9H SmartRanch™
Viability of Autonomous Drones in Ranching

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Executive Summary

Drones are uniquely suited to applications in farming and ranching due to the distances and rough terrain that ranchers must cover to do basic maintenance and checks on infrastructure. The last decade of development has made drones a viable tool to streamline ranch operations. The autonomous drone software, BeeFree Agro, was tested on the 9H Ranch outside of Laramie, Wyoming. The software tested three main use cases: cattle counting, infrastructure checks, and fence line checks. The tests found that the infrastructure checks worked very well, that there was room for improvement in the computer vision cattle counting program, and that the fence line flying program wasn't effective. The 9H Ranch's uniquely flat topography results in limited benefits from this drone system. However, there are many ranches with rougher, more jagged, more isolated terrain that would see some benefit. Lastly, we noted that certain factors, such as the local topology and ecology, cellphone and Wi-Fi connectivity, and what chores need to be done in the field, play a key role in determining the viability of this drone system.

9H SmartRanch™: Ranching in 2023

Ranching is hard. The hours are long, the work is tough, and the margins are slim. It's especially hard for small ranchers, who face all the challenges that any rancher faces, without the resources that large ranches have. It is for this reason that many worry that small ranches are going extinct: larger ranches are able to outcompete and buy up small, often family-run, ranches. It is no understatement to say that ranching is the west: it is our culture, our heritage, and to some hard-working men and women, our livelihoods. It was this vision that inspired the folks at the 9H Ranch to look for ways to make ranching more efficient. Gene Humphrey, the founder of the 9H Research Foundation, a sponsor of this project, once told me, "I don't want

to see one corporation own every acre of ranch land in Wyoming. If we don't figure out how to make ranching more economical, someone else will. And that's how small ranches will die out".

Today, technology is changing the future of ranching. While not new, tech today has the potential to make leaps and bounds towards making ranching more efficient, more sustainable, and more viable. In farming, we've seen tractors that can almost entirely drive themselves, and use satellite imagery to optimize crop rotations. However, these technologies are just the tip of the iceberg. Ranching is more difficult: livestock are unpredictable, and the terrain on many ranches is more challenging. Despite these constraints, ranching is undoubtably ripe for innovation.

There are many tasks in western ranching that are perfect candidates for automation. Many tasks are tedious, time consuming, and yet ultimately aren't "hard." For example, working in many pastures requires spending more time getting to the worksite than the actual work. Or worse, many hours are spent simply checking on infrastructure. Broken fences, open gates, empty water tanks, and clogged canals can all be devastating to a ranch, and yet can go unnoticed until they cause a mountain of problems. Today, miles of fence line need to be walked or driven, and stock tanks need to be checked manually by hourly workers.

Recent advancements in technology have made drones viable for productive use. Drones are themselves a technological marvel, whose full potential is still being uncovered. Imagine if a rancher started at sunrise, and by noon, every mile of fence, and every stock tank on a ranch could be checked, and every head of cattle accounted for. Tasks that used to take weeks could be done in hours and checked remotely. It's hard to understate the potential this technology has to make life easier, *if implemented right.*

Noam Azaran is the co-founder and CEO of BeeFree Agro. BeeFree is a drone software company started in Israel, whose software, named "Joe" after an old farm dog, flies autonomously, and images ranch land to make life easier for ranchers. Joe can count cattle in a pasture using the "Find My Cow" (FMC) feature, can scan infrastructure like gates, stock tanks, and water troughs, and can fly fence lines. Not only that, but it can also do all this autonomously. That means while the drone is flying, the rancher can be doing other work, or even eating his morning breakfast or spending time with his family.

Joe is designed by ranchers, for ranchers. As a result, it is incredibly easy to use, no drone experience required. The first step is to create a map of a ranch on the BeeFree Agro console from a laptop, tablet, or smartphone, and add any important infrastructure. Then, out in the field, all one needs to do is select the appropriate field, and the drone automatically flies, takes pictures and returns to exactly where it took off from. All without any user input. This study tests the capabilities to check stock tanks, count cattle, fly fence lines, and count hay bales.

Automated Stock Tank Checking

Checking the stock tanks may just be the most useful thing that this drone can do. The 9H Ranch has dozens of active stock tanks, and dozens more that are old and dry. After a little testing, it was found that the software works perfectly.

The most difficult part is the setup, because in order to "add" a tank into the software's map, the tank must be manually found on Google maps, which can be difficult. Often though, especially on older tanks, not only is the tank visible on the satellite image, but cattle paths can actually be seen to and from the tank, helping to locate them. Next, the "photo angle" must be specified, which sets how far away, how high up, and from what angle the drone takes the picture. The software allows the drone to get plenty close enough to get a clear picture of the tank. From there, it's very simple; open the app on the controller and select the tanks that need scanning. Then, the drone automatically flies, takes pictures and comes back.

This feature is the most easily integrated into a rancher's day-to-day. Dry or frozen tanks have big impacts on livestock health, and checking them can be a time consuming, tedious task. From the 9H Home Ranch, a drone can reach about 15 active tanks. In the summer months, this would streamline operations and provide an assurance that everything is running smoothly. In the winter, this saves the rancher from having to go out in subzero temperatures to check which tanks froze overnight.

Find My Cow

Checking on the cattle is an everyday chore for many ranchers. BeeFree Agro's "Find My Cow" feature was built to help ranchers automate this chore. This feature autonomously flies and scans a chosen pasture. Then, it analyzes the flight and identifies any cows that it saw. It then gives a count of where and how many cows are in the pasture.

This feature has limited value for a mostly flat-pasture operation like the 9H Ranch. First, the drone itself has a limited range. As a result, to fly a pasture larger than about 1.5 square km or ~370 acres, multiple batteries are necessary. Therefore, for many pastures, an accurate count of the cows is impractical. It is simply too easy for a cow to walk in and out of the drone's flight path, and either be double counted or skipped altogether. It takes time for the drone to return home to replace the battery with a fresh one, or to let the battery charge before replacement.

However, perfect accuracy is not always necessary for this feature to be useful. Often, an exact headcount is unnecessary. More important information is a general understanding of where herds are, whether the cattle are huddled together or spread out, if they are grazing the same spot or if they are moving around, etc. Although dependent on ranch topography, this same task can often be done from a truck for many of non-mountainous pastures. Although it may be helpful to have a bird's eye view of a pasture, many flat-pasture ranchers may not require a relatively more complex drone-based solution.

The software might be improved by allowing the user more control over the flight path, resulting in the ability to fly only specific areas of a large pasture, focusing flight efforts where the cows are located. Currently, once the pasture is defined in the console, the program decides how to fly the whole pasture, with no input allowed. In the current version, the only way to fly a smaller portion of a large pasture is to setup and define an entirely new pasture. Scanning a pasture larger than about 370 acres, with the Find My Cow feature forces the drone to scan the entire pasture, sometimes requiring multiple batteries and upwards of an hour. Recently, BeeFree Agro has made some changes to make it easier to only fly a portion of a pasture, by both allowing overlapping fields and letting the user create a new pasture directly from the drone controller in the field.

BeeFree Agro's software works by flying a pasture, and taking pictures of the ground as it flies. It then analyzes those pictures. The pictures it takes are from a bird's eye view, the photos look like a high-resolution satellite image. "High-resolution" is a relative term, since the drone flies about 60m-100m high. The photos are viewed through the BeeFree console, which pins the pictures to a Google maps interface. This results in a few issues. First, it's difficult to orient oneself when looking at these pictures, so after a while, every photo begins to looks like "just another picture of cows in a pasture." However, a more significant issue is that the drone must be connected to Wi-Fi to set up a mission. This means that for remote pastures where Joe would be the most helpful, the drone can't fly without having pre-loaded the mission beforehand.

The accuracy of the "Find My Cow" feature is good, but not perfect. During testing, it incorrectly identified a number of things as cows, such as prairie dog holes, bushes, stock tanks, trees, trucks, and even a cow's shadow. Midway through testing, BeeFree Agro updated the algorithm, yielding a definitive improvement in cow counting accuracy. As BeeFree Agro continues to update their software, the accuracy will improve.

Fence Line Flying

One of the most promising features that was tested was the ability to fly a fence line. If perfected, the ability to fly a fence and find breaks in need of repair could save thousands of dollars in man hours and potential cattle losses. However, the drone would need to be able to fly close enough to a fence see the fence wire, record high resolution images while flying at reasonable speeds, and do all of this with a very low error rate. If a break goes undetected, and thus doesn't get fixed, it has the potential to cause major damage. This technology does not seem to exist yet, at least for Wyoming 4-wire barbed fence posts. The drone simply must fly too close, and the resolution on the drone's camera isn't powerful enough to make out enough detail of skinny barbed wire.

BeeFree Agro's fence flying feature works by flying the perimeter of a pasture (where it assumes the fence line is) and taking pictures of that fence line. Using BeeFree's software, the altitude of the drone cannot be set, but the user can choose which side of the fence to fly. In

the current version, the drone flies about 40m high, and about 20m away. For reference, this is high enough to fly over high voltage power lines. At that altitude, the fence line cannot be seen. Fence posts are visible, but not the barbed wire. On one test flight, one part of the pasture had a complete fence, and the other part had no wire, leaving just the posts. From the drone imagery, there was no discernable difference between the "fences". Perhaps this feature works well for other types of fences, but is not currently useful for Western barbed wire fences.

Hay Bale Counting

BeeFree wants to develop a system to count hay bales, which would be useful for large ranching operations. For a large operation, knowing the quantity of hay bales allows ranchers to estimate how many they can sell and therefore accurately anticipate income. This could relieve some financial stress and streamline operations. Flying over pastures with thousands of Hay Bales gave BeeFree Agro data they will use to develop a new algorithm for a future feature.

Viability of BeeFree Agro's Drone Product

Ranchers want straightforward answers to questions like: "Is it useful? Is it cost effective? Should we buy this for the ranch?"

We tasked BeeFree Agro's Joe Software to count cows, check stock tanks, and to fly fence lines. Each of these tasks are regular chores for many ranchers, and so if Joe can successfully automate these tasks, Joe has the potential to make a significant positive impact on a rancher's day-to-day. With this "high reward" comes associated risk: if Joe can't complete the task consistently and effectively, then it may become a liability potentially resulting in cattle loss.

As established, Joe can quickly and easily check water tanks and can scan a field for cows. Using Joe to check infrastructure, not just water tanks, is simple, easy to use, and highly effective. However, Joe's drone vision system of identifying and counting cows will benefit from continued updates and testing. As discussed in this report, Joe can identify and count cattle, but does so with a high enough error rate to make it questionable. If a rough estimate of cows is all the rancher needs, Joe shines. However, for an accurate count of cows in a field, Joe is not yet reliable enough. Lastly, in its present form, Joe cannot fly a barbed wire fence line to check for breaks.

Alternatives

For each of Joe's features, there exists a viable alternative. In each case, there is the status quo, the BeeFree Agro solution, and a third option.

Infrastructure. Normally, a ranch checks its various infrastructure by sending a ranch hand out for manual inspections. This makes this task ideal to be automated, since sending a person out is expensive and wasteful. One alternative that the 9H Ranch has employed is a series of remote cameras. These cameras cost about $100 a piece and will send a live image of

the tank or other infrastructure to a rancher's phone. This is the ideal solution, but quickly gets expensive for the ranch's 50+ stock tanks. BeeFree Agro's Joe is a nice solution for this task, as it complete the stock tank check and can be used for other tasks.

Check on Cows. Traditionally, a rancher must go out and check the cattle in person. This, again, costs time that could be better spent elsewhere. However, there isn't as clear of an alternative. If a rancher wanted to make this task easier, their best bet would be a drone. Drones can fly over rough terrain and give a bird's eye view over the cows. However, Joe may not be the best solution for all ranchers. The high upfront cost of the drones that Joe is compatible with, as well as the monthly software subscription, encourages a rancher to pilot a less expensive drone without the BeeFree Agro software. However, without the BeeFree Afro software, the rancher is forced to manually fly the drone and has to pay close attention to get a good look at the cows. As discussed, Joe can give a rough idea of where the cows are, and how they're behaving, but Joe can't give an exact number of cows. Despite this drawback, Joe does have a few sizable advantages over the alternatives. Joe is totally autonomous, meaning that the rancher can do other work while the drone flies. Further, the cattle counting algorithm in conjunction with the BeeFree Agro console gives an easy way to get a bird's eye view of a pasture. Lastly, Joe creates something that no other solution presented can: Joe can allow someone to remotely verify what's happening on the ground. This could be a ranch manager, a family member, or a shareholder, any of whom may not be present on the ground at the ranch but may want to see for themselves what's going on. Ultimately, BeeFree Agro's cattle counting solution isn't a perfect solution, but a viable tool.

Cost

The most important factor in determining the viability of BeeFree Agro's solution is the cost. Ultimately, the goal here is not to develop the fanciest, most high tech, solution to a rancher's problem. The goal is to find the solution that best saves the rancher time and money. To get a picture of BeeFree Agro's overall effectiveness, we'll compare the cost associated with the tasks that BeeFree's system can automate to the cost of the whole BeeFree Agro System.

First, the drone itself, the Mavic 3 pro with a thermal camera and smart controller, costs about $5,500. Next, extra batteries will be needed: the 3-battery combo with a charging station costs $670. Lastly, the BeeFree Agro software costs $99 a month. Assuming a drone lifespan of approximately 5 years, and a battery lifespan of about two years, flying every day, the total cost is roughly $219 a month.

By comparison, a typical ranch hand is paid $12 an hour. For the same price as the BeeFree Agro system, a ranch hand could be hired for just over 18 hours a month, or about 4.5 hours a week. For many of the pastures on the 9H Ranch, that hand could probably accomplish what Joe does in that time. That accounts for the time it takes for that hand to drive out to the pasture and simply observe the cows, not including any other tasks they might do in the field, nor the gas or equipment cost. It is important to note as well that while a hand is in the field,

they can readily fix any problems that they see, or do other chores that need to be done in the field. Currently, for the 9H Ranch, BeeFree Agro's system does not justify the cost.

For the 9H Ranch specifically, the investment cost of the full system is too high, and the alternative is currently more appealing. As previously stated, the 9H Ranch's land is very flat. Except for a couple of pastures, one could check the cows from the side of the road, and most of the stock tanks are accessible by truck. For this ranch, a ranch-hand can accomplish Joe's tasks in the budgeted 4.5 hours a week. Further, it makes more sense to have a hand do other chores while they're out in the field, such as putting salt blocks out.

However, not every ranch in Wyoming is like this. Many ranches have hills and mountains. Some ranchers lease national forest or BLM land. In some places, labor is more expensive. Any of these factors can make Joe more appealing, but ultimately, the decision will come down to the specific circumstances of a particular ranch. There are undoubtedly ranches in Wyoming that would find value in BeeFree Agro's product.

Investing in an autonomous drone system isn't perfect for every ranch. There are several factors that need to be considered for Joe to be viable. Can the ranch afford the upfront cost of a drone? Is there enough wi-fi or cell phone coverage for Joe to function on the ranch? Are there flight restrictions on the land? Does the ranch regularly put salt blocks or other feed out to the cows that requires someone to be out with the cows? A Ranch's answer to these questions will determine whether a drone could be useful for them. No two ranch operations are the same, and all these factors must be considered when deciding if an autonomous drone is the right answer.