Agriculture into the future: New technology, new organisation and new occupational health and safety risks?

Kari Anne Holte [1], Gro Follo [3] Kari Kjestveit [1,2] and Egil Petter Stræte[3]

[1]International research institute of Stavanger, Norway
[2] University of Stavanger, Norway
[3]Ruralis, Trondheim, Norway
Kaho@Norceresearch.no

Abstract. Agriculture is a hazardous industry, with a high frequency of injuries. As working life has changed over the last decades, so has also agriculture. In Norway, farm size has increased, and agriculture has become technology intensive with a high amount of automated milking systems (AMS) and is now more dependent on hired help. The aim of the study is by sociotechnical system theory to explore how a new generation of farmers describe their work organisation in relation to occupational health and safety. The study is an explorative interview study at five farms having implemented AMS. An open interview guide was used. The interviews were recorded and thereafter transcribed. Analyses were based on the balance-theory with the domains technology, organisation, physical environment, task design, and individual characteristics. The results show that AMS changes the farm as a sociotechnical work system. AMS is considered a relief with regards how tasks become less physically demanding, less time consuming, and with less animal contact. On the other hand, cognitive demands increase. The results indicate that the technology increases both complexity and vulnerability, these factors being less considered by the farmers. The findings underline the importance of farmers' increasing awareness of their role as a manager and for an increased system perspective.

Keywords: agriculture, work organisation, sociotechnical system theory, injuries.

1 Introduction

Agriculture is a hazardous industry, with a high frequency of injuries [1, 2]. A Norwegian study concludes that farmers constitute a heterogenous group considering occupational health and safety (OHS) risk, asking for addressing specific groups of farmers [3]. Increased injury risk is found among dairy farmers [4]. Dairy farming is the major agricultural production in Norway. By the beginning of 2017, there were 8,326 dairy farms with an average of 27 dairy cows and 5,143 suckler cow farms with an average of 16 cows. Average numbers of cows on both types of farms have increased in recent years [5]. Dairy farming has undergone major technological developments past decades, one of the most important innovations being the introduction of milking robots or automatic milking systems (AMS). Implementation of modern technology alters work activities, behavior, and how work is organised, which in turn affect workplace safety [6]. Implementing AMS may therefore change the risk picture for dairy farmers. The aim of this study is by sociotechnical system theory to explore how a new generation of farmers, having implemented AMS, describe their work organisation in relation to OHS-risks.

1.1 Automated milking systems; organisational aspects

It is estimated that more than 35,000 AMS operate around the world [7]. Norway has one of the highest relative numbers of AMS: 44,5 % of the milk produced by end 2016 was milked by a robot [8]. The first AMS was installed in Norway in 2000 [9]. In 2006, there were 170 robots, and by end 2016 there were 1,726 dairy farms with robots (total number of dairy farms by end 2016 was 7,880). The number of AMS is rapidly increasing, and approximately 200–250 AMS are installed in Norway each year.

The milking robot is a device associated with increased efficiency and productivity, and it is often combined with other devices, like robot for feeding, activity measuring, robot for cleaning, etc. The milking robot requires loose-housing, which is a specific design of the cowshed, which enables the cows to enter the robot whenever they want to. Around the clock, cows can freely step into the robot, as well as freely move around in the cowshed, and the robot traffic becomes influenced by herd dynamics [10].

Arguments for investing in AMS involve reduced labor [11]. In a review of AMS studies, Jacobs and Siegford [12] reported a decrease in labor by as much as 18 percent. Others have found minor differences in labor use, but rather differences in task and work flexibility [13]. Similarly, Butler et al. [14] found that although AMS reduced the need for labor in the milking parlor, farmers' labor changed rather than decreased. This is firstly related to the maximum capacity of one milking robot (i.e. approximately 70 dairy cows). This maximum capacity can be viewed as a target to make optimum use of the robots from both a technical and an economic perspective, as higher milk volume reduces the fixed costs per liter. However, the higher volume of milk requires more fodder, which means need for more land and more transportation. All in all, more labor may be needed on the farm [15].

Moreover, farmers' main benefits of investing in AMS are; less time spent on milking, more interesting farming, more stable treatment of the cows, and less need for relief in the cow house [16]. To achieve the benefits, farmers must succeed in implementing AMS. Successful implementation depends on the motivation level of the farmers and whether they manage to adapt this technology to their specific needs (op. cit.). AMS may also have disadvantages for farmers, such as being constantly on call and information overload (op. cit.). A Norwegian study concludes that the primary motives for investing in milking robots include a more flexible work day, reduced physical work, and a desire to join what is regarded as the future standard of dairy farming. A motive is also increased flexibility and new opportunities and challenges related to the management of the herd [15]. In another Norwegian (interview) study, robot-farmers said they spend less time on milking and are less hands-on physically with each individual cow, particularly the udder, which changes the relationship with the animals, spending more time observing the "whole" cow and the herd. The authors point to farmers facing a transformation from emphasis on tacit knowledge, towards an increased importance of codified knowledge [15]. A biannual trend survey, conducted by a representative sample of Norwegian farmers in 2016, showed robot farmers being more satisfied with their own health, work environment and occupational safety compared to dairy farmers without a robot. However, standard of the operational building better explained the variation in satisfaction with the work environment and occupational safety than did the milking robot [17]. Considering the substantial changes in farming entailed by the implementation of AMS, there is a need for studies exploring *how* OHS risks may change due to the technology itself and the altered conditions brought along.

1.2 Sociotechnical perspectives applied on agriculture

The above studies argue for using a sociotechnical perspective when exploring how implementation of AMS may alter OHS risks, as sociotechnical system theory emphasizes the organisation's interdependence of both the technical and the social system [18]. Moreover, a questionnaire study among a representative sample of Norwegian farmers found factors like workplace design, production type, work organisation, income, and size as risk factors for injuries [3], pointing to a complex risk picture. A relevant model is the "balance theory" [6, 19], where the work system is described by the domains *technology and tools* (design and usability), *tasks* (job content, workload, control, repetitiveness, learning abilities, feedback, etc.), *organisational conditions* (social and organisational support, role ambiguity and conflict, job security, culture, work scheduling, etc.), *physical environment* (workplace design, noise, temperature, climate, lightening), and the *individual* (cognitive and physical characteristics, needs and abilities, experience, demographic characteristics), and where these domains interact with each other [19]. These domains together constitute and represent work activities, highlighting the sharp end, with the human in the center of the work system [6]. Moreover, the work system influence processes, which in turn affect certain outcomes, like risk [20]. The aim of this study is therefore, by means of the "balance theory", to explore how a new generation of farmers, having implemented AMS, describe their work organisation in relation to OHS risks. Research questions are:

- How do dairy farmers having implemented AMS reflect upon OHS risks?
- How may OHS risks change due to alterations in the work system caused by implementation of AMS?

2 Methods

The study is an explorative interview study, at five farms located in three areas of Norway. Common for these farms were dairy production by means of AMS. They otherwise constitute a variety of production combinations, topography/climate, and different organisational forms (lone farmers, family farms, and joint venture). The latter caused variations in number of informants at each farm, and the study includes a total of 12 informants.

The interviews were based on an open interview guide, covering topics like the farm as a work place and a home, accidents at the farm and their consequences, risk attitudes, and safety culture. The interviews lasted from 90 to 120 minutes. The interviews were audiotaped and thereafter transcribed verbatim and anonymized.
In the initial analysis, the text was searched for descriptions of accidents, injuries and OHS risk factors that were associated with the robot. Thereafter, these risk factors were associated with processes being influenced by the robot and assigned to the different domains of the model: task design, technology, organisation, individual, and environment, in accordance with how aspects of work are allocated to the different domains [19], as described in the former section. For each farm, we drew a picture of the actual configurations describing the dynamics between processes, domains and OHS risk. Then these pictures were aggregated to identify overall patterns of processes and associated system configurations.

3 Results

The farmers gave rich descriptions of their daily work, enabling us to explore how the milking robot changes activities and OHS risks. In the analysis we identified different processes, described by a specific work system configuration, that could be associated with changes in OHS risk. In this paper we will restrict our results to two of them; the *man-animal-robot interaction* and *animal-flow in the cowshed*.

3.1 The man – animal – robot interaction

Considering the milking process, implementation of AMS (*technology*) interacts highly with and completely alters the *task design,* furthermore also having impact on the *organisational domain.*

Changes in task design

The robot entails a complete change in the *job content* associated with milking, including exposures to risk factors like *physical demands* and *animal contact*. When installing AMS, cows are trained to enter the robot themselves and the robot takes care of cleaning and milking. This is seen as a positive outcome by the interviewed farmers, as they perceive their *total work load* as being reduced. On the other hand, the robot introduces new tasks, increasing the *cognitive demands*. One farmer says: *« (...) and then I go to the cow house. And there it's the daily routine; see through stuff with the robot, is there anything…? There are standard reports I must check. It takes about 5-10 minutes."* This description points to *routines* of checking the computer daily. However, the robot monitors many different variables for each animal. This provides the farmer with a huge amount of data to analyse and to use as a background for decisions. Another farmer states: *« (...) I would claim that the use of data and the… The information on the robot… I don't know if maybe 70 % of those who have a robot, don't make use of it at all, so to say. They only learn what they must to make it work."* In this farmer's opinion, most of the information goes to waste, because farmers do not know how to utilise it. If used in an efficient way, there is a large potential using this information for improving the production. Tasks may therefore become more interesting and challenging and allow for increased *possibilities for learning.*

Changes in task design due to implementing AMS lead to new risks. Two incidents are described involving the robot. An incident happened when the robot was new to the farmer and the herd. The farmer tried to prevent a cow from entering the robot, but he was not well located. As the cow was persistent, he was pushed into the robot along with the cow and thereafter squeezed between the cow and the device. Those witnessing could not assist. The incident was painful and gave the farmer bruises, but he did not see a doctor. Lessons were learned regarding how to place and protect oneself in the cow house when directing the herd. The other case was retold by our informants and was about a farmer being trapped in the robot with a cow. This robot was designed in a way that when opening the robot door, it stopped working and the entire system shut down. This made it impossible to identify what was wrong. The farmer may therefore have tried to step into the robot while it was running, and then squeezed by the robot arms and pushed underneath the cow.

Other situations were also associated with risks, for instance how cows had to be taught to use the robot. One farmer stayed in the cow house all day, pulling unwilling animals through the robot. Cows that do not want to enter the robot, do not fit in the robot, and even destroying elements of the robot by kicking, were described. Another potential risk situation mentioned was when having to help a cow: *« (...) with which the robot has a problem, for example."* Common for these situations was unpredictability in animal behavior, and situations arising when being outside of what the algorithms of the robot could handle. This required performing tasks that could be characterized as *non-routinised tasks,* leading to potential risk situations.

Changes in organisational domain

While regular tasks associated with traditional milking disappear, milking becomes a continuous around the clock process, and non-routinised tasks may show up at any time. This has impact on the *organisational domain*, particularly *working hours* and *training of employees.* When having technological breakdowns, the system itself sends a message to the farmer by means of the phone, and the farmer can be interrupted 24/7 irrespective of where he or she is. One farm was organised as a joint venture with five equal farmers and an established *shift schedule*. Thus, all farmers were allowed periods with relief from responsibility and unpredictable incidents that needed to be solved. Another farmer, operating the farm alone, was required to handle these interruptions himself. Farmers with employees can choose to leave responsibility for the robot to employees. This requires training, and there were different views considering *training of employees*, regarding how they approach skills, type of training, and experiences from allowing employees working with the robot. Several of the visited farms had foreign employees. When a farmer was asked for his view on involving employees within the robot, this entailed this reflection:

«Yes, you can easily switch the robot over to Estonian, of course. (I: Yes, that's what we've heard. And it's actually true?) That's not a problem, no. No, no, it is build-in.

You just have to remember to switch it back again. But I know (...) how to go and change the language."

This farmer seems to accept that just switching the language is enough, indicating that he understands the robot as logic and rational. He also trusts that the employees, as they are educated within agriculture, can handle the robot in a proper way, not reflecting upon the need for experience and training on the robot. At another farm the language issue entails a somewhat different reflection, when the farmers were asked about changing language at the robot:

«Husband: Yes, I think you can do that.

Wife: But it has to be taught anyway…

Husband: But we have needed long time too, to figure out the robot, so it's not "just"…

I: It's not as easy as that…?

Husband: But I think that if... Like, he who has been here for ten years… We could easily have taught him the robot, if that was what we wanted. I don't think that's the problem. However, they would have to be there on a regular basis, and not just on day now and then."

This couple talked about the robot as having certain qualities entailing a need for understanding the robot. This requires daily experience, which make them reluctant to let employees work with the robot. Yet another farmer reflected on involving a potential new employee: "(…) *regarding training him to take responsibility for the daily care, it is how he must respond when things stop. Because some things you may fix in a straightforward way, but other things you should not try to repair, because it can be dangerous*". This also address how they evaluate having the skills of knowing when *not to do* certain activities, like not to try to repair or fix the technology, especially where these tasks are non-routinised, as explained earlier.

3.2 The animal-flow in the cowshed

For implementing AMS, loose housing is a premise. Therefore, technology interacts and alters the *physical work environment*, influences *the tasks*, and impacts overall *organisational decisions* at the farm.

Changes in physical work environment

Workplace design impacts the flow of cows in the part of the cowshed where the animals choose themselves where to go. The farmers reflected upon a design that considers cows' behavior and the animal hierarchy. Does the chief cow hamper others to approach the robot, the feeder for grain concentrates, the huge drinking trough, or the brush? As said at one farm, it is important that the cowshed has a design that spread these areas, so the chief cow is unable to be at all these locations. When solutions are optimal, the result is a continuous robot traffic and increased amount of milk. Moreover, loose housing is more on the cows 'premises' compared to a tie-stall, giving better animal welfare.

Changes in task design

Removing physical barriers between animals and between the animals and the farmer may change certain exposures, changing injury risk when performing tasks within this area. Such tasks are cleaning of manure, clearing, and visual observations of animal health. When the physical barriers are removed, farmers must be observant in another way compared to the traditional tie-stalls. They talked about the need for having *"eyes in their neck"*, as these tasks demand them *to be attentive*. In the interviews, stories were told about cows almost and in fact running humans down, and of dangerous *"trains of cows".* One farmer with 100 milking cows and two robots claimed: *"Most of the cows are ok, but they are loose, and we never know".* On the other hand, when animals are well accustomed to the robot (if not adapted to the robot; sold or slaughtered), there is less need for chasing or physically moving animals as opposed to in the traditional tie-stalls. According to the farmers, this is perceived as reducing the risk for injuries.

Changes in organisational domain

When talking about the changes in physical work environment, the farmers also talk about how this interacts with what we could called *strategic decisions,* as well as *risk management*. This is underlined in one farmer's statement: «*Yes, but we have very calm cattle. It is very… Like… You should never say that nothing can happen, but the chances for injury caused by handling cattle, with the breed that we have, are very, very much smaller than with regular (...) cows"*.

Decisions about breed are part of strategic decisions considering how to improve the quality of the milk and increase the production at the farm. Decisions about breed is also about animal behavior within the cowshed, as farmers anticipate that a calmer breed reduces risk for injuries due to animal contact. The ability to take strategic decisions is further supported by and closely connected to the increased ability for learning, as the robot produce a lot of information, as described under the heading: *the man – animal – robot interaction.* When properly utilised, this give farmers increased opportunities for professionalising the organisation and increasing their production.

4 Discussion

The results show that implementing AMS changes the farm as a sociotechnical work system and alters OHS risk in both positive and negative terms. Despite the small number of informants, the results clearly point to changes that allow us to reflect upon arising OHS challenges. In the discussion we will firstly discuss the perceived changes in OHS risks. Thereafter, we will reflect around overall work system changes, and how it might entail risks in the longer term.

4.1 Perceived changes in OHS risks

Farmers who implement AMS experience a huge change in content and structure of work, changing OHS risks in both positive and negative directions. They experience an overall reduction in total work load. This is in line with a biannual trend survey conducted by a representative sample of Norwegian farmers. The survey showed in 2016 that robot-farmers were more satisfied with their own health, work environment and occupational safety compared to dairy farmers without a robot [17]. Figures from the Department of Occupational Health Surveillance (NOA) show that farmers are among the occupational groups with the highest proportions of self-reported work-related pain [21]. As physical demands reduce, we could assume that risk for musculoskeletal disorders decrease. Our results indicate a shift from physical demands to cognitive demands. One of the reasons why cognitive demands increase is the amount of data generated by the robot. A Norwegian study concludes that farmers face new opportunities and challenges related to data and computer work and in management of the herd [15]. In this way, increased cognitive demands become positive. In the demand-control model by Karasek and Theorell, high demands and high control constitute the active job situation, which may lead to increased motivation and learning opportunities [22].

A considerable risk factor for injuries among farmers is animal contact [23, 24]. The robot requires a design where physical barriers in the cowshed are removed. Interestingly, the farmers perceived this as a risk-reducing element, as animals are calmer in loose-housing system compared to a tie-stall. Despite few incidents to report, new risks seem to be unpredictable situations involving the robot, for instance being trapped inside the device. The descriptions point to situations that are extraordinary or unusual, as they are non-routinised tasks for the farmers and outside of algorithms for the robot. This is not surprising, considering repair and maintenance of farm machinery being activities related to injury risk [23]. However, there is lack of knowledge regards how OHS risks change due to implementation of AMS.

4.2 Changes in the work system – latent conditions

Sociotechnical system theory provides a holistic perspective allowing for exploring complexity and dynamics within work systems, as well as reflecting upon risk reductions through redesign [19]. In the results, we described two processes and their specific configurations. Both processes depend on the technology, making the processes tightly coupled and vulnerable for technological breakdowns [25]. The couplings are tighter than for a tie-stall, because of the build-in assumption that AMS increases the number of animals, which increases the vulnerability in case of a breakdown. This vulnerability is to a minor degree addressed among the farmers. As the robot is still new to many Norwegian farmers, there is lack of experiences and stories to learn from. However, those who in one way or another had experienced a robot incident, showed less trust in the technology compared to those without such experiences. We may therefore speculate if the work organisation is still being immature considering how risk introduced by the technology is understood and handled. Based on lack of experience, the technology is trusted and perceived as rational. The vulnerability of the technology itself and how it changes the overall organisation may therefore be overseen.

While the capacity of a milking robot is about 70 milking cows a day, utilisation of this capacity makes investment in a robot more efficient. Dairy farms often double their production when installing AMS, which in the next step requires more fodder and increases the amount of work load at the farm [15]. This is more or less the case for our farmers as well, and requires increased professionality, paying attention to new and upcoming tasks, reliance on external factors/suppliers, as well as on hired labor. All these factors may challenge the farmer as a manager.

The increased cognitive demands and potentially being accessible 24/7, are not addressed as a negative outcome of implementing AMS. We have previously referred to the learning potential and more interesting farming. However, increased cognitive demands may also be potential stressors. It may be difficult to discover the negative long-term effects of always being accessible in case of interruptions and breakdowns. Increased economic constraints and need for effectively utilising the AMS may be another cognitive demand that is overlooked, and which is a latent condition for OHS risk. Glasscock and coworkers [26] indicates that stressors and stress symptoms, like work overload/time pressure, role conflict, economic concerns, administrative burden, and unpredictability are risk factors for occupational injuries in agriculture. Several studies point to organisational complexity due to size, income level and number of employees [23, 24, 27, 28]. The immediate positive OHS outcomes from implementing AMS may therefore be replaced or balanced out by other, underlying outcomes, which over time may increase OHS risk in other ways than the farmers are able to discover after a few years with the new system. Studying the same farmers after some years might shed light on some of these elements.

References

1. Jadhav, R., et al., Risk Factors for Agricultural Injury: A Systematic Review and Meta-analysis. Journal of Agromedicine, 2015. 20(4): p. 434-449.
2. Jadhav, R., et al., Review and Meta-analysis of Emerging Risk Factors for Agricultural Injury. Journal of Agromedicine, 2016. 21(3): p. 284-297.
3. Kjestveit, K., O. Aas, and K.A. Holte. Can organizational aspects serve as latent conditions for occupational injury rates among Norwegian Farmers? (manuscript)
4. Hartman, E., et al., Risk factors associated with sick leave due to work-related injuries in Dutch farmers: an exploratory case-control study. Safety Science, 2004. 42(9): p. 807-823.
5. Norwegian Agriculture Agency, KU - Foretak med felles melkeproduksjon 2016, fylkesfordeling 2017.
6. Carayon, P., et al., Advancing a sociotechnical systems approach to workplace safety - developing the conceptual framework. Ergonomics, 2015. 58(4): p. 548-564.
7. Salfer, J., et al. Dairy Robotic Milking Systems – What are the Economics? 2017 [downloaded 2017 25.01.]; Available from: https://articles.extension.org/pages/73995/dairy-robotic-milking-systems-what-are-the-economics.
8. Norsk landbruk. http://www.norsklandbruk.no/nyhet/antallet-melkeroboter-oker-i-Norge. [downloaded 2017 06.12].
9. Kjesbu, E., O. Flaten, and H. Knutsen, Automatiske melkingssystemer - en gjennomgang av internasjonal forskning og status i Norge. 2006, NILF: Oslo.
10. John, A.J., et al., Review: Milking robot utilization, a successful precision livestock farming evolution. Animal: an International Journal of Animal Bioscience, 2016. 10(9): p. 1484-1492.
11. Drach, U., et al., Automatic herding reduces labour and increases milking frequency in robotic milking. Biosystems Engineering, 2017. 155: p. 134-141.
12. Jacobs, J. and J. Siegford, The impact of automatic milking systems on dairy cow management, behavior, health, and welfare. Journal of Dairy Science, 2012. 95(5): p. 2227–2247.

13. Steeneveld, W., et al., Comparing technical efficiency of farms with an automatic milking system and a conventional milking system. Journal of Dairy Science, 2012. 95(12): p. 7391-7398.
14. Butler, D., L. Holloway, and C. Bear, The impact of technological change in dairy farming: robotic milking systems and the changing role of the stockperson. Royal Agricultural Society of England, 2012. 173: p. 1-6.
15. Stræte, E.P., J. Vik, and B.G. Hansen. The Social Robot: A Study of the Social and Political Aspects of Automatic Milking Systems. in System Dynamics and Innovation in Food Networks. 2017. Innsbruck: International Journal on Food System Dynamics.
16. Hansen, B.G., Robotic milking-farmer experiences and adoption rate in Jæren, Norway. Journal of Rural Studies, 2015. 41: p. 109-117.
17. Hårstad, R.B. and E.P. Stræte, Melkerobotbønder mer tilfreds med HMS, ferie og fritid, in Faktaark 7/17, Ruralis, Editor. 2017, Ruralis: Trondheim.
18. Davis, M.C., et al., Advancing socio-technical systems thinking: A call for bravery. Applied Ergonomics, 2014. 45(2, Part A): p. 171-180.
19. Carayon, P., The Balance Theory and the Work System Model ... Twenty Years Later. International Journal of Human-Computer Interaction, 2009. 25(5): p. 313-327.
20. Carayon, P., et al., Work system design for patient safety: the SEIPS model. Quality & Safety in Health Care, 2006. 15: p. I50-I58.
21. Tynes, T., et al., Faktabok om arbeidsmiljø og helse 2015 - status og utviklingstrekk. STAMI - rapport, Årg 16, Nr 3 2015, STAMI, Oslo.
22. Theorell, T. and R. Karasek, Current issues relating to psychosocial job strain and and cardiovascular disease research. Journal of Occupational Health Psychology, 1996. 1(1): p. 9-26.
23. Karttunen, J.P. and R.H. Rautiainen, Distribution and Characteristics of Occupational Injuries and Diseases Among Farmers: A Retrospective Analysis of Workers' Compensation Claims. American Journal of Industrial Medicine, 2013. 56(8): p. 856-869.
24. Taattola, K., et al., Risk factors for occupational injuries among full-time farmers in Finland. Journal of Agricultural Safety and Health, 2012. 18(2): p. 83-93.
25. Perrow, P. Normal accidents. 1984: Basic books, New York.
26. Glasscock, D.J., et al. Psychosocial factors and safety behaviour as predictors of accidental work injuries in farming. Work and Stress, 2006. 20(2): p. 173-189.
27. Rautiainen, R.H., et al., Risk Factors for Serious Injury in Finnish Agriculture. American Journal of Industrial Medicine, 2009. 52(5): p. 419-428.
28. Van den Broucke, S. and A. Colemont. Behavioral and Nonbehavioral Risk Factors for Occupational Injuries and Health Problems Among Belgian Farmers. Journal of Agromedicine, 2011. 16(4): p. 299-310.