

Effectiveness of Drones In Monitoring Plants of Which Goats Are Tasked With Grazing

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Abstract

It is important to investigate the integration of drone technology with goat grazing practices, focusing on how drones can be employed to monitor goats and assess the vegetation they graze upon. Drawing from a multifaceted approach that includes interviews with farmers and goat ranchers, extensive literary research, and hands-on field studies with goats, this work explores the potential and challenges of using drones in agricultural and ecological contexts. I have found through my research that although there can be some complications with getting the drones to monitor the goats while they are in the field, drones should excel with being able to monitor the areas where the goats have grazed. This can be done by monitoring the fields and forests in which these goats graze.

Introduction

Over the course of humanity, the first animal humans have domesticated was the goat, or *Capra Hircus*. (Oklahoma State University, 2008) These valuable and hardy animals have been utilized for many varying purposes for over ten thousand years (Zeder and Hesse, 2000, and Hirst, 2019), such as for their meat, milk production, and companionship as pets, in part due to their abilities to form emotional bonds with people and their high intelligence (MacDonald, F., 2018; Four Paws, 2023). In addition, goats have shown to be extraordinarily hardy animals, in part due to requiring less space than other herbivorous livestock, being able to sustain themselves on a wide variety of vegetation, and an ability to adapt to a wide variety of climates and environments. This makes them ideal for poorer farmers or farmers without access to adequate resources for other, larger livestock, such as cattle or swine (Embrace Relief Foundation, 2024).

One of the most recent and increasingly trendy uses of goats is a process popularly known as “goatscaping,” or goat landscaping. This practice involves employing goats to clear vegetation in a natural, sustainable, and environmentally friendly way. Goatscaping has gained widespread popularity among homeowners, businesses, and municipalities alike, offering an

appealing, charming, and more socially acceptable alternative to traditional landscaping methods that often rely on heavy machinery or chemical herbicides (McDonald, 2007). In addition, goats excel in their role as natural landscapers due to their aggressive grazing habits and voracious appetites, which make them particularly effective at maintaining overgrown areas. Their four-compartmented stomach and digestive system allow them to process a wide variety of plants, including many that are toxic to other animals, enabling them to tackle tough vegetation that might otherwise require labor-intensive removal methods (McGuire, 2013).

Goats have been utilized in order to reduce invasive species rooting out invasive plant (Wolf and Larkin, 2021) in numerous places. In a nine-month study conducted in Odisha, India, it was found that goats preferred eating certain invasive plants, which was used as part of a method to reduce their spread (Valentine, McRoberts, & Cherney, 2020). In addition, goats have been used in eastern North America in order to free up the oak and hickory negatively affected by invasive plants (Novais, Wenner, Block, Power, Porteus, & Davies, 2023).

In stark contrast to the relationship between humans and domesticated goats which spans tens of thousands of years, a comparatively modern technological development that has gained prominence over the past decade or so is the unmanned aerial vehicle, commonly referred to as a “drone”. Drones have been utilized for numerous varied purposes, such as mapping and surveying of land, inspection of isolated areas, photography, delivery of packages and equipment, spraying, (Alvarado, 2021), transportation, and (in the interests of this paper) observation and surveillance (Paneque-Gálvez, McCall, Napoletano, Wich, & Koh, 2014). This is usually done by having a pilot operating a drone to watch one or more targets, although automated drones are also available and have seen quite a bit of usage.

Drones are capable of many things in part due to technical revelations. For example, many drones have the capability to navigate throughout forests (Zhang, Li, Chen, Wang, and Zhang, 2023) and mountaintops (Dai, Li, Xu, Tomás, Li, Jiang, Zhang, Yin, and Wang, 2023) and observe biomass in the tops of trees that are normally impossible for people to easily reach (Klosterman & Richardson, 2017, and van Geffen, Heim, Brieger, Geng, Shevtsova, Schulte, Stuenzi, Bernhardt, Troeva, Pestryakova, Zakharov, Pflug, Herzsuh, & Kruse, 2022). This is

due to many factors, including sensor technology which allows drones to view some objects and areas autonomously from a distance (Fasano, Accardo, Tirri, Moccia, & Lellis, 2015), as well as thermal sensors (Schroth, 2018).

In addition, drones, as a rapidly advancing technology, have garnered substantial support from prominent companies such as Nokia and Tesla, which have recognized their potential for innovation and practical applications (Worldwide Computer Products News, 2023) as well as artificial intelligence in the form of machine learning, which alongside mathematical optimization (Choset, 2024) is another way the technology has improved as that has allowed drones to optimize flight paths, identify obstacles, and make real-time decisions to avoid collisions, resulting in a measurable reduction in recorded impacts and accidents (Buchelt, Smith, Li, & Zhang, 2024).

Drones have also made rapid technological strides in other areas, such as size and radar capabilities. Smaller drones (Fioranelli, Richie, Griffiths, & Borrión, 2015) have been utilized to explore many dense or otherwise significant to human interest areas, such as cities and forests with dense foliage and shrubbery. This has been compounded by advancements in radar technology (Quevedo, Urzaiz, Menoyo, & Lopez, 2019) which has allowed for drones to view objects and locations which may be vague if not imperceptible to the naked human eye.

Drone technology is capable of assessing plant health based on size and radar specifications. Infrared radar can be used in order to assess the type and location of plants in forested areas, as well as various mammals within them (Wich, Dellatore, Houghton, Ardi, & Koh, 2020). Specific drone sizes can also be used to assess various areas for different people- for example, smaller, personal drones are cheaper and smaller, and therefore can be preferred for goat owners who operate goat grazing businesses independently and work with smaller areas. In direct contrast to this, larger, commercial drones tend to have more features for users such as advanced obstacle avoidance algorithms, advanced flight mapping, and the ability to carry payloads. They also tend to have an extended battery life, and therefore can be the preferred choice for larger industries or goat owners who are hired to have their goats graze larger forests or other flora. (Mukherjee, 2024)

The objective of my research revolves around using goats and drones for management of invasive species and vegetation. While there is extensive precedent for monitoring animals such as goats with drones for reasons such as health and general surveillance (GAO RFID Inc, 2024) my goal is explicitly to explore how drones can be used to monitor areas that goats graze in in order to determine the status of the plants. In order to achieve this, I have both done numerous literary reviews and field research assignments, such as conversations with goat owners and testing with drones. Research suggests that goats can be tracked while grazing with drones with up to 73% of surveillance sessions ending successfully without interruption (Vayssade, Arquet, & Bonneau, 2019), which indicates that utilizing drones on goats is indeed possible and can be effective for multiple different purposes. In addition, many of these drones can be automated (Vayssade, Arquet, & Bonneau, 2019), increasing the speed and efficiency of the surveillance.

Methodologies

Literary Research

In conducting my literary research, I relied primarily on articles and resources collected from the Allegheny AggreGator and Google Scholar, as well as additional articles and texts from other researchers and experts. This approach was intended to ensure that the research adhered to academic standards and that the findings were rooted in credible and authoritative sources. In general, most of the works I have pulled from related to goat behaviors and the capabilities and technical aspects of drones in order to create a more informed and cohesive picture of their attributes and create a researched estimate as to how they would behave around each other.

With the data I collected, I conducted an investigation to evaluate the effectiveness of drones in monitoring the grasses, trees, and other vegetation that goats are tasked with foraging. This was also based on information collected from these sources which I have assessed by creating an annotated bibliography. This bibliography included a detailed summary and evaluation for each of the sources, highlighting their relevance and contributions to the research.

Field Research

Field research was conducted in order to gain new knowledge in how drones can be used to monitor areas in which goats graze. Firsthand exposure to this topic can allow for a new and interesting perspective and topic for the senior thesis.

I approached my field research by observing the goats and their fields with my DJI Mini 3 Pro drone at approximately 10 meters above the ground for 30 minutes in order to observe potential places they may have trouble being observed. I also held virtual conversations with people associated with goat businesses in order to get their insight on this topic and their information on this matter. Finally, I observed the locations that the goats are in by myself without my drone, in order to view things that may not be easily accessible via a drone or would be better off with human experience.

My goat observation with my drone consisted of flying my personal drone around a large property with goats roughly 40-60 meters away from them for roughly an hour in order to test the video and surveillance capabilities of not only my aircraft but also drones as a whole. Although I was unable to record as much footage as I would have liked due to time constraints and weather, I gained some valuable experience needed for both drone utilization and goat behavior over an extended period.

In addition, I also approached the field research with numerous “goatscapers” with the goal of interviewing them to get their opinions and information on their experiences. This was in order to get local knowledge on the topic of drone usage with people who raise and maintain these animals for the sake of first-person research.

Results

My preliminary results indicate that drones can in fact be utilized to observe the plants upon which goats graze. This does depend on numerous factors, such as the type of plant being monitored, the type of goat, and various weather conditions.

The many capabilities of drones, such as observation and surveillance (Paneque-Gálvez, J., McCall, M. K., Napoletano, B. M., Wich, S. A., & Koh, L. P., 2014), inspection of isolated areas, photography, delivery of packages and equipment, spraying, (Alvarado, 2021), transportation, and, of course, observation and surveillance makes them excellent tools for monitoring goat grazing locations. All of these qualifications have proven to be essential for monitoring goats in these areas.

In addition, many drones have the capability to observe biomass in the tops of trees that are normally impossible for people to easily reach (Klosterman & Richardson, 2017, and van Geffen, Heim, Brieger, Geng, Shevtsova, Schulte, Stuenzi, Bernhardt, Troeva, Pestryakova, Zakharov, Pflug, Herzsuh, & Kruse, 2022). They can also navigate throughout forests (Zhang, Li, Chen, Wang, and Zhang, 2023) and mountaintops (Dai, Li, Xu, Tomás, Li, Jiang, Zhang, Yin, and Wang, 2023), both of which are popular locations for goatscaping job sites (McDonald, 2007).

This is usually done by having a pilot operating a drone to watch one or more targets, although automated drones are also available and have seen quite a bit of usage (Fasano, Accardo, Tirri, Moccia, & Lellis, 2015).

One of the factors influencing the effectiveness of drone behavior is the breed of goat being monitored. For example, hardier goat breeds such as the Nigerian Goat (Squire, 2024) are less likely to exhibit signs of stressful behavior when being monitored or being in direct contact with drones.

Larger goats, however, are also capable of remaining calm and composed when dealing with drones (Sartell, 2018), such as La Mancha Goats, whose relaxed disposition enables them to

handle themselves around potential stress inducers such as drones (Fossil Rim Wildlife Center, n.a)

In contrast, myotonic goats (more commonly known as fainting goats) are goats which are known for being naturally nervous. When they are startled or frightened, they will stiffen up and collapse (Kruzer, 2022). This can be caused by numerous factors, such as drones getting too close to the goats. Negative goat behavior can be mitigated via substantially large herds and socialization (Sartell, 2018) but this breed is nonetheless still easily stress-induced.

In addition, as part of my field research I decided to interview several workers and business owners in the goatscaping industry (as stated above). The results of my interviews are below (Figure 1.1)

Figure 1.1- Expert Informant Conversations

Expert	Uses drones?	Would goats be afraid of drones?	Other concerns/notes
Expert #1	Yes	No	"I believe drones are one vital piece of the largely evolving goatscaping business industry."
Expert #2	Yes	Potentially, if they got too close	N/A
Expert #3	No	No	Is relatively new to his business
Expert #4	Considered	Yes	N/A
Expert #5	No	Maybe	"Well, I love working with goats. I love having goats. I think they can be a wonderful tool to landscape in an environmental way. And I think there is potential for use for drones in the work we do. We work with people who do use drones. So yeah, I think there are things we can learn here. I always want to be learning and growing. Sso if the price is right, I think we could use drones."
Expert #6	Yes	No	"Drones are more useful in other places because of fires or environmental disasters (Nikki lives in Florida)"
Expert #7	Yes	Yes	"Cost, legal requirements, and land access all impact drone usage. The drone for animal management is only practical under certain conditions."

Expert #8	Yes	Yes	"Drones have become and will continue to become a game changer in the agriculture world in the coming years."
Expert #9	Yes	Maybe	N/A
Expert #10	No	No	N/A

Figure 1.2- Experts and Locations

Expert	Location
Expert #1	Ohio
Expert #2	California
Expert #3	Arizona
Expert #4	Iowa
Expert #5	Pennsylvania
Expert #6	Florida
Expert #7	Arizona
Expert #8	Iowa
Expert #9	Pennsylvania
Expert #10	Pennsylvania

In addition, during my drone flights I have had photographs taken in order to provide aerial evidence of my claims, as shown below:

Figure 2.1- Aerial view of Potential Farms, PA, with goats in view (Taken with Dji Mini 3 Pro)



Figure 2.2- Closer aerial view of Potential Farms, PA (Taken with Dji Mini 3 Pro)



Figure 2.3- Close up shot of goats (Taken with Dji Mini 3 Pro)



Figure 3.1- Goat Behavior Around Drones

Surveyed Experts on If Their Goats Were Scared of Drones

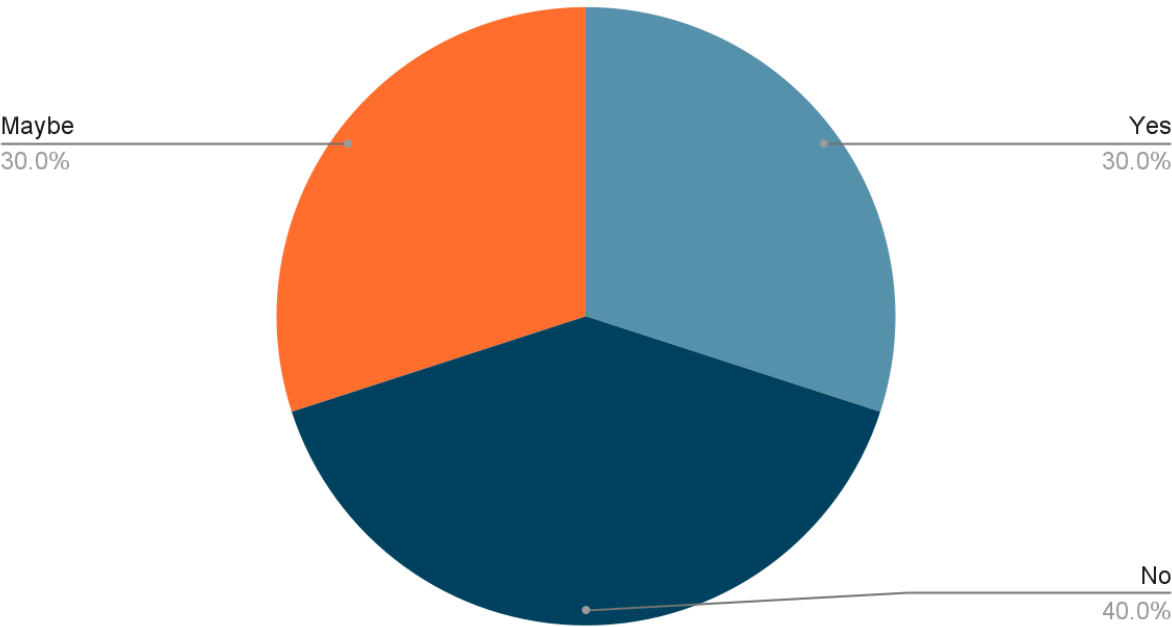


Figure 3.2- Goat Owners and Their Use of Drones

Goat Owners and Their Use of Drones

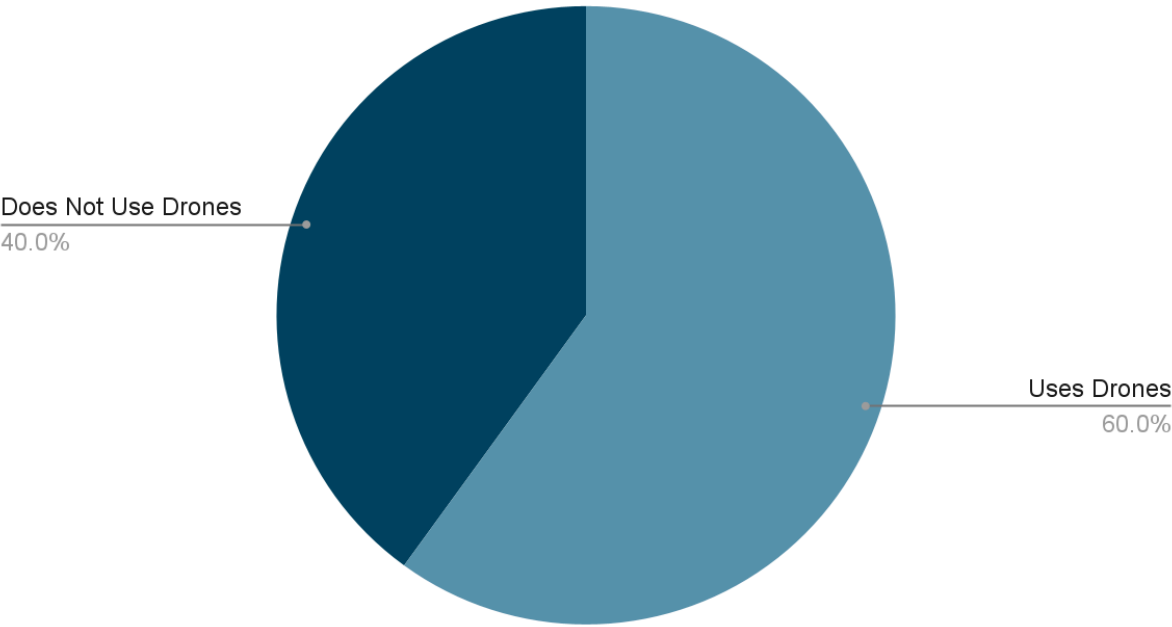
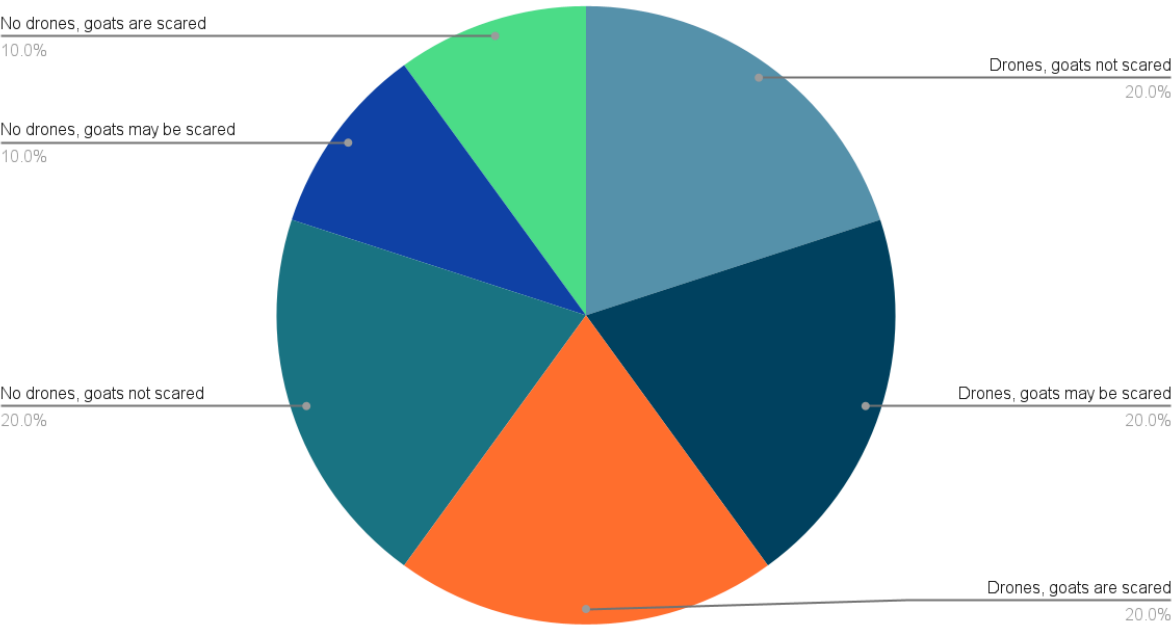


Figure 3.3- Goat Behavior Vs. Drone Ownership

Goat Behavior Vs. Drone Ownership



Discussion

The discussions with experts in this field, alongside the field research conducted and the literary research done through a review of scholarly articles, seem to indicate a general trend in favor of utilizing drones to monitor goats. This is due to multiple factors; utilizing drones to monitor the plants that goats graze has numerous benefits, such as security of the goats, most goats do not consistently show fear around drones, and the efficiency of drones in monitoring different locations.

The ability of drones to monitor several notable locations, such as mountainous and forested areas, suggests that they can be immensely useful tools for monitoring goat grazing sites regardless of climate. The diversity of drones available to consumers also allows for the choice between smaller, cheaper drones which can navigate smaller forests and other overgrown areas (Zhang & Kovacs, 2012) through recent technological adaptation (Choset, 2024) as well as larger commercial drones which excel at navigating larger areas (Mukherjee, 2024). This is supported by figure 2, with figures 2.1, 2.2 and 2.3 showing drones in action successfully monitoring goats in flat, open areas, such as plains and grasslands, with surrounding forests that these goats have occasionally grazed upon, which are all areas that studies have shown drones can operate in mountaintops, (Dai, Li, Xu, Tomás, Li, Jiang, Zhang, Yin, and Wang, 2023), forests (Zhang, Li, Chen, Wang, and Zhang, 2023) and other places that may be difficult for goat farmers to access (Klosterman & Richardson, 2017, and van Geffen, Heim, Brieger, Geng, Shevtsova, Schulte, Stuenzi, Bernhardt, Troeva, Pestryakova, Zakharov, Pflug, Herzsuh, & Kruse, 2022). The lack of climates that a goat would reasonably be expected to graze in that drones cannot handle adds to this conclusion.

Overall, drones have also been used in the past to monitor many species (Paneque-Gálvez, McCall, Napoletano, Wich, & Koh, 2014) through radar (Quevedo, Urzaiz, Menoyo, & Lopez, 2019), including goats (Vayssade, Arquet, & Bonneau, 2019) with great success.

In addition, the research suggests that while many goats who have been socialized can handle grazing around drones, some goats who have lacked human interaction may show signs

of fear when being around drones. Figure 1.1 shows that 40% of goat owners report their goats exhibiting fearful behavior around drones, while 30% of goat owners explained that their goats did not display fearful behavior, and the remaining 30% of experts either were not sure or stated that it depended on circumstances.

Figure 1.2, meanwhile, shows that a notable majority of goat experts that were communicated with utilize drones, as 60% of them owned these tools. Figure 1.3 shows that there is a general association between goat landscaping group owners who utilize drones and goats who are not fearful of them.

Many goat owners that have been interviewed seem to agree with the concept of increased human activity correlating with a tolerance of drones, with a few citing the fact that many of their goats have been repeatedly exposed to human activity as evidence that goats can handle being around drones while they are being monitored. This correlates with studies that have shown that human contact can influence behavior in goats to become more accepting of man-made activity (Mastellone, Scandurra, D’Aniello, Nawroth, Saggese, Silvestre, & Lombardi, 2020). This is assisted by a clear connection between goats and human domestication (Oklahoma State University, 2008).

Conclusion

Overall, the work behind my senior thesis indicates that drones can indeed be utilized to monitor plants upon which goats graze. This is based upon the observable evidence collected by my literary research, conversations with experts in this field, and field research via drones. The studies which I conducted showed that there was a clear majority of farmers which favored this approach, given the numerical advantage shown in Figure 3.2.

Potential limitations of my findings include a lack of locations of goat farmers that I could converse with and a lack of understanding of drone technology. Although the discussions I had with the goat farmers were indeed productive and provided crucial information for this

thesis, ultimately I feel as though a larger sample size would prove even more effective in proving connections between drones and their ability to monitor goats as well as their accessibility. The proportion of goat farmers that I discussed drones with were also biased towards being from Pennsylvania due to its immediate proximity, which biases things towards goat farmers who live in forested areas.

In addition, drone technology is a very complex field of which I have just scratched the surface. While I have done my research on different varieties of drones and their technological breakthroughs, as well as their sensing capabilities through radar, I can only continue to forward my research in these areas.

Future impacts of this research could indicate that drones could continue to become a reliable tool for goat owners. This is based on increasing support from these people in their interviews, as well as the observable evidence- 60% of the goatscaping industry workers that I had a conversation with owning drones points towards majority acceptance of these tools for the purposes of monitoring plants that goats graze upon.

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