Using new technology in agriculture

Securing sustainable food production in Norway

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ABSTRACT

The world population is growing and the demand for food will grow with it. As only 3% of the landmass of Norway can be used in agriculture, the available land should be fully utilized. The research question of this article is therefore how technology on farm level can help increase food production in Norway in a sustainable way. The method used is literature review exploring agriculture, precision farming and its environmental impact. Intensive agriculture does have negative environmental impacts like greenhouse gas emissions which leads to climate change, which in turn makes farming more challenging, as the industry already relies on weather conditions. Precision agriculture is a growing concept that could improve farming productivity and sustainability by adapting treatment to the needs of individual plants or animals. The result of the article chows that utilizing sensor data, GPS and farm management information systems together can revolutionize farming, but the shift is slow. Investing in new technology is expensive for the average farmer and the knowledge of how best to use it might not be readily available. Farming has still seen a historical productivity increase, and with the help of interest organizations, agricultural cooperatives and government funding and policy precision farming can make a difference, even for smaller farms.

KEYWORDS: Norwegian agriculture, sustainable agriculture, technology, precision agriculture, TPD4505

1. INTRODUCTION

The population growth and climate changes in recent years is challenging the global food production. The UN estimated that between 2005 and 2050 food production will have to increase by about 70% to feed a population of 9 billion (FAO, 2009), but the land on which to grow food is limited. Therefore, a more efficient agriculture is needed.

Historically the use of new technology has greatly increased the efficiency of the agriculture, most notably the use of artificial fertilizers and pesticides and mechanization mainly by using tractors instead of horses. Production has gone up as the population has grown, but negative effects of the industrial agriculture is hindering further development (Almås, 2002). New, more sustainable methods need to be taken into use.

This article explores what technology can do to help make the food production in Norway more efficient and still be sustainable, and environmentally friendly on farm level. The research question of this article what new agricultural technology exists and how it can be utilized in Norway to increase the food production in a sustainable way. It will also look closer at precision farming and examine if its value as a solution to this problem.

2. METHODS

Literature review is the method used in this article to answer the research question. General websites were used to get an overview and find keywords to use in more specific

literature search. Articles, books and statistics from public institutions, independent organizations within agriculture, scientific research articles and product websites were used. Literature on Norwegian agriculture and its environmental impact was used to add the context, and more specific searches were done to get an overview of technologies and go further into precision farming and its implications. As precision farming is still young in Norway it was difficult to find research on the possible consequences of a widespread adoption. To gain a better understanding of farmers approach to new technology, other methods like interviews could yield better results.

3. AGRICULTURE IN NORWAY

The production of food is important for any civilization to survive and agriculture has seen a rapid development throughout history. Like many other industries the use of new technology has greatly increased the efficiency of agriculture, most notably the use of artificial fertilizers and the use of pesticides. After World War II mechanical agriculture became dominant and reduced the need for manual labor (Almås, 2002).

The industrialized agriculture has increased the amount of food produces but has also had negative effects like depletion of nutrients, decreased biodiversity and emission of greenhouse gases leading to climate change. New ideas about sustainable agriculture has emerged though, for example organic farming and precision farming, and the greenhouse gas emissions have decreased by 5% between 1990 to 2016 (The Norwegian Environment Agency, 2016, p. 43).

In Norway only 3% of the land area is suitable for agricultural production, much less than most other countries. Most of this is used for gras as animal food, only a third is suitable for growing grains. The landscape consists mostly of mountains, hills, lakes and forests and therefore most of the farms are small and far from each other. The seasons are short and the median temperature low (Hohle, 2016, p.54). This makes efficient use of the available farmland even more important to sustain a sizeable food production for the Norwegian population.

From 1959 to 2015 the number of Norwegian farms has decreased by 79%, but the size of the combined farmland is almost the same (Rognstad et al., 2015, p. 30). This means that the average farm has become much larger. Farmers are also more specialized, most keep just a few types of farm animals or crop. The number of farmers has also decreased, in 2015 only 1,7% of the Norwegian workforce were directly employed within agriculture and their average age was 51 years (Rognstad et al., 2015, p. 37).

4. ENVIRONMENTAL IMPACT OF AGRICULTURE

Agriculture is a strong intervention of nature that changes the biodiversity of large areas, but intensive industrialized agriculture has also had other impacts on the farm land and the surrounding areas. The use of pesticides and fertilizer can spread toxins to surrounding animal and plant life and the food itself, soil can suffer from erosion, water can be contaminated or depleted, and greenhouse gas emissions affect climate change (Norwegian Environment Agency, 2017).

The effects of climate change make farming more unpredictable, and it is therefore in the farmers best interest to help reduce greenhouse gas emissions. Extreme weather such as hail storms, drought or floods can destroy a year's harvest. In recent years this has become more common, also in Norway, like the widespread drought in the summer of 2018. A project called "Klimasmart Landbruk" (climate smart agriculture) has been made to reduce the carbon footprint of Norwegian agriculture by developing tools for farmers to reduce their carbon footprint and document their measures to improve the climate. The project is initiated by many interest organizations within agriculture and it shows the industry's will to help reduce climate change (Klimasmart Landbruk, 2017).

4.1 Greenhouse gas emissions and energy consumption

In Norway about 8,5% of the greenhouse gas (GHG) emissions come from agriculture, less than the global average (SSB, 2018a). This is to be expected as the amount of farmland is relatively small. Though the amount might seem small, it is still a considerable contributing factor in climate change. The main source of GHG comes from livestock and livestock manure, but mineral fertilizer and agricultural runoff also contribute (Hohle, 2016, p. 66).

In Norway almost all electric energy used comes from renewable sources, 94% from hydropower, the rest from wind and solar energy (SSB, 2018b). This makes energy demanding storages and farm houses environmentally friendly, but most farm vehicles run on diesel, which have high CO_2 emissions that count for 0,6% of Norway's GHG emissions (Hohle, 2016, p. 68). Some vehicles like forklifts can run on electricity, and biodiesel can replace regular diesel. Biodiesel can be made from waste products, but to completely replace diesel crops would have to be grown for this purpose alone, and therefore reduce the areas for food production (Smedshaug, 2012, p.46-47).

4.2. Meat compared to plant-based food

The environmental impact is not the same for different types of produce. Plant based foods generally demand a smaller area than meat to produce the same amount of food. This means that the more plant-based food is produced the more food is produced. The government is already encouraging the production of more fruits and vegetables because the national demand is growing (Kalstad et al., 2018). Different animal species also have different carbon footprints where beef cattle and dairy cattle produces the most GHG emissions and poultry produce the least (Gerber et al., 2013, p. 16).
It is estimated that if everyone has one meat free day a week, 898,7 km^2 will be freed to grow plant-based foods like fruits or vegetables (Lindahl, 2016). Not all farmland is suitable for vegetable production though, about two thirds of the agricultural areas in Norway are used to produce grass for animal feed, 29% is used for grains and only 2,9% is used for potato and vegetable production (NOU 2016:3, p. 13).

4.3. Organic Farming

Organic farming is a farming system developed to utilize natural processes and thus creating a more sustainable agriculture with higher quality products. There are many restrictions in organic agriculture, most importantly artificial fertilizers and synthetic pesticides are not used. These restrictions can lead to smaller harvests, more mechanical weeding or nutrient deficiency, though the toxins and emissions from pesticides and fertilizers are reduced (OECD, 2016, p. 50). In 2015 5% of Norwegian farms were organic, though the government goal is 15% organic production by 2020 (Rognstad et al., 2016, p. 35).

4.4. Food quality and security

The rules and regulation within Norwegian agriculture is quite strict compared to many other countries, leading to high quality and safe food. According to the Norwegian Agrarian Association (Norges Bondelag) Norway is among the countries in Europe with healthiest livestock animals, leading to a low use of antibiotics and medicine and there is low occurrence of pesticides in Norwegian food compared to import (NOU 2016:3, p. 58). Farmers are required to document activities on the farm, like fertilizing, pesticides, Health and Safety etc. Because of the high income-level and price level in Norway it is difficult to compete on price alone, and quality and uniqueness is what makes the products attractive to both foreign and Norwegian buyers (Matmerk, 2015).

3. TECHNOLOGY IN AGRICULTURE

As previously mentioned, new technology on farm level has evolved the agricultural industry, and it could help improve it even further. There are several technologies emerged in recent

years that can improve various aspects of farming. A big change is the move from pure mechanic agriculture to the value of information, called the Data Revolution. The gathering, analysis and real-time actions taken are greatly improving the efficiency of modern farming (Thomas & McSharry, 2015, p.19).

Precision agriculture and smart farming are terms used for agriculture systems and can be defined as using the best available technology to adapt the treatment of a field after conditions and plant needs (NIBIO, 2018). Precision agriculture (PA) is a process for gathering data from the various fields, analyze it and use it to decide how best to manage the specific sites within each field. Some think that PA is the best way to make agriculture sustainable as it can reduce GHG emissions, cost and labor, and create food with higher quality (Walter et al., 2017).

Precision agriculture has mostly been used in plant production, but the same principles can be applied to manage livestock. Berckmans states that it is difficult to change people's habits radically and make them stop eating meat, so we should focus on improving livestock farming, not remove it. Modern farms tend to be bigger and therefore the GHG emissions and the risk of disease increase. In this context PA allows monitoring of animal health, movement, reproduction, growth or malfunctioning equipment like feeders (Berckmans, 2017).

3.1. Sensor equipment

There are many factors that determine the state and growth of plants, such as temperature, nutrients, humidity, light, pests and weeds. Livestock need food, water, movement and socializing. Sensors can monitor these conditions and can help the farmer decide how best to adapt the treatment of the different parts of a field.

Cameras have a wide field of application and can be used to detect pests, can distinguish weeds from crop, detect nutrient deficiencies, detect local draught and more. Input from the cameras can be connected to variable-rate application equipment like fertilizers that only spreads fertilizer where it is needed (Pedersen & Lind, 2017, p. 48). The cameras can be mounted on the tractor or equipment or drones can be used to collect visual data from a larger area to get a quick overview. Camera drones can also be used to monitor livestock and their movement (Jennings, 2017). Other types of sensors can be used to monitor things like humidity and temperature both in the air and in the soil (Pedersen & Lind, 2017, p. 36).

Using sensors collects a lot of data, but to utilize the data transfer between different units must be possible, from tractor to equipment to management systems. This can be a problem as some companies only allow data sharing between their own products. There is an international standard, ISOBUS, that can be used to connect all different products and more companies are implementing it (Pedersen & Lind, 2017, p. 41). They are realizing that their customers expect the freedom to choose their own equipment.

3.2. GNSS tracking systems and GIS

Global Positioning Systems (GPS) can determine geographical position of a receiver, and is a central technology in PA. A GPS receiver mounted on a tractor can accurately pinpoint its location and calculate the coverage of the equipment as the tractor moves (Pedersen & Lind, 2017, p. 25). GPS can also be used to steer tractors and other equipment to ensure even coverage and avoid overlap. The amount of driving on the field is at a minimum, and the amount of fertilizer and pesticides used is optimized to suit plant needs. (Pedersen & Lind, 2017, p. 129).

Geographical Information System (GIS) is a system that stores different kinds of data to specific geographical locations. This can be used together with GPS to adapt treatment according to the needs of areas of the field, e.g. fertilizing according to the nutrient measures of the soil (Thomas & McSharry, 2015, p.23).
Used correctly GPS systems connected to GIS mapping, sensors and farm equipment can

limit the amount of time, fuel, fertilizer and pesticides needed on a field, limit GHG emissions, save money and increase harvest (OECD, 2016, p. 144).

There have been several experimental developments of autonomous vehicles for agriculture, from self-driving tractors to small robots taking soil samples. These reduce the need for manual labor and smaller and lighter equipment decreases the toll on the soil. Equipped with advanced cameras and sensors, they can help the farmer look over the crops and act according to plant needs, whether that is fertilizer, pesticides, wedding, harvesting etc. (Løwe, 2017).

3.3. Alternative farming methods

To be able to grow enough food with limited farmland vertical farming and hydroponic farming has emerged. These are systems where plants are grown in special containers placed vertically or on top of each other, usually indoors. This gives a larger amount of food per square meter and the conditions can be monitored and adapted more easily, but the energy consumption and the setup cost are high (Tarantola, 2016). Because the conditions can be controlled it is possible to grow plants that otherwise would not survive in Norway, and import can be limited.

3.4. Farm management information systems

As the amount of data grows the farmer needs a way to monitor and understand all the information. Farm management information systems (FMIS) are made to do just that. They gather information about the different activities of the farm in one place and analyze and connect data sets to make the best foundation to make decisions. Access to the information is made easy through devices like smartphones or tablets. Others can also get an up to date view of the farm by connecting to the same system. By sharing this data with government agencies or other parties, the farmers can deliver required documentation without spending extra time doing paperwork (Pedersen & Lind, 2016, p. 46).

Advanced systems can calculate what changes should be made or estimate outcomes of different actions before you make them. Machine learning can further improve the system as each year gives more data to make new more accurate estimations (O'Grady & O'Hare, 2017). By combining farm data with weather data and forecasts, work can be performed when the conditions are optimal, and delays or damages caused by weather can be reduced (Walter et al., 2017). When the systems become more complex the need for a user-friendly interface grows. Even if the content is useful, if the farmer can't find the right information the system itself will not be useful (Selener, 2009).

There are many farm management systems from countries like the USA, but they are not adapted to Norway. A few Norwegian based systems exist, like Skifteplan, Jordplan and Agrilogg, and more are emerging, like Agdir and Mimiro. The need for a digital organizing tool that utilizes the available technology is growing. These can be connected to suit Norwegian conditions and help farmers keep within laws and regulations. Few systems give holistic management for farming though, most have specialized in one particular area and expanded the product around it. As these systems can't directly share all their data with each other it can be difficult to have multiple systems.

3.5. Farmers ability to utilize new technology

Technology comes with many benefits, but all farmers might not be able to take part in the modernization. On average Norwegian farmers have low salaries, in 2016 the number was 190 100 kr per year (SSB, 2018c), and not everyone can invest in expensive equipment. This is especially true for the small farms in the districts. Most farmers have another job besides farming to earn enough money (Rognstad, 2015, p.113). Alternative farming methods like vertical farming will be even more expensive to start. Organizations like Innovasjon Norge can offer loans for farm investments, but it might take many years for an expansion to pay for itself. Norway is also

one of the countries in the world with the highest agricultural subsidies (OECD, 2017), but the money might not go to the ones who need it the most, and the high amount of subsidies compared to low selling prices might not motivate to innovation and improvement. Despite the economic difficulties Norwegian agriculture produces more food with fewer farmers, which shows an ability for improvement (Agricultural cooperatives in Norway, 2016).

The growing average age of farmers can make it difficult to keep up with innovation. A lack of knowledge about new technology, especially computer technology, and their potential benefits can stop some. Interest organizations like Norwegian Agrarian Association and agricultural cooperatives like Felleskjøpet or Tine can be driving forces and encourage their users to modernize. Norwegian Agricultural Counseling (Norsk landbruksrådgiving) also has an important role in advising farmers with basis in the newest research within farming. Modernization of farming can help recruit young farmers more accustomed to using computer technology.

4. DISCUSSION

There is no doubt that technology will be an important factor in the development of farming and food production in Norway, and precision agriculture is gaining momentum both in the private and public sector. The government is funding research into the field through a center for precision agriculture of the Norwegian institute of bioeconomy research (NIBIO). The goal is to develop tools for a resource efficient and sustainable agriculture. Interest organizations, agricultural cooperatives and private companies are all aware of the potential for developing precision agriculture products and services. Used correctly these methods can increase yield and quality and still limit GHG emissions and the use of fertilizers, pesticides and water.

To get the full potential of PA the technologies previously mentioned; sensors, GPS, GIS, variable-rate equipment and farm management systems need to be used together. Bigger farms have the most to gain from adopting these technologies. However, a full transition to precision agriculture is difficult for most of the Norwegian farmers because of the natural limitations of Norway, cost and agricultural policies. Although product quality will increase, and environmental impacts will decrease, the economic benefits are more uncertain (Vogt, 2017). Before an investment is made careful consideration should be put in choosing the right investment for that particular farm. Adopting just some of what PA can offer might make a large difference, like buying a tractor-mounted GPS or a simple FMIS. Smaller farms are more expensive to run, for the farmer and for the community, but to be able to produce enough food these areas are important, and therefore PA should be adapted to fit these areas as well.

Neither organic farming or conventional farming is sustainable today, but the potential is there. Organic farming might not be the simple sustainable solution it was meant to be, especially when it comes to access to nutrients, which mainly comes from livestock manure. Though mineral fertilizers can satisfy plant needs better, it also produces GHG emissions and depletion of certain nutrients, like phosphorus, is a real threat (Farestveit et al., 2015). Both these methods can benefit from adopting PA principles, but conventional farming still seems to be the most productive and sustainable option in Norway overall (Grønlund og Joner, 2016). Conventional farms can still use methods from organic farming to avoid using pesticides or weed spraying when possible.

Holding on to traditions and have the freedom to choose how to run a farm is important to many farmers, but so is self-sufficiency of food. Norway must decide in what degree farmers should be forced to modernize. If the development is too radical farming culture and traditions can change or disappear as fewer people are needed to operate even larger farms. The small local communities can die out and cultural landscape disappear. The modern farmers will need more knowledge about

technology and system management than biology and tradition and can radically change the profession.

When it comes to environmental impact plant-based food is better that meat, but it is not realistic to force Norwegians to become vegan, and most farmland is only suitable for grass. There is already a growing demand for vegetables, and an overproduction of meat, milk and eggs that can't be exported with a profit (Aase, 2018). Therefore, there should be a gradual shift toward producing more plant-based food where possible. To encourage the shift something should be done above farm level, for example a change in agricultural policies.

5. CONCLUSION

The research question of this article was to explore the new technologies available on farm level and how they can best be used in Norway to make food production more productive and sustainable. Norway has a relatively small potential for food production due to natural conditions and all available farm land should be used to its full extent. Precision agriculture is a promising new development, where time, GHG emissions, input resources like fertilizer, pesticides and water can be reduced, and profit and quality can be increased. Technology alone cannot solve the problem of food production but can be a big contributor.

Precision agriculture using sensors, GPS and farm management systems adapted to their farm can help farmers increase their yield and income and reduce the carbon footprint. This system works best for big farms but can help smaller farms as well if they are able to invest in the technology needed. The precision agriculture center run by NIBIO will no doubt contribute to further explore how PA can be utilized by Norwegian farmers. Action should also be taken by other parties above farm level, such as interest organizations and government policymakers, to encourage a big shift and adapt it to the varied agriculture of Norway.

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