Management, Virginia Tech. Drone Data Analytics Workshop, Virginia Tech Tidewater AREC.

Delavarpour, N., Gao, W., Zhang, C., & Ni, S. (2021). A Technical Study on UAS Characteristics for Precision Agriculture Applications and Associated Practical Challenges. *Remote Sensing*, 13(6), 1204.

Defalque, G., Miller, A. R., & Hayes, B. (2023). A Review on Beef Cattle Supplementation Technologies. *Information Processing in Agriculture*.

Duncan, E., Espejo, G., Sawyer, S., & Bell, M. (2021). New But for Whom? Discourses of Innovation in Precision Agriculture. *Agriculture and Human Values*, 38, 1181-1199.

Finger, R., Swinton, S. M., El Benni, N., & Walter, A. (2019). Precision Farming at the Nexus of Agricultural Production and the Environment. *Annual Review of Resource Economics*, 11, 313-335.

Freeman, P., & Freeland, R. (2014). Politics & Technology: U.S. Policies Restricting Unmanned Aerial Systems in Agriculture. *Food Policy*, 49, 302-311.

Grenzdörffer, G., Engel, A., & Teichert, B. (2008). The Photogrammetric Potential of Low-Cost UAS in Forestry and Agriculture. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 31(B3), 1207-1214.

Hagan, M. (2024, March 29). Owner, Chief Executive Officer: Hagan Cattle Company, Christiansburg, Virginia. In-person interview.

Khanal, S., Kc, K., & Fulton, J. (2020). Remote Sensing in Agriculture—Accomplishments, Limitations, and Opportunities. *Remote Sensing*, 12(22), 3783.

Kiropoulos, K., & Kalogiros, C. (2021). Precision Agriculture Investment Return Calculation Tool. In 2021 17th International Conference on Distributed Computing in Sensor Systems (DCOSS) (pp. 1-2). IEEE.

Lee, C.-L., Ho, Y.-C., Hsu, Y.-H., & Kuo, S.-F. (2021). Analyzing Precision Agriculture Adoption Across the Globe: A Systematic Review of Scholarship from 1999–2020. *Sustainability*, 13(18), 10295.

Lachowiec, J., Millar, C., & Smith, C. (2024). Adoption of Unoccupied Aerial Systems in Agricultural Research. *The Plant Phenome Journal*, 7(1), e20098.

Lim, K. G., Lau, P. W., & Law, L. S. (2021). Optimization of Crop Disease Classification Using Convolution Neural Network. In 2021 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAET) (pp. 1-6). IEEE.

Loures, L., & Nunes, L. (2020). Assessing the Effectiveness of Precision Agriculture Management Systems in Mediterranean Small Farms. *Sustainability*, 12(9), 3765.

McDade, Z. J. (2012). Population Growth in the Exurbs Before and Since the Great Recession. Urban Institute. <https://www.urban.org/urban-wire/population-growth-exurbs-and-great-recession>

Mohsan, S. A. H., Bajwa, U. I., & Ali, A. (2023). Unmanned Aerial Systems (UAS): Practical Aspects, Applications, Open Challenges, Security Issues, and Future Trends. *Intelligent Service Robotics*, 16(1), 109-137.

Pathak, H., & Poudel, S. (2020). Use of Drones in Agriculture: Potentials, Problems, and Policy Needs. ICAR-National Institute of Abiotic Stress Management, 300, 4-15.

Quan, X., Tian, Y., & Zhang, Y. (2023). The Economic Effects of Unmanned Aerial Systems in Pesticide Application: Evidence from Chinese Grain Farmers. *Precision Agriculture*, 24(5), 1965-1981.

Rahman, M. F. F., Zhang, Y., & Salam, A. (2021). A Comparative Study on Application of Unmanned Aerial System Systems in Agriculture. *Agriculture*, 11(1), 22.

Rivas, A., Bell, B. T., & Sinclair, R. (2018). Detection of Cattle Using Drones and Convolutional Neural Networks. *Sensors*, 18(7), 2048.

Rodriguez III, R. (2023). Measuring the Adoption of Drones: A Case Study of the United States Agricultural Aircraft Sector. *Eng*, 4(1), 977-983.

Saunders, J. (2024, April 2). Executive Vice President: Saunders Brothers, Inc., Piney River, Virginia. In-person interview.

Sharpe, R. (2024, April 13). Chief Operations Officer: Glenview Farms, LLC., Louisa, Virginia. In-person interview.

Slimani, H., Zaoui, F., & Merabet, A. (2024). Assessing the Advancement of Artificial Intelligence and Drones' Integration in Agriculture Through a Bibliometric Study. *International Journal of Electrical and Computer Engineering (IJECE)*, 14(1), 878-890.

Stöcker, C., Bennett, R., Nex, F., Gerke, M., & Zevenbergen, J. (2017). Review of the Current State of UAS Regulations. *Remote Sensing*, 9(5), 459.

Tisseyre, B., & McBratney, A. (2008). A Technical Opportunity Index Based on Mathematical Morphology for Site-Specific Management: An Application to Viticulture. *Precision Agriculture*, 9(2), 101-113.

Turner, D., Lucieer, A., & Watson, C. (2012). An Automated Technique for Generating Georectified Mosaics from Ultra-High Resolution Unmanned Aerial System (UAS) Imagery, Based on Structure from Motion (SfM) Point Clouds. *Remote Sensing*, 4(5), 1392-1410.

Turner, J. M. (2016). *The Economic Potential of Unmanned Aircraft in Agricultural and Rural Electric Cooperatives*. Oklahoma State University.

Velusamy, P., Munusamy, P., & Amirthavalli, V. (2021). Unmanned Aerial Systems (UAS) in Precision Agriculture: Applications and Challenges. *Energies*, 15(1), 217.

Walter, A., Finger, R., Huber, R., & Buchmann, N. (2017). Smart Farming is Key to Developing Sustainable Agriculture. *Proceedings of the National Academy of Sciences*, 114(24), 6148-6150.

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big Data in Smart Farming—A Review. *Agricultural Systems*, 153, 69-80.

Xie, Y., & Kovacs, J. M. (2023). U.S. Farmland Under Threat of Urbanization: Future Development Scenarios to 2040. *Land*, 12(3), 574.

Yang, G., Liu, J., Zhao, C., Li, Z., Huang, Y., Yu, H., & Wang, J. (2017). Unmanned Aerial System Remote Sensing for Field-Based Crop Phenotyping: Current Status and Perspectives. *Frontiers in Plant Science*, 8, 1111.

Yousefi, D. M., Rezapour, S., & Khosravi, H. (2022). A Systematic Literature Review on the Use of Deep Learning in Precision Livestock Detection and Localization Using Unmanned Aerial Systems. *IEEE Access*, 10, 80071-80091.

Zhang, C., & Kovacs, J. M. (2012). The Application of Small Unmanned Aerial Systems for Precision Agriculture: A Review. *Precision Agriculture*, 13(6), 693-712.

Appendix

A. University of Tennessee 2024 Soybean NT, NI Enterprise Budget

2024 Soybean, No-Till, Non-Irrigated Budget						
	Uni	Quantity	Price	Total	Your Farm	
Revenue ¹						
Soybeans	Bu/acr	55	\$10.70	\$588.50	\$	588.50
Government Payments	\$/acre	1	\$0.00	\$0.00	\$	-
Other Revenue	\$/acre	1	\$0.00	\$0.00	\$	-
			Total	\$588.50	\$	588.50
			Total Farm Revenue		\$	117,700.00
Variable Expenses						
						(200 Acres)
Seed ²	Thous.	140	\$0.45	\$63.00	\$	63.00
Fertilizer & Lime (Table 1)	Acr	1	\$62.66	\$62.66	\$	62.66
Chemical (Table 2)	Acr	1	\$87.15	\$87.15	\$	87.15
Crop Scout or Consultant	Acr	1	\$10.00	\$10.00	\$	10.00
Repair & Maintenance (Table 3)	Acr	1	\$33.13	\$33.13	\$	33.13
Fuel, Oil & Filter (Table 3)	Acr	1	\$17.37	\$17.37	\$	17.37
Operator Labor (Table 3)	Acr	1	\$8.90	\$8.90	\$	8.90
Crop Insurance ⁶	Acr	1	\$11.22	\$11.22	\$	11.22
Machinery Rental	Acr	0	\$0.00	\$0.00	\$	-
Custom Work	Acr	0	\$0.00	\$0.00	\$	-
Drying (Fuel/Electric)	Bu	50	\$0.00	\$0.00	\$	-
Other	Acr	1	\$0.00	\$0.00	\$	-
Other	Acr	1	\$0.00	\$0.00	\$	-
Operating Interest ⁷	%	\$293.42	8.50%	\$12.47	\$	12.47
			Total Variable	\$305.89	\$	305.89
			Total Variable Expenses	\$305.89	\$	61,178.00
Fixed Expenses						
Machinery						
Capital Recovery (Table 3)	Acr	1	\$115.28	\$115.28	\$	115.28
Other Fixed Machinery Costs	Acr	1	\$0.00	\$0.00	\$	-
General Overhead	Acr	1	\$20.00	\$20.00	\$	20.00
Cash Rent ⁸	Acr	1	\$113.00	\$113.00	\$	113.00
Insurance (Non-Machinery)	Acr	1	\$0.00	\$0.00	\$	-
Management Labor	Acr	1	\$25.00	\$25.00	\$	25.00
Other	Acr	1	\$0.00	\$0.00	\$	-
			Total Fixed Expenses	\$273.28	\$	273.28
			Total	\$54656.00	\$	54,656.00
Total Farm Net Profit 2024						\$ 1,866.00
Breakeven Price for Selected Yield			Breakeven Yield for Selected Price			
Yield (bu)	Variable Cost (\$/bu)	Total Specified Cost (\$/bu)	Price (\$/bu)	Variable Cost (bu)	Total Specified Cost (bu)	
30	\$10.20	\$19.31	\$10.50	29	55	
35	\$8.74	\$16.55	\$11.00	28	53	
40	\$7.65	\$14.48	\$11.50	27	50	
45	\$6.80	\$12.87	\$12.00	25	48	
50	\$6.12	\$11.58	\$12.50	24	46	
55	\$5.56	\$10.53	\$13.00	24	45	
60	\$5.10	\$9.65	\$13.50	23	43	
65	\$4.71	\$8.91	\$14.00	22	41	
70	\$4.37	\$8.27	\$14.50	21	40	

B. RStudio Code for 200 Acre Soybean Farm UAS and Non-UAS Implementation Visualization:

```
1. > library(readxl)
2. >
3. > # Load the Excel file
4. > Soybean_Farm_Pro_Forma <- read_excel("C:/Users/thomp/OneDrive/Desktop/Thompson
   Folders/VTCALS/OMALS Program_Project/Soybean Farm Pro Forma.xlsx")
5. >
6. > # Create Data Frame
7. > df <- read_excel("C:/Users/thomp/OneDrive/Desktop/Thompson Folders/VTCALS/OMALS
   Program_Project/Soybean Farm Pro Forma.xlsx")
8. >
9. > # Explore the Data
10. > head(df)
11. # A tibble: 6 × 16
12.   Year `Revenue (Non-UAS)` `Revenue (Hiring UAS)`
13.   <chr>      <dbl> <chr>
14. 1 2024      117700 123585
15. 2 2025      120054 126056.7
16. 3 2026      122455. 128577.834
17. 4 2027      124904. 131149.39068000001
18. 5 2028      127402. 133772.37849360003
19. 6 2029      129950. 136447.82606347202
20. # i 13 more variables:
21. #   `Revenue (Purchasing UAS)` <dbl>,
22. #   `Variable Expense (No UAS)` <dbl>,
23. #   `Variable Expense (Hiring UAS)` <dbl>,
24. #   `Variable Expense (Purchasing UAS)` <dbl>,
25. #   `Fixed Expenses (No UAS)` <dbl>,
26. #   `Fixed Expenses (Hiring UAS)` <dbl>, ...
27. > str(df)
28. tibble [25 × 16] (S3: tbl_df/tbl/data.frame)
29. $ Year          : chr [1:25] "2024" "2025" "2026" "2027" ...
30. $ Revenue (Non-UAS) : num [1:25] 117700 120054 122455 124904 127402 ...
31. $ Revenue (Hiring UAS) : chr [1:25] "123585" "126056.7" "128577.834"
   "131149.39068000001" ...
32. $ Revenue (Purchasing UAS) : num [1:25] 123585 126057 128578 131149 133772 ...
33. $ Variable Expense (No UAS) : num [1:25] 61178 62402 63650 64923 66221 ...
34. $ Variable Expense (Hiring UAS) : num [1:25] 51342 52321 53320 54338 55377 ...
35. $ Variable Expense (Purchasing UAS): num [1:25] 49742 50721 51720 52738 53777 ...
36. $ Fixed Expenses (No UAS) : num [1:25] 54656 55749 56864 58001 59161 ...
37. $ Fixed Expenses (Hiring UAS) : num [1:25] 54656 55749 56864 58001 59161 ...
```

```

38. $ Fixed Expenses (Purchasing UAS) : num [1:25] 70656 68749 66864 65001 63161 ...
39. $ Total Expenses (Non-UAS)      : num [1:25] 115834 118151 120514 122924 125382 ...
40. $ Total Expenses (Hiring-UAS)   : num [1:25] 105998 108070 110184 112339 114538 ...
41. $ Total Expenses (Purchasing-UAS) : num [1:25] 120398 119470 118584 117739 116938 ...
42. $ Net Profit (No UAS)           : num [1:25] 1866 1903 1941 1980 2020 ...
43. $ Net Profit (Hiring UAS)       : num [1:25] 17587 17986 18394 18810 19234 ...
44. $ Net Profit (Purchasing UAS)   : num [1:25] 3187 6586 9994 13410 16834 ...
45. >
46. > # Convert Year column to numeric
47. > years <- as.numeric(df$Year)
48. Warning message:
49. NAs introduced by coercion
50. >
51. > # Replace NAs with 0 in Net Profit and Total Expenses columns
52. > net_profit_no_uas <- ifelse(is.na(df$`Net Profit (No UAS)`), 0, df$`Net Profit (No UAS)`)
53. > net_profit_hiring_uas <- ifelse(is.na(df$`Net Profit (Hiring UAS)`), 0, df$`Net Profit (Hiring
    UAS)`)
54. > net_profit_purchasing_uas <- ifelse(is.na(df$`Net Profit (Purchasing UAS)`), 0, df$`Net Profit
    (Purchasing UAS)`)
55. >
56. > total_expenses_no_uas <- ifelse(is.na(df$`Total Expenses (Non-UAS)`), 0, df$`Total Expenses
    (Non-UAS)`)
57. > total_expenses_hiring_uas <- ifelse(is.na(df$`Total Expenses (Hiring-UAS)`), 0, df$`Total
    Expenses (Hiring-UAS)`)
58. > total_expenses_purchasing_uas <- ifelse(is.na(df$`Total Expenses (Purchasing-UAS)`), 0,
    df$`Total Expenses (Purchasing-UAS)`)
59. >
60. > # Function to format numbers in dollar format
61. > format_dollar <- function(x) {
62. +   paste0("$", format(x, big.mark = ",", scientific = FALSE))
63. + }
64. >
65. > # Year 1 UAS purchase: $15,000 initial cost in Year 1
66. > uas_purchase_cost_year_1 <- 15000
67. >
68. > # Add the $15,000 UAS purchase cost to Year 1 total expenses for the Purchasing UAS scenario
69. > total_expenses_purchasing_uas[1] <- total_expenses_purchasing_uas[1] +
    uas_purchase_cost_year_1
70. >
71. > # Plot Net Profit Comparison (2024-2034)
72. > plot(years, net_profit_no_uas, type="o", col="navyblue", ylim=c(0, 30000), xlim=c(2024,
    2034),

```

```

73. +   xlab="Year", ylab="Net Profit", main="Net Profit Comparison: Non-UAS v. UAS (2024-
      2034)",
74. +   lwd=3, axes=FALSE) # lwd=3 for thicker lines, axes=FALSE to customize axes
75. >
76. > lines(years, net_profit_hiring_uas, type="o", col="darkorange", lwd=3)
77. > lines(years, net_profit_purchasing_uas, type="o", col="darkred", lwd=3)
78. >
79. > # Format axes with dollar formatting
80. > axis(1, at=seq(2024, 2034, by=1)) # X-axis
81. > axis(2, at=seq(0, 30000, by=5000), labels=format_dollar(seq(0, 30000, by=5000))) # Y-axis
82. > box() # Add box around the plot
83. >
84. > # Add Legend Box
85. > legend("topright", legend=c("No UAS", "Hiring UAS", "Purchasing UAS"),
86. +   col=c("navyblue", "darkorange", "darkred"), lty=1, lwd=3,
87. +   xpd=TRUE, inset=c(0, 0.5), cex=0.8) # cex=0.8 reduces the size of the legend
88. >
89. > # Plot Total Expenses Comparison (2024-2034)
90. > plot(years, total_expenses_no_uas, type="o", col="navyblue", ylim=c(100000, 150000),
      xlim=c(2024, 2034),
91. +   xlab="Year", ylab="Total Expenses", main="Total Expense Comparison: Non-UAS v. UAS
      (2024-2034)",
92. +   lwd=3, axes=FALSE) # lwd=3 for thicker lines, axes=FALSE to customize axes
93. >
94. > lines(years, total_expenses_hiring_uas, type="o", col="darkorange", lwd=3)
95. > lines(years, total_expenses_purchasing_uas, type="o", col="darkred", lwd=3)
96. >
97. > # Format axes with dollar formatting
98. > axis(1, at=seq(2024, 2034, by=1)) # X-axis
99. > axis(2, at=seq(100000, 150000, by=10000), labels=format_dollar(seq(100000, 150000,
      by=10000))) # Y-axis
100. > box() # Add box around the plot
101. >
102. > # Add Legend Box
103. > legend("topright", legend=c("No UAS", "Hiring UAS", "Purchasing UAS"),
104. +   col=c("navyblue", "darkorange", "darkred"), lty=1, lwd=3,
105. +   xpd=TRUE, inset=c(0, 0.7), cex=0.8) # cex=0.8 reduces the size of the legend

```

C. Military Installation/ Airport Density Calculation

Process	Calculation	
Square mile factor		1000
Number of military installations (East Coast)		50
Number of military installations (Midwest)		35
Land area (East Coast in square miles)		150,000
Land area (Midwest in square miles)		400,000
Density of military installations per 1,000 square miles (East Coast)	$50 / 150,000 * 1000 = 0.33$	0.3333
Density of military installations per 1,000 square miles (Midwest)	$35 / 400,000 * 1000 = 0.09$	0.0875
Number of public-use airports (East Coast)		550
Number of public-use airports (Midwest)		450
Density of public-use airports per 1,000 square miles (East Coast)	$550 / 150,000 * 1000 = 3.67$	3.6667
Density of public-use airports per 1,000 square miles (Midwest)	$450 / 400,000 * 1000 = 1.13$	1.125
Average density (military + airports) per 1,000 square miles (East Coast)	$(0.33 + 3.67) / 2 = 2.00$	2.0000
Average density (military + airports) per 1,000 square miles (Midwest)	$(0.09 + 1.13) / 2 = 0.61$	0.60625

D. Saunders, J. (2024, April 2). Interview on the Utilization of UAS for Agricultural Advancements in the Mid-Atlantic United States. Executive Vice President, Saunders Brothers, Inc.

1. What is the name of your business and how long has it been in operation?
 - Saunders Brothers, Inc., a 5-generation family operation.
2. How many acres does the farm operate?
 - Approximately 350 acres comprising nursery, boxwood plots, and fruit orchards (peaches, apples, Asian pears).
3. Do you currently use, or plan to use, UAS technology for agricultural purposes within your operation?
 - Not much consideration is given due to the general lack of relevant and available information. Open to limited nursery use and more usage for orchard and boxwood areas.
4. If yes, what specific applications do/would you use UAS for in your agricultural operations?
 - N/A, but would be interested in information on crop monitoring, pest management, and irrigation management.
5. Please share if any of the following were concerns as you consider(ed) adopting UAS technology in your agricultural practices.

- Lack of awareness, investment cost concerns, ROI concerns, regulatory uncertainty, limited access to technology/support, and skepticism of UAS benefits.
 - 6. Have you conducted any trials or experiments with UAS technology in your agricultural operations?
 - No.
 - 7. What do you see as the potential benefits of UAS technology in improving efficiency and productivity in your operation?
 - UAS could be beneficial as a standalone tool or as a support for manned operations.
 - 8. Are you familiar with any local or regional initiatives supporting UAS adoption in Mid-Atlantic agriculture?
 - Not aware of any initiatives for agricultural UAS training, sales, or support.
 - 9. What level of support or guidance would your organization require to integrate UAS technology effectively?
 - Training and awareness, with a challenge in training seasonal, immigrant crews under Department of Labor agreements.
 - 10. How do you envision UAS technology impacting the future of agriculture in your region?
 - UAS technology has potential, but more focus is needed on available options and support for farmers.
- E. Hagan, M. (2024, March 29). Interview on the Utilization of UAS for Agricultural Advancements in the Mid-Atlantic United States. Owner, CEO of Hagan Cattle Company.
1. What is the name of your business and how long has it been in operation?
 - Hagan Cattle Company, a first-generation farming operation founded in 2015.
 2. How many acres does the farm operate?

- Approximately 1,000 acres for beef, strawberries, and hemp products.
3. Do you currently use, or plan to use, UAS technology for agricultural purposes within your operation?
- Not currently, due to a lack of information and providers in the region. The terrain and scale may limit ROI.
4. If yes, what specific applications do/would you use UAS for in your agricultural operations?
- N/A, but interested in information on crop monitoring, pest management, and irrigation management.
5. Please share if any of the following were concerns as you consider(ed) adopting UAS technology in your agricultural practices.
- Concerns include lack of awareness, investment costs, ROI, regulatory uncertainty, limited access to technology/support, and skepticism of UAS benefits.
6. Have you conducted any trials or experiments with UAS technology in your agricultural operations?
- No, but open to the concept.
7. What do you see as the potential benefits of UAS technology in improving efficiency and productivity in your operation?
- Potential benefits are recognized, but knowledge is limited.
8. Are you familiar with any local or regional initiatives supporting UAS adoption in Mid-Atlantic agriculture?
- No, there is a lack of information on UAS technology in the area.
9. What level of support or guidance would your organization require to integrate UAS technology effectively?
- Likely to hire a service provider if cost-effective, given other operational priorities.

10. How do you envision UAS technology impacting the future of agriculture in your region?

- There is potential for UAS adoption if more information and training are made available.

F. Sharpe, R. (2024, April 13). Interview on the Utilization of UAS for Agricultural Advancements in the Mid-Atlantic United States. Owner, COO of Glenview Farms, LLC.

1. What is the name of your business and how long has it been in operation?

- Glenview Farms, operating for over 20 years since 2001.

2. How many acres does the farm operate?

- 180 acres for approximately 85 head of cattle.

3. Do you currently use, or plan to use, UAS technology for agricultural purposes within your operation?

- Not currently, due to the lack of information and services available in the region. Concerned that UAS is more suitable for larger farms.

4. If yes, what specific applications do/would you use UAS for in your agricultural operations?

- Not considering it at this time due to the small scale of operations.

5. Please share if any of the following were concerns as you consider(ed) adopting UAS technology in your agricultural practices.

- Concerns include lack of awareness, investment costs, ROI, regulatory uncertainty, limited access to technology/support, and skepticism of UAS benefits.

6. Have you conducted any trials or experiments with UAS technology in your agricultural operations?

- No, not interested in this investment due to cost and training requirements.

7. What do you see as the potential benefits of UAS technology in improving efficiency and productivity in your operation?

- Unlikely to see benefits unless used in larger farming operations.
8. Are you familiar with any local or regional initiatives supporting UAS adoption in Mid-Atlantic agriculture?
- No, little information is provided on UAS in the area.
9. What level of support or guidance would your organization require to integrate UAS technology effectively?
- This would need to be offered by an external service provider.
10. How do you envision UAS technology impacting the future of agriculture in your region?
- UAS technology may benefit larger operations but is less relevant to smaller livestock operations.

G. Summary from Discussion

Chandel, A. K. (2024, April 22). *Summary of Ag UAS Discussion*. Virginia Tech.

1. **Lack of Information and Training:** There is a significant deficit in available information and training for both practitioners and farmers. This lack of knowledge impedes the ability to fully utilize UAS technology.
2. **Community Engagement:** Universities and the private sector are progressing with UAS technology, but the lack of engagement with the entire community, including would-be process owners, creates a gap that widens each year.
3. **Infrastructure Readiness:** The technology's adoption is further hampered by the lack of infrastructure in remote areas where internet and cell service are unreliable. Without consistent internet or cell service, initiating conversations about UAS technology becomes challenging.

4. Accessible Training: Information and training on agricultural UAS need to be accessible to non-technical practitioners to avoid alienating potential users. Building connections between farmers, practitioners, and experts is crucial to removing barriers and fostering opportunities.

H. 200-Acre Soybean Farm Pro Forma Profitability Projection

Year	Revenue Net-	Revenue	Revenue	Variable	Variable	Variable	Variable	Fixed	Fixed	Fixed	Fixed	Fixed	Total Expenses	Total Expenses	Total Expenses	Total Expenses	Net Profit (No)	Net Profit	Net Profit	
2024	\$ 117,700.00	\$ 123,585.00	\$ 123,585.00	\$ 61,178.00	\$ 51,342.40	\$ 49,742.40	\$ 54,656.00	\$ 54,656.00	\$ 54,656.00	\$ 70,656.00	\$ 87,491.20	\$ 104,326.40	\$ 115,334.00	\$ 105,998.40	\$ 120,398.40	\$ 136,298.40	\$ 1,086.00	\$ 1,086.00	\$ 17,586.60	\$ 3,186.60
2025	\$ 120,054.00	\$ 126,066.70	\$ 126,066.70	\$ 62,401.56	\$ 52,321.25	\$ 50,721.25	\$ 55,749.12	\$ 55,749.12	\$ 55,749.12	\$ 70,749.12	\$ 87,584.16	\$ 104,419.16	\$ 115,426.68	\$ 106,070.57	\$ 119,470.57	\$ 135,370.57	\$ 1,963.32	\$ 1,963.32	\$ 17,966.33	\$ 6,366.33
2026	\$ 122,455.08	\$ 128,577.83	\$ 128,577.83	\$ 63,649.59	\$ 53,319.67	\$ 51,719.67	\$ 56,864.10	\$ 56,864.10	\$ 56,864.10	\$ 71,864.10	\$ 88,701.10	\$ 105,536.10	\$ 116,543.69	\$ 107,183.78	\$ 120,583.78	\$ 136,473.78	\$ 2,941.39	\$ 2,941.39	\$ 18,394.06	\$ 9,994.06
2027	\$ 124,904.18	\$ 131,149.39	\$ 131,149.39	\$ 64,922.58	\$ 54,338.07	\$ 52,738.07	\$ 58,001.38	\$ 58,001.38	\$ 58,001.38	\$ 73,001.38	\$ 89,841.38	\$ 106,676.38	\$ 117,683.97	\$ 112,329.45	\$ 125,729.45	\$ 141,619.45	\$ 3,919.21	\$ 3,919.21	\$ 18,794.14	\$ 10,394.14
2028	\$ 127,402.27	\$ 133,772.38	\$ 133,772.38	\$ 66,271.03	\$ 55,376.83	\$ 53,776.83	\$ 59,161.41	\$ 59,161.41	\$ 59,161.41	\$ 74,161.41	\$ 91,001.41	\$ 107,836.41	\$ 118,844.00	\$ 113,489.48	\$ 126,589.48	\$ 142,474.48	\$ 4,897.21	\$ 4,897.21	\$ 19,184.14	\$ 10,784.14
2029	\$ 129,949.31	\$ 136,447.83	\$ 136,447.83	\$ 67,645.46	\$ 56,426.36	\$ 54,826.36	\$ 60,344.64	\$ 60,344.64	\$ 60,344.64	\$ 75,344.64	\$ 92,184.64	\$ 109,020.64	\$ 120,027.10	\$ 114,677.10	\$ 128,177.10	\$ 143,329.10	\$ 5,875.21	\$ 5,875.21	\$ 19,574.16	\$ 11,174.16
2030	\$ 132,548.32	\$ 139,176.78	\$ 139,176.78	\$ 68,966.36	\$ 57,517.09	\$ 55,917.09	\$ 61,501.33	\$ 61,501.33	\$ 61,501.33	\$ 76,501.33	\$ 93,321.33	\$ 110,456.33	\$ 121,433.65	\$ 115,723.65	\$ 129,223.65	\$ 144,184.65	\$ 6,853.21	\$ 6,853.21	\$ 20,064.16	\$ 11,564.16
2031	\$ 135,200.30	\$ 141,960.32	\$ 141,960.32	\$ 70,274.29	\$ 58,619.43	\$ 57,019.43	\$ 62,619.43	\$ 62,619.43	\$ 62,619.43	\$ 77,619.43	\$ 94,561.43	\$ 111,598.43	\$ 122,600.96	\$ 116,816.96	\$ 130,316.96	\$ 145,039.96	\$ 7,831.21	\$ 7,831.21	\$ 20,554.12	\$ 12,054.12
2032	\$ 137,904.31	\$ 144,799.32	\$ 144,799.32	\$ 71,679.78	\$ 59,743.82	\$ 58,143.82	\$ 63,743.82	\$ 63,743.82	\$ 63,743.82	\$ 78,743.82	\$ 95,683.82	\$ 112,812.82	\$ 123,653.19	\$ 118,006.19	\$ 131,366.19	\$ 145,904.19	\$ 8,809.21	\$ 8,809.21	\$ 21,044.18	\$ 12,544.18
2033	\$ 140,662.40	\$ 147,695.32	\$ 147,695.32	\$ 73,113.37	\$ 60,890.70	\$ 59,290.70	\$ 64,890.70	\$ 64,890.70	\$ 64,890.70	\$ 79,890.70	\$ 96,865.70	\$ 113,947.70	\$ 124,622.55	\$ 119,159.55	\$ 132,417.55	\$ 146,779.55	\$ 9,787.21	\$ 9,787.21	\$ 21,534.14	\$ 13,034.14
2034	\$ 143,475.64	\$ 150,649.43	\$ 150,649.43	\$ 74,576.64	\$ 62,060.51	\$ 60,460.51	\$ 66,060.51	\$ 66,060.51	\$ 66,060.51	\$ 81,060.51	\$ 97,945.51	\$ 115,030.51	\$ 125,479.00	\$ 120,366.00	\$ 133,470.00	\$ 147,654.00	\$ 10,765.21	\$ 10,765.21	\$ 22,024.10	\$ 13,524.10
UAV Purchase																				
Price Year 1	\$ 15,000.00	Price/Bushel	10.7																	
Depreciation Year 2	\$12,000.00	Acres Planted	200																	
Depreciation Year 3	\$9,000.00	Bushel/Acre	55																	
Depreciation Year 4	\$5,000.00																			
Depreciation Year 5	\$3,000.00																			
Depreciation Year 6	\$0.00																			
Depreciation Year 7	\$0.00																			
Depreciation Year 8	\$0.00																			
Depreciation Year 9	\$0.00																			
Depreciation Year 10	\$0.00																			
Depreciation Year 11	\$0.00																			
Purchase Maintenance Cost	\$1,000.00																			