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Boundaryless boundary-objects: Digital fencing of the CyborGoat in rural Norway

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ABSTRACT

This article describes a case study of virtual herding and digital fencing technology implementation for goats in Norway. With the abolishing of physical fences, the goats can roam free in a physical sense, but in the digital realm, they are controlled by a virtual fence. The virtual fence, or digital boundary, is set by the famers and interacts with a collar around the goats' necks. The collar first give a sound signal and thereafter a small electric shock if the goats cross a boundary, resulting in the creation of new classifications and orderings of reality. This article focuses on what this disruption means for contemporary goat farming in terms of practices, perceptions and policies of (smart) farming, as well as how the goats themselves are given new meanings and ways of being. We analyze this with the theoretical concept of "boundary object" and see how goats, which contain a multiplicity of agency and autonomy, are transformed by smart-farming technologies. Collaboration and interaction are made possible despite the fact that the actors have widely different goals. Through negotiations between multiple actors, a new type of goat emerges between nature-, culture- and technology. We conceptualize this as "CyborGoat." This boundary object facilitates new everyday agricultural settings, which brings new benefits and issues for different stakeholder actors involved.

1. Introduction

This paper is about a particular boundary object—goats enhanced by and through technology—who, in contemporary Norwegian society, are facing a radical ontological restructuring through digital fencing. Through our case study of digital fencing, we address the development, governing, and implementation of new "smart" technologies in modern agriculture by exploring cyborgification of livestock animals. How can we understand the goat as socio-constructed between nature, culture, and technology? To understand such a change, we explore how, as the digital-mediated governing of agriculture gains momentum, governing policies can change and be modified in response to the technology's socio-political importance. When investigating how regulation-at-a-distance is done, it is important to study how policymakers shape agricultural technology by policy and how those policies are in turn shaped by the technologies they govern. To investigate this, let us first look at the new practice of digital fencing in the agricultural sector.

Digital fencing of livestock, also known as virtual herding, is a relatively new phenomenon and has not been widely studied. In recent years there have been some studies testing virtual fence technologies on livestock animals (Brunberg et al., 2015; Kearton et al., 2019; Lomax et al., 2019; Marini et al., 2019; Umstatter et al., 2015; Verdon et al., 2020), but there is a lack of social scientific points of view. Virtual herding is part of a larger shift in modern farming practices that is most popularly called "smart farming" (Vate-U-Lan et al., 2016). Related concepts in the literature are "precision farming" (Daberkow and McBride, 2000), "data driven farming" (Bolman, 2016) and "digital agriculture" (Van Es and Woodard, 2017). A common feature is the use of sensor- and monitoring technologies to support farming practices while at the same time generating and systemizing data from the various farming operations. According to Gralla (2018), there will be an average of 4.1 million data points generated per farm per day in 2050. The expectation is that this will lead to major changes in what it means to be a (digital) farmer. Smart farming and the automation of agriculture holds the potential for optimizing practices and processes of farming (Carolan, 2018), but they also hold the risks of surveillance, data storage, and privacy issues (Klauser, 2018). Some hold that there is a growing divide between the "smart farms" of the future and the "not-so

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smart" farms of the past (Roberts et al., 2017; Salemink et al., 2017); in pressured farming sectors, adapting could be key to economic survival.

Digital fencing, because it reduces the need for traditional fencing and human-control alone (e.g. by traditionally employing herders), allows for an increase of farming in the outfields and mountains, In Norway, the fragmented and hilly nature of agricultural land (Forbord et al., 2014) made fencing an important, but labor demanding practice in traditional farming. Since WWII, the prevalence of grazing in outfields has gradually decreased (Austrheim et al., 2008), therefore farmers have, to an increasing degree, stopped doing traditional fencing. This is partly emblematic of a trend of structural concentration with fewer and larger farms, but it is also a consequence of a political economy where labor is scarce and costly (Vik, 2020). Consequently, pastures and outfields are left out of production. Therefore, virtual fencing is framed as a technology that has the potential to fix some of the flaws of modern agriculture, while advancing smart technology and digital fences connect discourses on digitalization and new technology with discourses on the utilization and conserving of cultural landscapes. Two of the farmers that use the system claim that "This (the Nofence system) make it possible for us to utilize our resources utterly, on places where it is expensive and almost impossible to build a traditional fence. It is a revolution for agriculture" (Nofence, 2020). This aligns with emerging topics of Responsible Agricultural Innovation (Bronson, 2018, 2019; Carolan, 2020; Klerkx et al., 2019), which builds on concepts from Responsible Research and Innovation for agriculture technology (Rose and Chilvers, 2018).

Our focus is specifically on the development and diffusion of smart-farming solutions with a particular virtual fencing technology for goats as a case study. Goats have been domesticated by humans for over 10,000 years and are a common sight in many agricultural regions of the world. Domesticating goats is not straightforward. Goats are both agile and intelligent beings, and they learn quickly. So confining them in a fence can be quite difficult, as they will often mangle, tear down, or, if it is not high enough, simply jump over the fence. Goats are expert "prison-breakers."

In this paper we investigate the intricate relationship between goats, humans, and novel smart-farming technology—which come together in the concept we term the "CyborGoat"—a product of nature-culture-technology. Unwrapping this concept includes looking at the process of developing the technology. This entails examining the political and organizational aspects of the development and implementation process, whereby we also address the interaction with authorities that have made possible the digitalization and governing of goats in Norwegian agriculture. In addition, we look at how smart-farming techniques intervene in the control and regulation of everyday farming practices and what benefits and problems arise in regard to this. In order to explore this, we first give a case description of "Nofence"—the innovative system that we have studied— as well as the goats in question and our methodological choices. We then explain our theoretical framework of "boundary objects," which gives us three distinct points of departure for our analysis, seeing the "interpretive flexibility," the "structural needs and arrangements," and the "dynamic between different uses" of the new technologized goat as a boundary object. We conclude with a discussion of the cyborgification of husbandry.

The technology studied in this paper is a specific brand of virtual herding technology called "Nofence" made by a small Norwegian company called Nofence AS. The innovation company was started in 2011 with, as one developer said in an interview, a vision "to contribute to making better use of outfield areas and increasing the wellbeing of animals by giving them more agency and less restricted space to move in." Nofence works by applying a collar to a goat containing a beacon for sending and receiving signals by satellite running a 4G network. The unit contains a battery and a Bluetooth unit in order to find the device should the GPS malfunction due to, e.g., batteries falling out of their sockets.

The farmer sets a digital boundary on the system's app, thus making a virtual boundary for where the goats can—and cannot—roam. When a goat wearing the collar ventures out of the designated virtual fenced area, a beeping sound will start. If the goats move further out of the area, it will increase in volume, and, after the third and loudest note, the goat will be provided with a small electric shock. This prompts the goat to run back quickly the way it came. The farmers have full access in their apps to see which goats have received what number of sound and shock triggers and can thus follow up with goats who get an unusual number of triggers. As the digital herding technology represents a quite novel innovation in Norwegian agriculture, the company has been given substantial media attention.

2. "Boundary objects" and "cyborgs" as theoretical perspectives

For many decades, Science and Technology Studies (STS) has been opening the "black boxes" of technology, arguing for a social constructivist understanding of how technologies are produced and implemented as intricate social processes between producers, users, policymakers, and human and non-human actors (Latour, 1987). This approach challenges technological determinism (Bijker et al., 1987). Balancing the sociological debate around structure and agency, STS allows for a heterogenous "flat" analysis of technological objects in coexistence with humans and non-human actors (see e.g., Aradau et al., 2019).

Many STS programs, studies, and projects are predicated around the non-neutral position of technology understanding, i.e., a technology might have vastly different implications for different people and groups. This becomes particularly poignant with the term "boundary object," which is a suitable term for the study of goats meeting virtual fences and which will be our main avenue of theoretical departure.

Susan Leigh Star introduced the term "boundary object" in 1989, defining them as "objects that are plastic enough to be adaptable across multiple viewpoints, yet maintain continuity of identity" (Star, 1989, p. 37). Thus, collaboration and interaction between multiple actors with stakes in what the boundary object should "be" and what it should "do" is made possible despite the fact that the actors have widely different goals. This concept has become highly influential and is most often used to explain interpretative flexibility of an object or phenomenon (see e.g., Betzold et al., 2018; Hoogstra-Klein et al., 2017; Konefal and Hatanaka, 2011; Teil, 2012; Vik and Villa 2010).

Star (2010, p. 601) later revisited and refined the concept, saying that boundary objects have three main characteristics: "(1) interpretive flexibility, (2) the structure of informatic and work process needs and arrangements, and, finally, (3) the dynamic between ill structured and more tailored uses of the objects." This refinement was necessary because many scholars only applied the first part—interpretative flexibility—when using the term while disregarding the two other components, thereby taking away the full theoretical weight of the concept and turning it simply into justification for multiple interpretations. It is worth noting that this can also be seen as a critique on scholars who, when they apply boundary objects as an analytical tool, often focus overly on "agency" (the interpretative flexibility) and less on structure – which we take to mean the social arrangements and situatedness of the object. Structures are important to understand how users (farmers in this case) adapt to the technology, how policymakers situate innovation into existing legal, i.e., structural, frameworks, and, of course, the limitations that both technology and nature have on the actual development possibilities seen from the developers' side. Structures are necessary for dynamic discussions and interpretations to take place; for a boundary object to change, the ramifications of what it can change from and what it can change into help build a common framework with which to (re) shape it. In our article, we have thus built our discussion to touch on all three characteristics for boundary objects identified originally by Star: (1) interpretative flexibility of the technology; (2) the structural arrangements of the technology, and (3) the dynamic between different uses of the technology.

Animals have been investigated from multiple angles in STS. While humans have shaped and changed the ontologies of animals through domesticating them, animals have also changed us, as Swanson et al. (2018) note. The way we live and interact with nature, technology and human culture is inseparably connected. Haraway (2016) argues for a holistic understanding of ontological inquiry, and by seeing the world through a lens of multinatures (Latour, 2012; Lorimer, 2012) we can better understand this entanglement.

We thus build on the theoretical concept of cyborg-theory to highlight this inseparable connectedness between nature, culture, and technology. In her "Cyborg Manifesto," Haraway (1990, p. 191) described a radical new way of thinking about nature-technology connections, through her conceptualization of the cyborg as: "a cybernetic organism, a hybrid of machine and organism." Cybernetic organisms are mashups of technology and biology, and, although Haraway's cyborg was used primarily as a semiotic discourse inquiry set within critical feminist studies, it can give insight into how we think of—and define—the goat in contemporary, past, and future society. Cyborg-theory has been used in a wide variety of ways for understanding agricultural practices, see e.g., Tulloch's (2016) argument for how becoming a cyborg enforces vegan ideas, or the weaponization of animals through insect cyborgs (Salter, 2015).

3. Methodology

This paper draws on a larger study of emerging novel digital and robotic technologies for Norwegian agriculture investigated through a mixed method approach. In this paper, our primary data source is interviews and observations related to the Nofence technology and its users and producers. We conducted qualitative semi-structured open-ended interviews with three of the producers/employees of the technology company as well as eight farmers who are active users. These interviews included questions on how the technology is impacting and potentially changing their ways of farming. The farmers had a variety of backgrounds, ages, and genders, as well as herd sizes—ranging from a dozen to over 100 goats in their herds. Most interviews lasted several hours and were followed by observational trips to their goat pastures. The interviews were transcribed verbatim and anonymized. The interviews are supplemented by ethnographic observations of goats in rural areas, seeing how the technology affects them. Our study also draws on secondary material of white-papers, official documents, legal assessments, and technical manuals which were involved particularly in the implementation and approval process Nofence AS undertook to legitimize the technology.

4. The new goat as boundaryless boundary-objects

The goats at the center of the study are, on the one hand, an ancient domesticated object of the Anthropocene. Bred for meat, fur, milk, and other raw materials harnessed in the goat body itself, it is certainly a being of nature. But, on the other hand, the goat also embodies human culture: the domestication breeding process has for thousands of years selected goats that give *more* milk, *more* meat, and *more* of the goat qualities humans have deemed important. Generations of domesticated goats and generations of human farmers have been interlinked in socio-material networks, where the farmers have not simply used the goat, but have also *constructed* it through a domestication process, thus changing the animal in the process (Swanson et al., 2018).

A goat is both nature and culture, and, undoubtedly, it is part technology. From ancient times goats have been used to drive human technology development through agricultural inventions and new ways of using the natural landscape e.g., by goats grazing to keep nature from taking back its domain fully. However, with new digital technologies, we are seeing a new "pathway of the goat." To explore this, in the following three subsections we explore the goats and this technology in connection to Star's (1989) three definitions of boundary objects to show that, by implementing the Nofence technology, farmers are enabling the creation of a new type of technologized goat as a boundary object – one without physical fence boundaries, but with digital boundaries. Is the goat then boundaryless, or are new boundaries drawn?

4.1. *Interpretive flexibility of the CyborGoat*

The understandings of what the Nofence technology is have developed over time and are also different between various human and non-human actors, especially for the goats themselves. As a first step towards understanding how fencing technology is negotiated, we must negotiate what a goat is. To do so we draw on the concept of boundary object to see the structure of information and work process, needs, and arrangements, and the dynamics between these in developing and implementing the digital fencing technology for goats. For Nofence, this officially started in 2011, but the story goes far back to the 1990s when the inventor of the technology developed his idea:

> The idea to fence animals this way stems from my childhood, where I grew up with a very, very large lawn where we had goats, lambs, pigs and rabbits roaming. It was just cozy to be on that lawn, with no work to do, and to be with the animals. Later, when I studied in a large city, I thought "what if we had rabbits jumping along in the university-park, instead of lawn-mowers? I've thought about this for a long time, and after GPS became more commonplace, I thought "aha, there is the technology I need to realize my idea!"
>
> Developer, Nofence

However, one person's vision is not enough to realize major technological change. For others to see the technology as feasible, financial support was needed. This was partly made possible through good collaboration with the local municipality and industrial clusters in the area. In 2007, the inventor received €2000 from Innovation Norway—a public organization that promotes and finances innovation projects—to conduct a market analysis on virtual fences. However, this was described as quite a frustrating process. The funding body wanted to know how much the farmers wanted to pay for such a technology. They saw it as a commodity, whilst the farmers that participated in the market analysis wanted to talk about how the technology could help them without putting a specific price on it. So, "this was completely useless as a market analysis" (Developer, Nofence). However, most farmers interviewed found the technology to be quite a good idea ("if it works") and thus recommended the innovator to continue with their projects.

The major hurdle for the project turned out to be on a political level. The Norwegian Food Safety Authority NFSA (NO: *Mattilsynet*) was worried about the animal welfare aspect of the technology and was not easily convinced. The first meeting with them could have ended in a disaster from the developer's perspective:

> We had a meeting with NFSA, and they were super-skeptical about this. And we just went on stating "this can bring the sheep down from the mountain, and have several great opportunities, if we can get it to work." And that was not a good idea, as it led NFSA to think that here they deal with something invisible and an electroshock attached to animals, and this maniac does not seem to know what he is doing. So, this does not seem ok … After that feedback, we had to change our approach, to "we are not all the way yet, but step by step, we can make it work." So, I learned to be more modest and communicate better with policymakers.
>
> Developer, Nofence

Based on their own mandate (which they describe as a responsibility to "contribute to ethical keeping of animals and encourage environmentally friendly production, to draft legislation and provide guidance on existing legislation, [and to] perform risk-based inspections"[1]), the NFSA interpreted the potential technology in a rather different way than the developers. Here we see two quite opposite interpretations of the technology: one overly positive and one quite negative. While the developers ask what could go right and would be the best outcome, the NFSA—as is their job—focuses on what, from the goats' perspective, could go wrong. One of NFSA's main political governing documents is "Law 19. June 2009 nr 97 about animal welfare" (Lovdata.no) which in § 8, translated by the authors, states:

> "Keepers of animals shall ensure that operating methods, equipment, and technical solutions used for animals is suitable for safeguarding animal welfare. Anyone who markets or sells new forms of operation, methods, equipment, and technical solutions used on animals or in animal husbandry shall ensure that these have been tested and found suitable from the point of view of animal welfare. The King [de facto the government] may issue further regulations on the sale and use of certain forms of operation, methods, equipment, and technical solutions, as well as on approval and documentation of suitability."

While the regulatory framework provides a valid argument for animal welfare, there are obviously parts of the legal regulatory language here that are not suitable for the daily life of farmers. In 2016, the NFSA gave the following report (Det Kongelige Landbruk- og Matdepartment, 2016):

> "(1) The Norwegian Food Safety Authority considers that 'NoFence' as of today has not been sufficiently tested and documented in relation to the Animal Welfare Act. The use of electric collars for goats is not permitted, except under the direction of an approved animal experiment. (2) The manufacturer of 'NoFence' is ordered to inform the 78 participants in the pilot project on the Norwegian Food Safety Authority's assessment and conclusion. (3) If the local Food Inspectorate demonstrates by inspection that an electric collar is still used in violation of regulations, this shall be followed up."

In order to become successful, innovative technology must survive legislative and regulatory scrutiny. Therefore, although the flexibility of technological interpretations between developers and regulators can differ, they must align in some manners. The problem for Nofence was that the NFSA compared them to other types of technology that were considered rather unbeneficial. Their skepticism must be seen in relation to the idea of giving the animals an electric shock. In the dairy industry, there has been a years-long process of getting rid of another technology, the so-called cow-trainer, an artifact used to keep cow stalls clean by giving the cow a small electric shock if they try to defecate without backing into their stall. Some NFSA regulators probably thought it was a bad idea to introduce another technology that could potentially give animals electric shocks.

> They were afraid of giving the animals electrical shocks overall. Especially if the technology was not made well and shocks were constantly given. And that's a full crisis, right. Shocks to animals are stringently regulated, there are some solutions for dogs that are forbidden for example, and "cow-trainer" shock technology is highly regulated. They compared us a lot to these technologies...
>
> Developer, Nofence

It was therefore essential that the Nofence technology not be regarded as part of the wider frame of "evil shock technologies" that the NFSA had had to deal with previously. Before Nofence could become a real commercial product, the NFSA demanded major user-testing for it to be approved. This, according to the developer, was a rather long process. The Nofence developers wanted a rapid testing environment for their technology. They had goats, researchers, and technologists involved. If something was suboptimal with the technology while it was being tested, they wanted to take it back to the garage to fix it immediately. But this was not possible because the testing requirements dictated that all tests had to be completed before changes could be made:

> If I see that something is not working, I want to take the tech back to my office, fix it, and hang it on the goat the next day. But no, it had to hang there until the testing was complete. And then, the test project was over, and we had to apply to do yet another test project for the next year, where also everything had to be perfect and no changes could be made mid-testing—and this is if we manage to get the new test-project financed. So, it has been an extremely heavy process.
>
> Developer, Nofence

Technological interpretation and governance may depend on which political bodies are set to govern the technologies. In the case of the Nofence technology, one governing body was the "Animal Experiment Committee" (NO: *Forsøksdyrutvalget*). This committee was tasked with approving animal experiments and tests. They had a quite good relationship with the Nofence developer team; the team viewed them as fair in their treatment of experiment applications, while at the same time ensuring that animal tests were carried out in a proper manner. However, this committee was dissolved in the middle of the approval process, and their responsibility was transferred to NFSA, which had a much stricter approach. The NFSA was partly skeptical due to a case in Bergen, where Norwegian researchers had started a pre-project on cultural landscapes involving the Nofence goat-technology. According to the researchers, this was a project about the cultural landscape. According to the NFSA however, it was an animal experiment:

> The NFSA in Bergen viewed this as a professor doing animal experimentation, and as this had not been approved as an animal-experiment project, but rather as commercial use, it became problematic. From a developer side, we were done with the animal-trials, we were ready to start using it. But in the Bergen case, it was a researcher, new technology and animals involved. So, there was a misunderstanding that led to a horrible period, partly because this was a perfect case for the media.
>
> Developer, Nofence

From the farmers side, the new ways of being goat farmers through technology was crucial for allowing them to conduct such farming. Through our interviews with farmers, multiple understandings of how the technology impacted the life of the goat—but also their ways of farming were discovered. For example, one farmer told us how the technology saved the life of one of their goats:

> I discovered that one of my goats was separated from the herd, and she was very still on the map. I thought that either something is wrong with the technology, or something has happened to her. So, I went out to look, and found her in the forest, injured, probably by a lynx. However, she was alive, I saved her due to the Nofence. I would never have found her without it and would have to search the whole forest with a carrion-trained dog, but probably never would have found her.

For the goat, this life-or-death situation is heavily impacted by the technology, and for the farmer, it's also an economical question. A lost goat is lost revenue. For many farmers, being a goat farmer through Nofence was a side job to their main job that would not have been possible without the technology. Non-digital goat herding simply was, as the farmers in our study explained to us, "too time and resource demanding." As a boundary object, the new understanding of the technologized goat was interpreted differently by different actors. Farmers could see it as a cultural landscape tool. The Bergen professors were seen as researchers when they used the product, and thus the

[1] https://www.mattilsynet.no/language/english/about_us/.

governing forces did not interpret this as a commercial activity. We will explore the structural needs and arrangements of the boundary object further in the next section.

4.2. The structural needs and arrangements of the technology

The Bergen case soon blew out of proportion and became a prestige case of the NFSA to handle according to their (new) guidelines. As Leigh Star (2010, p. 602) writes, boundary objects have information needs and work requirements to structurally work as "stuff of action." Through the interpretations of the NFSA, the legal status of the (use of the) technology became a structural work requirement for the boundary object to constitute such a "stuff of action". For Nofence AS, it was seen as quite the trial, and something out of their control. "We decided that we needed to be very proactive with this" (Developer, Nofence). The problem worsened after the technology report written as part of the project was sent to a third party, the veterinarian institute, which decided that the documentation was not sufficient. This led to several intense board meetings for the young company that needed to hire a lawyer to "speak the language" of the policymakers and negotiate what should constitute this new way of using goats. The flexibility of the boundary object thus decreased considerably, before it could be widened. "We could not afford to be in a conflict situation with the NFSA. We cannot invite to a conflict, even though they do that. So, we had to step extremely careful when dealing with this" (Developer, Nofence). The newly hired lawyer, who framed the boundary object in a legal interpretation, thus expanded the interpretative flexibility of the technology, connecting it to a potential breach by the NFSA in the legislation relating to procedure in cases concerning the public administration (NO: *Forvaltningsloven*). However, a legal process was not a desired solution, as it could potentially draw on for a very long time.

The interpretation of the technology was thus locked in a potential legal dispute. Help came from an unexpected, higher power: The Norwegian Minister of Agriculture and Food. The Minister, who came from the same region as the company, decided to contribute to a solution. The day after his intervention, the company was invited to the NFSA Headquarters in the capital, where directors of major governing boards where present, and a polar opposite attitude was shown: "they told us 'of course we are going to make this possible, how can we solve this?' and that was like a brand-new start for us" (Developer, Nofence). Soon afterwards, Nofence received funding for further testing at the Norwegian University of Life Sciences—which also received funding for an "Industry-PHD" jointly funded by the university and Nofence. The parties agreed that valuable time had been lost in the slow bureaucratic process and were thus finally eager to test the new technology in the correct manner. The new goat reached a politically acceptable interpretative flexibility. However, there was still one major party that needed to be enrolled: the goats themselves.

The bureaucratic delays had let the seasons pass, and by the time the new testing could start it was already winter. "We then saw that the goats were not interested in walking out in the snow to test the product" (Developer, Nofence). But, after the passing of yet another season, the product was tested on goats to the satisfaction of the political actors. The developers and the regulators had different interpretations of what this novel coupling of goat and technology could imply. Bringing in another actor: the Norwegian famer—the end user of the product—and considering their acquisition and implementation of the technology, can give further insight into structural needs of the technology-use on the goats.

Anderson et al. (2014, p. 25) are concerned about how "maximizing the benefits of virtual fencing will require a paradigm shift in management by using virtual fences as a 'virtual herder' rather than simply as a tool to manage livestock within static physical barriers." This shows how a transition or shift in thinking and planning is required for full scale changes; it requires cognitive rather than manual labor. In order to make this happen, the farmers need to be enrolled. By exploring them and their acquisition and implementation of the technology, we may study the structural needs of the technology-goat.

According to Nofence, the average farmer-customer ordered four collars (although the largest order was in excess of 30). As of writing, the price for one collar is 1850 NOK (€180), and the cost per collar decreases as more collars are bought. Although most customers are close to the company's headquarters in western Norway, they are spread over the country, including some in the northernmost parts. The developers have nicknamed the average user as "hobby-users":

> We have customers with larger herds, but the package we sell the most of is the four-collar package, which isn't a lot. So, the farmers often start with that one, and then they might expand after a while. These "hobby-users" might discover that they can rent out their goats and make a business out of that.
>
> Developer, Nofence

In Norway there is no tradition or business practice of using full-time herders. For the hobby users, both the building and keeping of large-scale fences would require too much time, materials, costs and manpower. With virtual fences however, the situation is changing. The virtual fences allow the farmers to go into goat-business with much less resources. Anderson et al. (2014, p. 25) predict that when virtual fencing "becomes a commercial reality, manual labor will be replaced in large part with cognitive labor for real-time prescription-based livestock distribution management that is robust, accurate, precise and flexible." This remains to be seen, but a key structural need of the new goat-technology is its usability, both as technology around the neck of goats, but also as mobile phone app technology for the farmers.

For many farmers, it was crucial for their existence as a farmer to have access to this technology, as it allowed them to be pluriactive or diversified: to be goat farmers *in addition* to their main job, which was often something completely different. For example, the goat farmers interviewed for this study worked as craftspeople, veterinarians, in politics, or were retired. Being a goat farmer was thus made possible as a side-gig due to the accessibility of the technology. This way they could sit and follow the goats' movements from somewhere far away—even when they were on vacation and hired help, thus control from distance was made possible. Additionally, digital data infrastructures are key. Good internet coverage, satellite signals, mobile data coverage are all imperative for the technology to work—but this was seldom mentioned as an issue for this Norwegian case as coverage is quite good. A Bluetooth solution is also implemented as a back-up solution if satellite signals or battery life should fail.

4.3. The dynamic between different uses of the technology

The technology in question has quite different uses. For the developer, it was important that the sound the collar gave would not be similar to other sounds in nature, so that it was crystal clear for the goat why and what made the sound. In the process, other solutions were also investigated such as Anderson et al.'s (2014) investigation of rattlesnake sounds in relation to cows. This was not seen as an optimal suggestion, as cows are afraid of the sound, but see through the trick quickly. Additionally, rattlesnakes aren't found in Norway, so Norwegian animals have no experience with them. Also, when the speaker system was chosen (primarily due to very low cost) it only emitted one sound—so the choice was simple (Developer, Nofence).

Although humans are governing, buying, and placing the technology, the goats are also users of the technology. The goats who use Nofence use it in widely different manners, learn how to use it, and then develop new ways to use it. This can be illustrated with how some goats, according to our informants, developed an understanding of the quite complex "GPS-shadow":

> The goat understood that by laying low and crawling next to an old stone-fence by pushing itself forward, it could escape. She

understood she was free, when she didn't get sound signals or electric signals. There have been a couple of those instances, so the goats, they are really smart.

Interview, developer

Previous studies, e.g. Despret's (2016) "What would animals say if we asked the right questions?" warn against simplifying animals, arguing that we should use animal ontologies to add to human knowledge, rather than using pre-defined human epistemologies, similar to what Swanson et al. (2018) explore in "Domestication gone wild." This is similar to our findings of goats not behaving "as scripted" in the technologies and to human farming practices, but instead acting as living creatures of own agency that do what they want.

The technology was also understood differently in different regional contexts—as further explained by the developers: Irish customers were mostly interested in the potential rotation-farming, while Germans—because of wolf-problems—where interested in how it could be used to have better alerts when wolves came. Americans, on the other hand, were extremely profit oriented and were interested in whether the technology could cut costs or increase revenue. Neighboring Scandinavian countries, however, "got it" immediately, as they have similar issues with the use of outfield resources.

The dynamics of using the technology was also quite apparent in how the different farmers adapted and used the technology. Yet, a techno-nature-culture dynamic between different uses of the technology had to be settled, as can be seen with an interview of a farmer:

> It's a learning process, the goat has to understand that something is happening. When the beeping sound comes, the goats have to understand that if they turn around, they are safe. The goats realize this pretty quickly. But it is a learning process that demands a lot from us too. Sometimes when the goats are moved from one pasture to another, they think they have to run back to the previous "safe space," not connecting the sound to the new place. And, one time, the whole herd collectively decided to run off, disregarding the beeping altogether!

The farmer shows that there are new ways of dealing with goats, as they have to be taught how to use the technology, and to "make them settled" in new technology-governed digitally fenced spaces. The farmer, however, told us that their goats learned from older goats how to properly use the technology and that a lot of habitual knowledge was being transferred from the older and more experienced doe "users" of the technology to their kids.

As we described, The Norwegian Food Safety Authority was initially quite worried about the potential electric shocks of the technology, which needed to be negotiated to a common acceptable level from both the producer and the user side. One mutually agreed upon criteria that makes the boundary object possible was the desire that there be as few electric shocks as possible. The regulatory bodies were especially concerned about excessive shocking. However, following thousands of hours of usage, this worry did not come to pass, as the case of one farmer's "musical-goats" below show:

> When I got the technology, I wanted to test it in my large backyard. The southern side had very good vegetation, and the northern side was not so delicious to graze on, but that was the side I needed the goat to trim by grazing. But the goat quickly realized that she had 8 s from when the sound started before she would be shocked. So, she developed a technique of running from the northern side over to the southern side which triggered the sound effect, gobbled up all she could, then ran back to the northern side before the shock came. I was standing on my balcony and observed this, and during the one day this happened, she ran over and triggered the sound 122 times, and got only one shock. It's really easy to train the animals if you do it correctly; goats are smart animals.

For the technology to be used optimally a new constellation of the goat was required where nature meets culture meets technology, as we will discuss below.

5. Discussion: digital control and the emergence of CyborGoat

The boundaryless boundary objects we have studied—the goats enhanced by the technology that herds them—are made possible through negotiations. As part nature, part culture, and part technology all mashed up in one, we propose the CyborGoat as a being transcending traditional understandings of what a goat is—creating new pathways and possibility for goat and goat farming, conceptualized in Fig. 1 below:

This new type of goat-farming through technology we here conceptualize as a CyborGoat-boundary object. By imbedding technologies such as virtual fences, technology enhances nature; but this is co-creational, as nature enhances technology back. The technologized-goat thus is a cyborg of some sort—a mash-up of nature, culture, and technology—negotiated as a boundary object between different actors. As our informant farmers have told us a, goat familiar with Nofence technology is more valuable than a regular goat—some farmers even see this skillset of using the technology as so important that they delay slaughtering the goats for meat and prefer to keep them as precision grass-eaters instead.

One farmer we interviewed rented out their goats to a local power-line company, so that the goats could eat in a direct line under the powerlines—thus reducing the need for maintenance in areas where the infrastructure is threatened because of overgrowth. These goats had an important *job*, thus transcending the animals' primary job as getting fat to get eaten, eat grass to provide milk, or to reach a max height so that their fur can be skinned from their bones and sold. The goats in question were thus worth more alive than dead. This, in a cyborg-theory sense, could imply that, through technological enhancement, the goat was now inseparable from the technological network it finds itself in. This is notable from an economic point of view, where most of the farmers were quite frank in saying that without virtual herding, they could not have had goats, as the time and costs with traditional farming would not be cost-efficient.

Notably, a boundary object is not a static entity, but in constant negotiation and change. The goats obviously changed, as they needed to

Fig. 1. "The CyborGoat" by Nienke Brujining.

change their daily practices, e.g. on where to graze, for how long, and to adapt to running back if they heard luminous sound signals. The culture, here represented by the farmers and their built environment, also changed. New areas that were previously impossible to fence in a sensible way became accessible for grazing, creating a new manner to govern the culture landscape and thus changing nature back. Additionally, the technology was not a static entity, but did, and continues to, improve, change, and be tested. For example, the straps around the collars of the goats changed in material design, as some material types were proven to be insufficient for some goats by digging too deep into their necks. These changes happen in the relation of animal and human, but also in the nexus of the natural world—the pastures cultivated by humans where the goats roam—and the virtual world where the goats can be followed online. Thus, nature, culture, and technology together are co-creating the boundary object of the CyborGoat.

The new being, the CyborGoat, emerged as a consequence of it being a boundary object, as the interpretative flexibility of the technology provided an opportunity for the goat to be part nature, part culture, and part technology. Collaboration and interaction were made possible despite the fact that the actors had widely different priorities and goals for what a modern goat using technology should be like. If the Norwegian Food Safety Authority did not change its regulatory stance, the CyborGoat would have been an illegal creature, without digital fences. If the farmers did not jump into testing—and eventually buying—the technology, the culture would not be there for a CyborGoat. As Leigh Star (2010, p. 604–605) describes: “When necessary, the object is worked on by local groups who maintain its vaguer identity as a common object, while making it more specific more tailored to local use within a social world.”

The structural arrangements thus had to be in place to facilitate its creation, especially through local groups and tests, who could tailor it to the legal-structural requirements of e.g. animal welfare, as well as technological structural adjustments. GPS technology that could pinpoint were the goat was located in a precise manner was crucial. So was the feedback that the company gave and continues to provide for the farmers who keep CyborGoat herds. The intricate dynamics between different uses of the technology is also what keeps the CyborGoat in the boundary. For some it is a way of mowing underneath powerlines. For others it is a way of keeping goats safe from dangers so that they can grow big and fat. And for the Norwegian Food Safety Authority, the technology had to be flexible enough to be fully tested to be included in the laws and regulations.

For the farmers, the goat had always been a useful tool for keeping the landscape under control—which through CyborGoat gained novel advanced ways of doing so. This is in accordance with developments we have seen in relation to other innovations and cyberization of farm animals and farm practices—the advent of “the new farming(s)” of, e.g., precision farming, digital agricultures and smart farming (Bolman, 2016; Carolan, 2018; Daberkow and McBride, 2000; Gralla, 2018; Klauser, 2018; Van Es and Woodard, 2017). Relating to these new views and views on the radical restructuring of what farming is and can be, our study adds both novel conceptualization of the way nature, culture, and technology is mashed-up into new manners of farming—indeed the farmers would in their own words not be able to do this farming if the technology was not available. Additionally, this new form of goat farming relates to Haraway’s (2016) narratives and can be understood as working with, in, and through nature, while also adhering to a responsible and just farming, as conceptualized in the emerging Responsible Agricultural Innovation frameworks (Bronson, 2018, 2019; Klerkx et al., 2019; Carolan, 2020). This can, as Rose and Chilvers (2018, p.1) argue, connect Responsible Agricultural Innovation to Agriculture 4.0: “policy-makers, funders, technology companies, and researchers to consider the views of both farming communities and wider society […] that ideas of responsible innovation should be further developed in order to make them relevant and robust for emergent agri-tech.” This, we would argue, aligns with our contribution to work with boundary objects, and that through discussing CyborGoat as a boundary objects through its *interpretive flexibility*, it’s *structural needs and arrangements*, and finally the *dynamic between different uses* of the new technologized goat as a boundary object.

6. Summary

In the paper, we have followed a digital fencing technology for virtual herding of (primarily) goats, seeing how the technology was developed, governed, and implemented. The technology is now also legal for herding sheep and cattle in Norway. We showed how so-called “Smart-technology” faces certain boundaries when it enters as something novel in a governing-policy landscape that was created when such technologies were not possible. We also showed how, in due time, such governing policies can change and be modified to adapt to the technology. The technology we investigated received socio-political importance, as the digitally mediated governing of agriculture gained momentum. We suggest that policymakers shape agricultural technology by their policies, and that the policies in turn are shaped back by the technologies they govern. Ordering and regulation-at-a-distance becomes increasingly difficult when digital realities mix with analog animals, natural landscapes, and the practices of new types of farming. However, as Leigh Star (2010, p. 605) writes, “when standardized, then boundary objects begin to move and change into infrastructure, into standards” and thus becomes a new normal. Just as we would not describe the physically fenced, domesticated goat, as a boundary object anymore, in due time, the CyborgGoat might also blend into contemporary techno-society and become “normal.” As for now though, it is still being negotiated and fitted into networks and infrastructures of technology, culture, and nature.

A key finding is that the new digital fences is a change agent. It changes goat farming from an activity that, in the contemporary Norwegian context, has been almost entirely for dairy purposes, to a production that for many is centered around landscape cultivation. The technology contributes to changing the goats themselves as they become more selected not based on their milking qualities, but on their adaptation to the fencing technology. The farmers have adapted as well: they went into a relationship with Nofence as the deliverer of technology and continuing service. The technology also contributed to a form of mobilization of a new type of goat farmers—less productivity oriented and more landscape oriented. Whether the virtual fence is able to serve as an agent for changing the Norwegian agriculture back—or forward—to a practice were outfields once again are import remains to be seen. However, the virtual fence has proven to enable a new type of goat being negotiated forward as a boundary object that transforms the agricultural practices for both human and non-human actors.

We see this as the emergence of the CyborGoat-boundary object. As part nature, part culture, and part technology, we propose the CyborGoat as a being that transcends traditional measures of farming—thereby creating new pathways and possibility for goat and goat farming. By imbedding technologies such as virtual fences, technology enhances nature—but this is co-creational as nature enhances technology back.

7. Implications

This study might have the following implications for various stakeholders (interest groups):

(1) **For policymakers:** When novel technology developed does not fit well into existing policy governance, refrain from trying to force it into outmoded categories; rather, open the possibility for parallelly novel policy changes. Policies and regulations are based on what already exists, not what possibilities might exist. With new technology, policy and regulation should adapt accordingly by holistically understanding the new technology.

(2) **For technology developers:** Continue to develop, dream and test new technologies, whether they be incremental changes to existing technology or novel inventions. Be proactive in relating to policymakers and users by encouraging their feedback early in the process. Pushbacks might come in many forms and having plans to deal with them is crucial.
(3) **For farmers:** Realize when technology is in an early development phase, but do not let that discourage use. Share feedback, e.g. through forums so that others might learn how to use the technology well. Give your voice to the policy debate when technology works well for you.
(4) **For researchers:** Be aware of the multifaceted boundary objects of nature-culture-technology hybrids and take into account the interpretative flexibility of the technology, the structural arrangements of the technology, and the dynamic between different uses of the technology.

Author statement

Both authors (Søraa & Vik) contributed to the paper's conceptualization, empirical work, analysis and writing. Søraa is first author and wrote the first draft, while Vik contributed in writing, review and editing.

Special Issue

Special Issue in Journal of Rural Studies on the "Politics of Big Data in Agriculture."

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