Enhancing Efficiency and Yield in Swedish Crop Agriculture

The Role of Autonomous Machines

Josefin Molander

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Enhancing Efficiency and Yield in Swedish Crop Agriculture. The Role of Autonomous Machines

Ökad effektivitet och skörd inom svensk odling. Autonom teknologi i jordbruket

Josefin Molander

Supervisor:	**Abozar Nasirahmadi, SLU, Department of Energy and Technology**
Examiner:	Gunnar Larsson, SLU, Department of Energy and Technology

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Swedish University of Agricultural Sciences

Faculty of Natural Resources and Agricultural Sciences

Department of Energy and Technology

Abstract

What role could automation play in shaping the future of farming in Sweden? Overall, the shift towards autonomous agriculture is driven by the need to balance cost reduction, sustainability goals, and labour challenges in the agricultural sector [1].

This thesis aims to assess how autonomous machinery can enhance economic efficiency and minimise environmental impact in agriculture, contributing to more sustainable and economically viable farming in Sweden.

By focusing on specific activities within different sectors of agriculture, the research analyses key factors within the realm of sustainability, productivity and costs. The study develops a model through radar charts to evaluate how these factors influence financial, environmental and productivity outcomes; both in current conditions and with the introduction of autonomous technologies within Sweden. Based on the findings, a prototype for future autonomous farming in Sweden will be recommended.

The results show that Sweden is exploring digital and automated technologies in agriculture to improve productivity and sustainability. For the users, productivity is where automation shows the most positive impact, especially for yield efficiency and time savings. Cost savings over time is a major driver, although initial investments remain a perceived barrier. Sustainability benefits are modest and vary by environmental factor, with water efficiency scoring highest and biodiversity support among the lowest. An automated irrigation and fertilisation system is the recommended prototype, drawing from the results of the survey.

Keywords: Automation in farming, Swedish agriculture

Sammanfattning

Vilken roll kan automatisering ha för framtidens jordbruk i Sverige? Generellt är omställningen mot autonomt jordbruk driven av behovet att balansera kostnadsreducering, hållbarhetsmål och arbetskraftsutmaningar inom jordbrukssektorn. [1]

Denna uppsats syftar till att bedöma hur autonoma maskiner kan förbättra ekonomisk effektivitet och minimera jordbrukets klimatpåverkan. Detta med syfte att bidra till hållbart jordbruk i Sverige, både på en ekonomisk och klimatpåverkansnivå.

Genom att fokusera på specifika aktiviteter inom jordbruk i Sverige går uppsatsen in på olika nyckelfaktorer inom begreppen hållbarhet, produktivitet och kostnader. Studien utvecklar en modell för analys av hur dessa nyckelfaktorer nyttjas och bidrar till både klassiskt och autonomt jordbruk. Baserat på dessa faktorer presenteras en rekommenderad prototyp för autonomt jordbruk till framtida användning i Sverige.

Resultatet påvisar att Sverige är i en utforskandefas gällande digitalt och automatiserat jordbruk inom hållbarhet och produktivitet. För användarna är det främst inom produktivitet som automatisering påvisar en positiv inverkan. Kostnadsbesparingar över tid är också en ledande faktor, men den initiala investeringen är fortsatt ett upplevt hinder. Fördelarna inom hållbarhet är modesta och beroende av miljöfaktorer, där effektiv vattenanvändning är i centrum och biodiversitet prioriteras lägre.

Studien presenterar ett automatiserat bevattnings- och gödningssystem som den rekommenderade prototypen. Prototypen är baserad på resultatet av undersökningen.

Nyckelord: Automatisering inom jordbruk, svenskt jordbruk

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1. Introduction

Industrial farming has led to high environmental cost, contributing to biodiversity loss, pollution, and climate change. Therefore, there is a need to balance food production with sustainability. [2] Transitioning away from intensive farming is challenging, as farmers require more skills to manage diverse systems and the entire supply-chain must share responsibility. Research, and innovation are two key concepts to unlocking solutions, enabling a shift towards sustainable food production. [3]

In this context, autonomous machinery has the potential to make agriculture both more economical and environmentally viable, mainly by increasing productivity [4]. Economic pressures, climate change, and sustainability goals are driving the adoption of automation in agriculture. Rising input costs, particularly for fertilisers and labour, are putting pressure on farmer's profitability, while extreme weather events and environmental regulations add further challenges. Automation technologies offer solutions by improving efficiency, reducing costs, and supporting sustainable practices. Automation in farming could involve the use of sensors, analytics, robotics, and automated equipment, among other things, to enhance decision-making and optimise resource use. Despite their potential, adoption remains low globally for these advanced technologies. Economic and regulatory pressures, along with growing consumer demand for sustainable products, are expected to accelerate the shift towards increased automation in farming. [1]

Reducing labour costs and enhancing the precision and timing of resource applications like fertilisers, autonomous systems can increase operational efficiency and reduce environmental impacts [5]. The effects of adopting autonomous technologies vary across different sectors of agriculture. In largescale grain farming, for instance, machinery can quickly cover vast areas [6], while small scale vegetable farming often involves labour intensive tasks like handpicking and weeding [7]. As a result, different types of agricultural production will experience distinct challenges and benefits with the adoption of autonomous machines. [8]

Overall, the shift towards autonomous agriculture in Sweden is driven by the need to balance cost reduction, sustainability goals, and labour challenges in the agricultural sector. [9]

Agricultural automation has the potential to improve efficiency, sustainability, and productivity in farming [1]. However, its implementation varies across regions, and in Sweden, the extent to which automation meets the needs of farmers remains unclear. This thesis investigates the current state of agricultural automation in Sweden to identify potential gaps in adoption and effectiveness. By assessing existing implementations and their impact, the study aims to determine whether significant gaps exist and, if so, how they can be addressed. Based on these findings, a prototype will be developed to target the outliers, contributing to the advancement of automation in Swedish agriculture.

1.1 Purpose

The purpose of this thesis is to evaluate the potential of autonomous machinery to improve productivity, economic efficiency and reduce environmental impacts in agriculture, ultimately offering pathways for more sustainable and economically viable farming practices in Sweden. The study will present a prototype for future autonomous farming in Sweden.

1.2 Research questions

- How is automation implemented in agriculture, and what are its potential applications in Sweden?
- What is the current status of agricultural automation in Sweden, and how can selected metrics be used to evaluate its impact?
- How can a prototype be made to address the key gaps, as identified through the analysis of current implementation and its impact?

2. Theory

The theoretical framework of this thesis provides the foundation for analysing the role of autonomous machinery in Swedish agriculture. By drawing on relevant theories and existing research, this section will explore the economic, technological, and environmental aspects of farming.

2.1 Key concepts

In this section, the key concepts relevant to this thesis will be presented. These concepts form the foundation for understanding the role of autonomous machinery in Swedish agriculture.

2.1.1 Sustainability

Sustainability is generally defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs. It is often categorized into three main types, sometimes referred to as the three pillars of sustainability: environmental, social, and economic sustainability. [10]

Ecological sustainability focuses on maintaining ecological balance by protecting natural resources, conserving biodiversity, and minimizing pollution. Environmental sustainability aims to prevent depletion of resources to ensure future generations can meet their needs, and it is encouraged to reduce the ecological footprint through resource management. [11]

Ecological sustainability requires that human activities stay within the earth’s regenerative limits, ensuring that production and consumption do not outpace nature’s capacity to restore resources [12]. This concept covers air and water quality, soil health and biodiversity. By maintaining these natural processes, ecological sustainability supports long-term environmental resilience. [13]

Sustainable agriculture is an environmentally friendly approach that minimizes dependency on finite natural resources. These careful farming strategies contribute to long-term ecological balance and resilience in agricultural systems. [14]

Social sustainability involves recognising and managing a business influence on people by prioritising strong connections with stakeholders such as employees, customers, and local communities. A company’s commitment to social sustainability often hinges on its commitment to social responsibility, as factors like poverty and inequality can affect its operations. Great social initiatives can open new markets, foster innovation, and improve employee engagement. [15]

Human rights form a core part of social sustainability covering areas like labour rights, gender equality, and public health. While governments hold the primary duty to protect human rights, businesses are expected to prevent harm and when possible contribute positively by providing fair jobs, goods, and partnerships. [15]

Sustainable agriculture fosters social equity and contributes to a more just food system. By utilising sustainable production techniques, agricultural yields become more dependable and adaptable, ensuring consistent access to affordable food for all individuals, regardless of their financial circumstances. Additionally sustainable practices often support local farming, empowering farmers to do well within their communities. [16]

Economic sustainability seeks to support long-term economic growth without negatively impacting social, environmental, and cultural aspects of the community. It involves sustainable economic practices that allow communities to thrive, such as creating job opportunities that do not rely on harmful environmental practices or exploitative labour. This aspect emphasises fair resource distribution and sustainable business practices. [17]

Economic sustainability has two main interpretations. In the first, it ensures that economic growth does not harm ecological or social sustainability, preserving natural and social resources alongside economic capital. The second interpretation equates economic sustainability with overall economic growth, allowing an increase in economic capital even at the potential cost of natural resources or social welfare. Some argue that economic sustainability may be better understood as the economy's role in promoting or hindering sustainable development. [18]

Sustainability in agriculture can enhance local economies and create economic opportunities for small-scale farmers, enabling them to produce more food using fewer resources. This approach often provides significant financial benefits compared to conventional farming. [19] Traditional farming methods are vulnerable to droughts and natural disasters, which can lead to substantial economic losses. In contrast, sustainable agriculture typically invites lower costs by requiring fewer inputs, making it a more resilient choice for farmers. [20]

2.1.2 Water Efficiency

Water management is a critical challenge in agriculture, particularly as climate change alters environmental conditions. Efficient use of water is essential for both sustainable crop production and maintaining soil and water quality. [21]

Research focuses on soil structure and physical properties to develop improved methods for water management in agriculture. This includes optimising irrigation strategies, studying waterborne transport of nutrients and pesticides, and assessing how land use and climate influence water quality. The goal is to enhance crop production while minimising environmental impacts. [21]

By integrating fundamental and applied research these efforts support the development of sustainable agricultural practices [21]. Crop water efficiency refers to how effectively crops use available water to produce biomass or yield. It can be improved through better field management, breeding, and genetic modifications. Scientists work to enhance plant mechanisms that control water use, ensuring higher productivity under limited water conditions. [22]

Transpiration, photosynthesis, and stomatal conductance (the rate at which water vapour and gases, such as carbon dioxide, pass through the stomata of plant leaves) are key factors influencing crop water efficiency. Most water absorbed by plants is lost through transpiration, while photosynthesis converts carbon dioxide into energy. Stomatal openings regulate both processes, balancing water loss and carbon intake. [23]

Different types of photosynthesis affect crop water efficiency. Some plants lose more water due to photorespiration, while others have adaptations that help them use water more efficiently, particularly in warm or dry environments. Some plants reduce water loss by opening stomata at night instead of during the day. [24]

To improve crop water efficiency, researchers focus on breeding plants with optimal root systems, leaf structures, and stomatal behaviour. Precision irrigation, nutrient management, and advanced monitoring tools also contribute to better water use in agriculture. [25]

2.1.3 Soil Health

Soil health is essential for sustainable agriculture influencing crop growth, nutrient availability, and overall ecosystem stability. Maintaining healthy soil ensures long-term productivity and resilience for environmental challenges. [26]

Soil is a dynamic and life-sustaining resource, rich in microorganisms that form the foundation of a complex ecosystem. Soil health is defined by its ability to function as a living system that supports plants, animals, and humans by regulating water, filtering pollutants and cycling nutrients. [27]

Managing soil health involves principles such as minimising disturbance, maximising biodiversity, ensuring continuous soil cover, and maintaining living roots. By adopting practices like no-till farming, cover cropping (an agricultural practice where specific plants are grown primarily to improve soil health rather than for harvest), and diverse crop rotations, farmers can improve soil structure, increase organic matter, enhance water retention, and boost productivity. Healthy soils contribute to sustainable agriculture by reducing erosion, improving nutrient availability and creating a more resilient farming system. [27]

Weeding and spraying robots improve soil health by reducing the need for excessive labour and chemical use. Traditional methods often lead to soil degradation, but autonomous robots use advanced technology to remove weeds and apply treatments with precision. This targeted approach minimises chemical runoff, protects beneficial microorganisms, and preserves soil structure. [26]

These robots also help prevent soil erosion by maintaining plant cover and promoting stability. By adopting such solutions, farmers can enhance crop health and yields while reducing their environmental footprint. The integration of robotic technology supports more efficient and sustainable farming, ensuring healthier soils for the future. [26]

A fertigation automation system (the process of delivering fertilisers to crops through an automated irrigation system) helps improve soil health by delivering nutrients accurately, reducing salt buildup, saving water, and supporting helpful microorganisms. By providing the right nutrients at the right time, it prevents imbalances and over-fertilisation, keeping the soil in good condition. [28]

These systems also reduce soil salinity, which helps tiny organisms in the soil thrive and improve fertility. With better control, farmers can avoid overwatering, which can cause soil erosion and wash away nutrients. Keeping the soil at the right moisture level helps plants grow strong roots, which will help the plats absorb nutrients more effectively. [28]

Fertigation automation also makes farming more adaptable to climate changes, such as droughts or heavy rainfall. By using water and fertilisers more efficiently, farmers can reduce waste and pollution while increasing crop yields. In the long run this system supports sustainable farming and healthier soil. [29]

2.1.4 Pesticide Use

Pesticides are essential for modern agricultural production as they help farmers control weeds and insect pests, leading to significant increases in crop yields [30]. The rapid growth of the global population in the 20th century would not have been possible without a corresponding rise in food production, which has been largely supported by pesticide use [31]. Pesticides play a crucial role in disease control and yield enhancement worldwide. [32]

While pesticides effectively eliminate pests and manage weeds, their chemical properties also pose risks to non-target organisms, including beneficial insects, birds, aquatic life and plant species. Pesticide residues can also spread beyond treated crops, leading to environmental contamination. These pollutants impact human health through exposure in food and the surrounding environment. Climate change related factors also influence pesticide application, contributing to environmental pollution. [32]

While pesticides play a crucial role in disease control and yield enhancement worldwide, pesticide use continues to rise with highly toxic chemicals still in circulation. Crops are now treated more frequently and with a greater variety of pesticides than ever before. [31], [32]

People are exposed to pesticides through food, environmental contact, and occupational exposure. Scientists increasingly suggest that no level of exposure is to certain pesticides is truly safe. [33]

Pesticides also play a major role in the decline of farmland wildlife. While some chemicals have been banned, they are often replaced with other harmful substances. Reducing reliance on pesticides is essential to break this cycle. [33]

A key issue is the combined effect of multiple pesticides, as safety tests typically assess individual chemicals rather than the mixtures actually used in farming [33]. The cumulative presence of multiple pesticide residues in food raises concerns about potential health risks, as these substances can accumulate in the human body over time [34]. One study also shows that insecticides affected enzyme activity and energy levels in solitary bees. These effects depended on the insecticides, their combinations, and the sampling time, showing complex interactions that could not be predicted by studying each insecticide alone. This highlights the need to consider pesticide mixtures in risk assessments, as their combined effects may be more harmful to wild pollinators than previously thought. [35]

2.1.5 Carbon Footprint

A carbon footprint quantifies the total greenhouse gas emissions generated directly or indirectly by an organisation, individual, product or service. Businesses assess their footprint by considering emissions from energy consumption, transportation and industrial activities (sometimes extending to supply chain operations). [36]

Tracking carbon emissions enables organisations to manage and reduce their impact environmental, meet corporate sustainability targets and provide transparent reporting to stakeholders. As the shift toward a more sustainable economy gains momentum, businesses are recognising the importance of carbon footprint as a strategic tool for environmental responsibility. [36]

Emissions are typically measured in a unit called carbon dioxide equivalent, to reflect the varying global warming potential of different gases, such as methane, nitrous oxide, and fluorinated gases [36]. The Greenhouse Gas Protocol classifies emissions into three scopes: Scope 1 covers direct emissions from owned sources, Scope 2 includes indirect emissions from purchased energy, and Scope 3 accounts for additional indirect emissions from supply chains and business activities. While Scope 1 and Scope 2 are essential for all organisations, Scope 3 reporting depends on individual business considerations. [37]

Reducing emissions varies in difficulty depending on whether they fall under Scope 1, 2, or 3. Businesses have greater control over Scope 1 and 2 emissions, as they can choose energy-efficient technologies, switch to renewable energy, or adopt low-emission transport options. These emissions are also easier to quantify since data on gas and electricity consumption can be directly converted into greenhouse gas values. [37]

Scope 3 emissions are much harder to control because they come from sources outside the company, like suppliers and customers. Businesses cannot dictate how products are used or disposed of, but they can work with suppliers and customers to find ways to lower overall emissions. The terms Scope 1, 2, and 3 come from the Greenhouse Gas Protocol, the world's most widely used standard for measuring and reporting greenhouse gas emissions. [37]

The Greenhouse Gas Protocol continuously updates its standards and provides tools, training, and resources to support emissions measurement. It also works with cities and countries to develop national emissions tracking programmes and helps organisations align with climate deals like the Paris Agreement. [38]

Reducing the carbon footprint in agriculture requires adopting sustainable practices that maintain productivity while minimising environmental impact. Investing in renewable energy and energy efficient equipment can significantly lower emissions. Using data driven approaches to monitor and manage greenhouse gas emissions also helps optimise farm operations. [39]

2.1.6 Biodiversity

Biodiversity is crucial for life on Earth, providing food, medicine, and a stable climate. Over 75% of food crops rely on pollinators, and many modern medicines come from nature. [40]

Biodiversity plays a crucial role in maintaining the health and productivity of ecosystems. Rich and diverse biological communities contribute to essential ecological functions, including oxygen production, soil formation and water purification. Scientific advancements have allowed researchers to isolate the impact of biodiversity, demonstrating that ecosystems with greater species richness tend to be more stable and resilient. [41]

A decline in biodiversity, whether due to climate change or human activity, can weaken an ecosystem's ability to adapt to environmental stressors. Maintaining species diversity is therefore fundamental to ensuring sustainable and productive natural systems. This highlights the importance of conservation efforts aimed at preserving ecological balance and resilience. [41]

Biodiversity is declining rapidly, putting over a million species at risk. This loss affects food production, spreads diseases and damages ecosystems that clean air and water. [40]

2.1.7 Yield efficiency

Crop yield is the quantity of production gathered per unit of land that has been harvested. In most instances, yield figures are not directly documented but are instead derived by dividing total output by the corresponding harvested area. [42]

Data on yields for permanent crops are generally less precise than those for seasonal crops. This is often due to the fact that reported land measurements may reflect planted rather than harvested areas. [42]

Yield efficiency is becoming an important metric for assessing farm profitability, offering three key benefits. [43]

First, it helps transform raw data into meaningful insights. Simply comparing yield does not provide enough information, but analysing factors like soil fertility and applied nutrients enables more informed agronomic decisions. [43]

Second, it allows farmers to compare their performance beyond their own operation. By using data visualization and anonymous group comparisons, they can measure efficiency against others and track their own progress over time. [43]

Third, it contributes to better profit margins by focusing on input management. Since growers have more control over input costs than yield, adjusting inputs based on productivity zones rather than applying a flat rate across a field improves overall efficiency. [43]

2.1.8 Labour reduction

Mechanisation in agriculture plays a significant role in reducing physical labour by enhancing efficiency. Tools and machinery allow farmers to accomplish larger tasks in a much shorter time than manual labour would allow. For instance tasks that once required numerous workers can now be done by a single combine harvester. Over time advancements have increased the capacity of machines, allowing modern harvesters to harvest 6–8 hectares per hour. Mechanisation also offers ergonomic benefits, aiming to replace intense human labour with machinery to create more favourable work conditions. [44]

Heart rate studies help quantify the physical workload during both manual and mechanised tasks. For example, in milking, workers using traditional methods showed higher heart rates than those using automated systems. Research reveals that mechanical aids can minimize the physical strain on workers, particularly on the cardiovascular system, suggesting a need for comparisons of workloads across different methods to further understand these benefits. [44]

2.1.9 Energy consumption

The energy consumption and environmental impact of the food industry highlights its vital role in the global economy, where it provides millions of jobs. This sector accounts for approximately 30% of global energy use and greenhouse gas emissions, with a significant portion sourced from fossil fuels. To promote sustainability, energy performance indicators are essential for identifying opportunities for energy savings and efficiency improvements throughout the food supply chain. [45]

Energy consumption in open-field agriculture across the EU is estimated to be at least 1,431 petajoules. A significant portion, 31%, comes from diesel fuel used on farms. Additionally, indirect sources contribute to 55% of the total energy inputs in this sector. To facilitate a transition into more sustainable farming the adoption technologies free of fossil fuels and practices is essential. Utilising sustainable fertilisers and pesticides can help decrease reliance on indirect fossil energy. [46] In 2021, the agriculture and forestry sector in the EU consumed energy equivalent to 28.3 million tonnes of oil [47].

3. Method

This thesis relies on a design thinking process as the method for product development. Through literature review and interviews, the thesis will provide estimates and insights into how autonomous machines can transform the economics and sustainability of agricultural production in Sweden. With this data, these criteria will be evaluated.

A systematic approach to conducting literature reviews is particularly advantageous for researchers, especially those new to their field. Traditional narrative methods often rely on the author's expertise, making them challenging for novices. In contrast, a more effective method involves systematically searching online databases to identify relevant studies based on specific criteria. This process is referred to as a literature review. [48]

Qualitative interviews are an effective research method that allows for in-depth personal interaction and the gathering of detailed information from participants. This approach facilitates a conversational format where open-ended and follow-up questions are employed, enabling researchers to explore participants' perspectives thoroughly. Compared to general questionnaires or focus group studies, qualitative interviews provide richer insights by focusing on the nuances of participants' experiences. [49] Quantitative research focuses on collecting and analysing numerical data to study psychological, social, and economic processes. It involves measuring and organising information, whether naturally numerical (like income) or structured through scales. Researchers use this data to find patterns, identify relationships, and make comparisons through statistical analysis. Common methods include surveys, structured observations, and experiments. The main goal is to gain knowledge and better understand social phenomena by systematically studying data from groups of stakeholders. [50] Interviews shall be conducted in order to establish a base point for the state of the field.

A prototype is an early model of a product that simulates its design and functionality. It is used to test concepts, gather feedback, and refine the design before full development. Prototyping is the process of creating these models, ranging from simple paper sketches to highly detailed digital simulations. [51]

Prototyping is an essential step in the design process, following research and idea generation. It allows designers to test and refine their concepts before full development, ensuring a user centred approach and a more successful final product. [51]

3.1 Design thinking process

Design thinking is a way of thinking and working that focuses on solving problems by putting people’s needs first. Unlike other methods, it starts with the user and aims to find practical solutions, rather than just analysing the problem itself. [52] The design thinking cycle can be described as a micro cycle that takes part of a macro cycle [53]. The micro cycle can be described as seen in Figure 1 below, where we see the six phases understand, observe, define point of view, ideate, prototype and test.

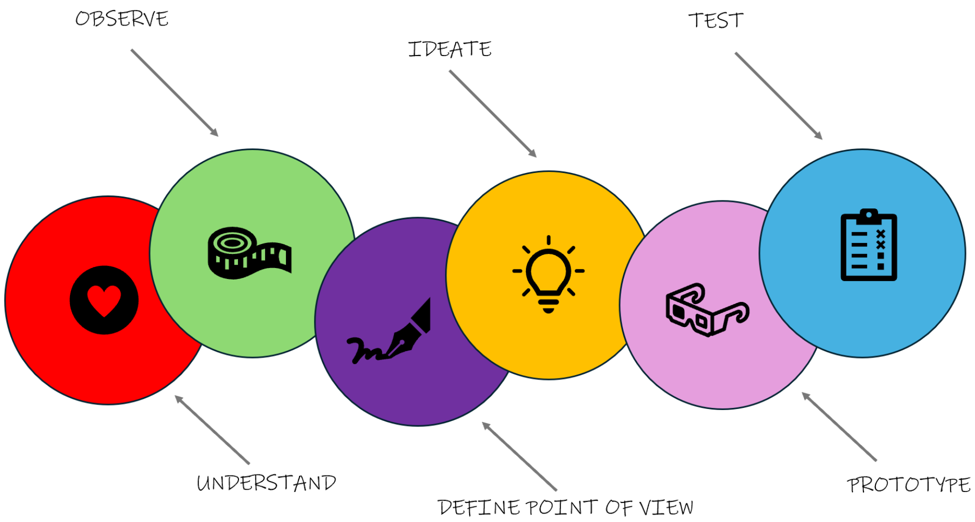

Figure 1 - The Design Thinking micro cycle [54]

The understanding phase of the micro cycle is used to define the problem statement at the right level for the project. [54] Trendwatching is a way to spot important changes or patterns that might affect a business or industry. It helps predict what products or services people will want in the future. This is useful in product development because it focuses on future customer needs and gives a head start over competitors. [55]

At the observe phase, data is collected and analysed all through different user perspectives. The point of view is decided after the observations have been made, the point of view can be defined as finding an answer to the question "How might we..?". Based on the established point of view the ideation can start. A classic ideation method is brainstorming, where the team gets together and collect all possible ideas that will answer the previous question of the defined point of view. [53] A Minimum Viable Product (MVP) is a simple version of a product with just enough features to test an idea and get early user feedback. It helps teams learn what works before spending time and money on full development. The MVP should still be usable and solve a key problem for users. [56]

Developing a prototypes makes the ideas tangible and concrete. Prototyping and testing goes hand in hand and are conducted in close relations to each other. [53]

The micro cycle should be used an iterative process, revisiting the different phases throughout the project [54]. This is presented in Figure 2 below.

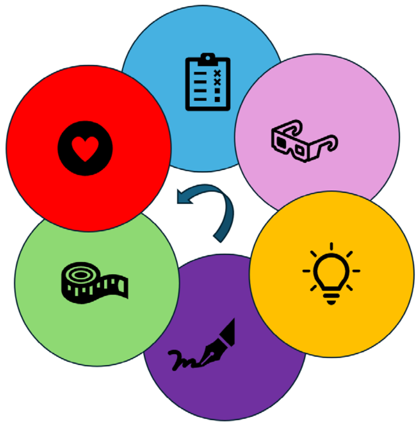

Figure 2 - the iterative rendition of the micro cycle [54]

When put in a context over the wider project scope, the iterative micro cycles can be used in what is referred to as the Design Thinking macro cycle [54]. This is presented in Figure 3 below, where its shown that the iterations flows and repeats with the project over time.

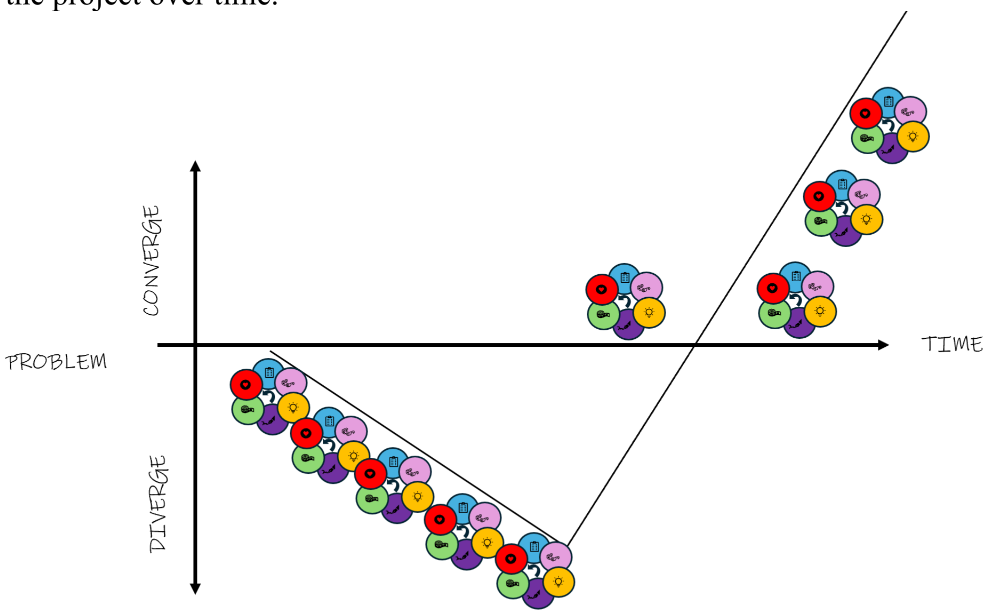

Figure 3 - The Design Thinking macro cycle [54]

This thesis presents the final iteration of the Design Thinking process in the following ways:

- **Understand**
  Trendwatching trough a literature review lay the foundation for the understanding of the current state of the field. This can be found in Section 4.1.
- **Observe**

Interviews of current users of automation technologies in agriculture are presented in Section 4.2.

- **Define point of view**
  The gaps identified are presented in Section 4.3, this defines the point of view.
- **Ideate**
  The gaps identified are analysed and the ideation for solutions is presented in Section 4.3.1. The minimum viable product is presented.
- **Prototype**
  The prototype is presented in Section 4.4.
- **Test**
  The testing phase is closely related to the prototype phase and they have been used in correlation with each other in order to present the final prototype. A recommended scenario for further testing the prototype is presented in Section 5.8.

3.2 Methods for interviews

As part of the observation phase, interviews has been used to conduct needfinding through the use of interviews. Needfinding is a research method in product management used to discover what users truly need, even if they do not say it directly. What makes needfinding different from other customer research methods is that it doesn’t rely on users clearly explaining their needs. [57]

3.2.1 Likert scale

A Likert scale is a common method for measuring attitudes, opinions, or perceptions in a structured way. It allows respondents to express their level of agreement or experience on a numerical scale, making it easier to quantify subjective data. [58]

In this study, a 5-point Likert scale will be used to assess the impact of automation on **productivity, costs, and sustainability**. Each statement will be rated on a scale from 1 to 5:

1. Strong Negative Impact
2. Slightly Negative Impact
3. No Impact
4. Slight Positive Impact
5. Strong Positive Impact

For example, a question could be:

"How has automation affected your farm's productivity?". The Likert scale would, for the one responding, read:

1. Strongly Decreased Productivity
2. Slightly Decreased Productivity
3. No Change
4. Slightly Increased Productivity
5. Strongly Increased Productivity

3.2.2 Radar chart

A radar chart is used to visually represent multivariate data, making it easier to compare multiple variables at once. Each variable is represented as an axis extending from the centre of the chart. The values along these axes are plotted and connected, forming a web-shape. [59]

Radar charts are most effective when comparing a small number of observations across multiple variables. They can be produced by overlaying multiple datasets on the same chart or by displaying several charts side by side. [59]

The main advantage of radar charts is that they make outliers and similarities immediately visible. If a particular value is significantly different, it stands out clearly. Commonalities between observations are also easily identified. [59] In order to combat cluttered data the thesis will present three radar charts, one per area of **productivity, costs, and sustainability**.

Below is an example of a radar chart and it's Likert scaled data. This data is purely fictional for the purposes of making an example. Below is an example for productivity comparison.

Table 1 - Example data for the questions for productivity, answered by three farms

Productivity	**Farm A**	**Farm B**	**Farm C**
Yield Efficiency	4	3	5
Labour Reduction	5	4	3
Automation Integration	3	5	4
Crop Monitoring Effectiveness	4	3	5
Time Savings	5	4	3

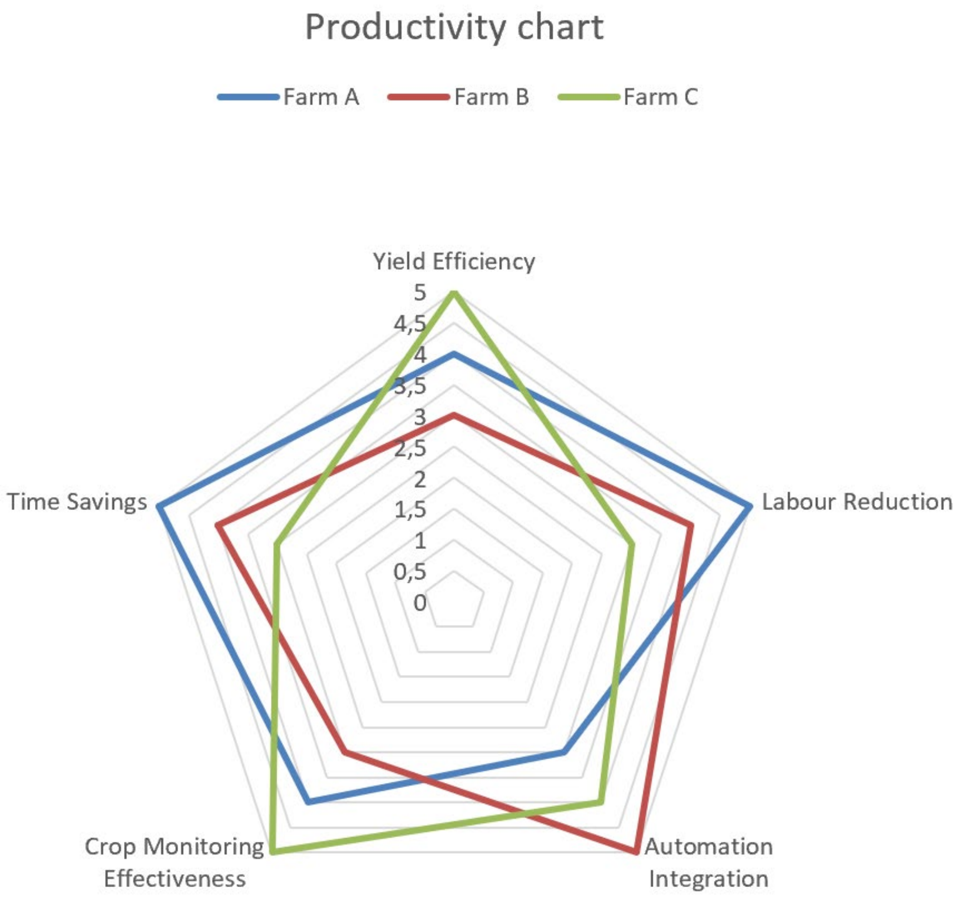

Figure 4 - An example of a radar chart showing the data for productivity, answered by three farms

This could be read as follows:

- Farm A prioritises labour efficiency and time savings, but its automation adoption is not as strong as the others.
- Farm B leads in automation integration, but this has not yet resulted in improved yield or monitoring.
- Farm C is the most effective in yield and monitoring, meaning its automation is benefiting crop outcomes, but it does not reduce labour as much.

All three farms rely on automation to enhance productivity. They all see benefits in crop monitoring, yield efficiency, and automation integration, but the degree to which they prioritise aspects like labour reduction and time savings differs.

3.2.3 Questionnaire

The questionnaire is presented below. The corresponding name of the data in the radar chart/table is written in parentheses. The questionnaire was sent out as a

Swedish translation of the questions below. The full questionnaire in Swedish and its format can be seen in Appendix 1.

Productivity

- How effective has automation been in enhancing efficiency and output in farming? (Yield Efficiency)
- To what extent do you think automation has contributed to reducing labour in farming? (Labour Reduction)
- How well is automation integrated into farming operations? (Automation Integration)
- How effective do you think automated systems are in monitoring crops in farming? (Crop Monitoring Effectiveness)
- How much time do automated technologies save in farming tasks? (Time Savings)

Costs

- How significant is the initial investment required for automation in farming? (Initial Investment)
- How costly do you think the maintenance of automated farming is? (Maintenance Costs)
- To what extent has automation led to cost savings over time? (Cost Savings Over Time)
- How much has automation affected energy consumption in farming? (Energy Consumption)
- How much financial risk do you associate with implementing automation? (Financial Risk)

Sustainability

- In your view, how effectively has automation improved water efficiency in farming? (Water Efficiency)
- To what extent has automation contributed to better soil health? (Soil Health Improvement)
- How much has automation reduced pesticide use in farming practices? (Reduction in Pesticide Use)
- How well do you think automation has contributed to reducing the carbon footprint of farming? (Carbon Footprint Reduction)
- How has automation supported biodiversity in farming? (Biodiversity Support)

3.3 Delimitations

This thesis is limited to exploring the impacts of ecological and economic sustainability along with overall productivity. No weight shall be put on the social sustainability aspects on the results.

The research is also limited to agriculture within Sweden, to crop fieldwork. This thesis does not cover any agriculture related to animal farming.

The study will present suggestions for future implementation, called a prototype.

4. Results

4.1 Literature review of automation implementations in Swedish agriculture

According to the findings of this study, Swedish agriculture has changed significantly in recent years with new technology, different working methods and a focus on natural resources. To reach Agenda 2030, it is moving towards more digital and automated solutions. [60] Agenda 2030 is an action plan that aims to create a sustainable society for people, the planet and prosperity. Its goals and targets are closely connected and can not be separated, covering the economic, social and environmental aspects of sustainable development. [61]

In recent decades farming has become more focused on large-scale, monoculture crops, mainly to accommodate bigger machinery. The rise of robots and AI in agriculture marks a new phase of automation, offering new ways to grow crops. Different types of robots are being explored for their potential to improve sustainable and ecofriendly farming. [62]

Smart and Precision Agriculture technologies can use advanced tools to improve farming efficiency, productivity, and sustainability. Smart agriculture incorporates IoT devices, AI, drones, and farm management software to collect and analyse real-time data for better decision-making. Precision agriculture focuses on optimising resource use, using GPS, remote sensing, and data analytics to apply inputs like water and fertilizers more precisely. Together these technologies claim to help reduce waste, increase yields, and promote sustainable farming practices. [63]

Precision agriculture, a part of smart agriculture, focuses on optimising resource use by using technology. The use of GPS and Global Navigation Satellite Systems helps farmers apply inputs such as water, fertilisers, and pesticides with precision. This technology may ensure that the right amount of resources is applied to each part of the field, reducing waste and improving yields. Remote sensing, including satellite imaging and drones, plays a role in providing data on crop health and soil conditions. Data analytics is used to interpret this information and make real time adjustments to farming practices. [64]

Smart and Precision Agriculture technologies can be important for enhancing sustainability, competitiveness, and productivity in European farming. However, smaller farms struggle to afford and implement these technologies effectively. Without adequate financial support, they risk losing competitiveness against larger farms and international counterparts in countries like the USA and Canada. [65]

There is increasing demand for more sustainable, efficient, and diverse farming systems. Using resources more efficiently can reduce fertiliser, pesticide use, and climate impacts. While some people are sceptical about the development of agricultural robots, these technologies have the potential to meet sustainability goals. Instead of intensifying conventional farming with harmful environmental effects, small, collaborative robots could help improve productivity, biodiversity, and labour management. [62]

Digital Farming builds on Precision Farming by incorporating intelligent networks and data management tools to automate sustainable agricultural processes. It utilizes advanced technologies such as sensors, microprocessors, GPS, and big data analytics to improve the precision and efficiency of farming operations. This allows for optimized plant and animal growth while minimizing input. Unlike industrial processes, agriculture is influenced by natural and biological factors, making Digital Farming unique in its approach. [66]

By optimizing resource use, Precision Agriculture technologies contribute significantly to more efficient fertilization, irrigation, and pest control, ultimately reducing environmental impact. [65]

Agricultural intensification has led to monocultures, driven by the need for larger machinery to boost productivity and reduce labour costs, resulting in negative impacts on biodiversity. The focus is now shifting towards Precision Farming, aiming to improve resource efficiency, foster biological growing conditions, and address climate change and biodiversity loss. [62]

The transformation of agriculture requires collaboration across various fields. Autonomous robots are a promising solution for small-scale farming due to their flexibility compared to large machinery. This seems to be applicable in smaller ecosystems. [62]

4.1.1 Engineering applications

Automated irrigation technology is revolutionising agriculture by enhancing efficiency, sustainability and productivity. Traditional irrigation methods often depend on manual labour and can be inefficient in both water usage and cost. As the global population grows and climate conditions change, adopting sustainable practices is essential for optimising resources. [67]

By using sensors, controllers, and actuators, automated irrigation systems precisely regulate water distribution based on real-time data, ensuring crops receive optimal hydration when needed. This innovation plays a vital role in water conservation by minimising waste and irrigating only as required, leading to reduced water consumption and lower operational costs. [67]

These systems also improve crop yield and quality by maintaining consistent moisture levels, minimising plant stress, and fostering uniform growth. Furthermore, automation simplifies farm operations by decreasing reliance on manual labour and enabling remote monitoring and control, significantly boosting overall efficiency. [67]

One example of innovation in Swedish agriculture is Vultus, an agtech company based in Lund that uses satellite imagery to help farmers apply fertiliser and water more efficiently. By providing detailed soil data, their technology claims to reduce waste and prevents environmental damage like eutrophication. The claim is that farmers can lower fertiliser and water use by nearly 20%, saving money and protecting natural resources. [68]

The Swedish startup IRRIOT (Irrigation Internet of Things) claim to be revolutionising agriculture by incorporating smart technology into irrigation systems. Their innovation may enables farmers to conserve water and enhance crop yields through automation. [69]

IRRIOT's system relies on sensors that track key soil conditions such as moisture, temperature, and pH levels. These sensors transmit data to a remote terminal, which then relays it to a central controller. The controller processes the information and adjusts irrigation accordingly, ensuring water is used efficiently. Unlike conventional systems that depend on manual operation or timers, IRRIOT's wireless solution claims to eliminate the need for underground cables, reducing environmental impact. [69]

They claim that this technology has proven highly effective, allowing farmers to reduce water consumption by up to 50% while boosting crop yields by as much as 30%. While most installations are currently in Sweden, the company is expanding globally, with a large-scale project in Egypt covering several thousand hectares. [69]

Originally developed by one of its founders as a solution for remote garden irrigation, the system has since evolved significantly. IRRIOT is now advancing its technology to integrate plant signals, enabling crops to indicate their hydration and nutrient requirements. [69]

Another water irrigation automatization is provided by Spowdi, a Swedish green-tech company, who focuses on supporting small hold farmers in India with its solar-powered drip irrigation system. Designed to reduce dependence on fossil fuels and improve water efficiency, the system enhances crop yields and profitability. The system claims to be highly energy efficient. Through rolled out hoses, it enables drip irrigation directly onto the plant and its roots for up to a one-acre farm, generating fertile crops. It theoretically provides far better precision by focusing irrigation on the plant, thereby reducing water use on the farm compared to flooding. The system is also mobile, allowing farmers to bring it home at night or share it with neighbouring farmers. By partnering with local distributors and offering financing solutions, Spowdi claims to promote sustainable and regenerative farming in India. [70]

Researchers at Linköping University have developed an electrically conductive cultivation substrate, known as eSoil, which claims to enhance plant growth in hydroponic systems. The university claims that barley seedlings grown in this innovative medium demonstrated a 50% increase in growth when their roots were stimulated with low-power electrical currents. Unlike traditional hydroponics, which often relies on non-biodegradable mineral wool, eSoil is made from cellulose combined with a conductive polymer, potentially making it a more sustainable alternative. [71]

Hydroponic farming offers an efficient, space-saving solution, particularly in urban areas and regions with limited arable land. The electrically stimulated seedlings also showed improved nitrogen processing, though the precise biological mechanisms remain under investigation. Unlike previous high voltage root stimulation methods, eSoil claims to operate with minimal energy consumption and no safety risks. [71]

This advancement can also be linked to soil health as traditional agriculture often depletes nutrients and degrades soil quality over time. By improving plant growth efficiency and reducing reliance on conventional farming methods, hydroponic systems like eSoil could help alleviate pressure on agricultural land, promoting more sustainable soil management in the long term. While hydroponics alone may not solve global food security challenges, this technology presents a promising step towards more efficient and environmentally friendly crop production, especially in regions with harsh growing conditions. [71]

KTH researchers are advancing hydroponic farming, using water and LED lighting to grow vegetables year-round in windowless spaces. While reducing transport emissions, energy efficiency remains a challenge. Research focuses on optimising energy use, repurposing surplus heat, and exploring hydroponics for pharmaceuticals. Sweden leads in this field, with high demand for hydroponically grown herbs and vegetables. Despite energy use, locally grown vegetables using hydroponic farming may be more sustainable than imports. Their goal is to expand crop diversity and develop circular systems for greater sustainability. [72]

There are in fact multiple companies operating within the field of hydroponic farming within Sweden. Green City Farming, based in Gothenburg, develops high-tech hydroponic systems for indoor vertical farming. By combining IoT connectivity, automation, and proprietary technology, the company produces cost-effective, locally grown lettuce that outcompetes imports. Their scalable, sustainable approach addresses urbanisation and food security challenges by minimising environmental impact and reducing transport emissions. [73]

Swegreen provides moderns in store farming solutions, allowing retailers and restaurants to grow fresh, pesticide free leafy greens directly on site. Also based in Gothenburg, Sweden, their service model eliminates the need for upfront investment, with businesses simply paying for what they harvest. By using AI-driven monitoring and a fully controlled indoor environment, Swegreen claims to optimise growth conditions while reducing water consumption by 99%. This sustainable approach minimises food waste and transport emissions, offering a highly efficient, ecofriendly alternative to traditional agriculture. [74]

Another example is the company Grönska. Grönska develops and provides hydroponic farming technology to promote local food production. Founded in 2014 by three friends experimenting with LED lighting, the company has since grown into a leading provider of vertical farming solutions in the Nordics. In 2018, they opened one of Europe's largest vertical farms near Stockholm, advancing their vision of self-sufficient cities. Their business model uses small-scale indoor farming with up to 300 plants per month per square metre. [75]

Their closed farming environment eliminates the need for pesticides while ensuring optimal growing conditions. By carefully managing water use, they claim to save up to 95% compared to traditional agriculture, preventing unnecessary waste. Additionally, their focus on local production significantly reduces the need for transport, cutting energy consumption and air pollution. Based in Stockholm, Grönska is working towards a more sustainable future in food production. [76]

Healthy soil is vital for farming, ecosystems, and food production. Digital technologies are making it easier for farmers to monitor and manage soil, helping them make better decisions while improving efficiency and sustainability. [77]

New tools like sensors, drones, and satellite imaging provide real-time data on soil moisture, nutrients, and structure. Sensors placed in fields or on farm equipment track humidity, temperature, pH, moisture, and nutrients, sending this information through phone networks, WiFi, or satellites. Some systems link these sensors to automatic drip irrigation, making sure crops get the right amount of water without waste. [77]

Satellites and mapping tools help assess soil quality by measuring moisture, organic matter, texture, salinity, and iron content. This helps predict crop yields and detect soil damage early. Drones with special cameras can check for nutrient problems in crops and apply the right amount of fertiliser or pesticides, reducing waste, costs, and pollution. Mobile phones also play a big role, letting farmers collect, process, and receive real time data. [77]

RISE, a Swedish research institute, has developed a digital testbed to explore automation, electrification, and digitalisation in farming. Their work includes testing autonomous electric machines, which could make farming more sustainable by reducing emissions and soil compaction. Smaller, self-operating machines/drones may also help smaller farms stay competitive. [68]

One European initiative focuses on improving soil health, led by a Swedish research institute. The project addresses the urgent need for sustainable soil restoration by developing practical, scalable solutions. With 60–70% of EU soils currently degraded due to pollution, urbanisation, and intensive farming, this work plays an important role in tackling these challenges while supporting biodiversity, climate resilience, and long term agricultural sustainability. [78]

The project is part of a EU Mission and aims to restore soil health by reducing pollution, strengthening soil structure, and raising public awareness. To achieve this, six labs across Europe are testing and refining sustainable farming methods suited to different regional conditions. In Sweden, the lab focuses on improving soil health in intensive farming systems. [78]

By combining scientific research with practical application, the initiative ensures that new soil health strategies are effective and accessible. It also emphasises collaboration between researchers, farmers, and policymakers to drive meaningful change. Running from 2024 to 2028, the project aims to establish globally recognised standards for soil restoration, creating long term benefits for both agriculture and the environment. [78]

Another example is Finngarne farm, near Norrtälje, who is leading the way in testing new farming technologies. It became a Swedish innovation farm in 2021 through a partnership with Arla. The farm is a testing site where researchers and companies try out new methods to make farming more efficient and environmentally friendly. [68]

One key project at the farm focuses on soil health. In collaboration with the Swedish Environmental Institute, the farm plans to use environmental DNA (eDNA) to study biodiversity. [68] eDNA is the detection of DNA traces left in the environment by different organisms [79]. This will help understand how different farming methods affect nature [68].

By using smart farming tools, automation, and digital technology, Finngarne farm shows how modern methods can improve harvests while protecting the environment. Its work supports Sweden's climate goals and helps make farming more sustainable. [68]

To further enhance soil health and sustainability, the project is testing advanced methods such as precision-controlled drainage and the application of biostimulants and biochar. These approaches complement ongoing efforts by focusing on optimising water management and soil enrichment. The goal is to create long-term improvements in soil quality while supporting resilient and productive farming systems. [80]

The study Advanced Farm Technology and Automation in Swedish Agriculture showed that many Swedish farms have introduced advanced technology and automation, but the degree to which they use these systems differs. Farmers recognise the benefits of automation but often take advantage of only a small part of the available technology. One farmer estimated that they used just 20 percent of their machinery's automation features, except for GPS functions that were used a lot. [81]

Fuel efficiency was another significant advantage of automation. Modern tractors give operators the ability to control engine speed and transmission separately, which allows for more effective fuel use. Farmers reported that this function had helped them cut costs while keeping operations smooth and efficient. The responders to the survey stated that advanced farm technology and automated systems had both good and bad sides. They did not feel that the technology caused them mental strain all the time and saw it as important for their future work. But they pointed out that for the technology to be helpful without causing stress, it needs to work properly, be easy to use and be reliable. [81]

4.2 Current status of agricultural automation in Sweden and evaluating the Impact of Automation on Swedish Agriculture

This section shows the results from the survey about automation in Swedish farming. The survey was sent to people working in farming and related areas, such as farm workers, advisors, developers, and growers. In total, twelve people answered. They all had some experience with or knowledge about automation and farming. Their answers give a mix of views on how automation is seen today, when it comes to productivity, costs, and sustainability and can be seen in Table 2 below. The full responses are presented in Appendix 2.

Table 2 - Survey results with names corresponding to the responders, in Swedish

Productivity	Gård i Blekinge	Bärodling	IoT sensors	Robot-utveckling	Rådgivning	Gårds-arbetare	Odling	Odlar grödor	Automation	Stads-odling	Automations-lösningar	Rådgivare
Yield Efficiency	5	5	4	2	4	5	5	5	4	4	3	4
Labour Reduction	3	3	3	3	3	3	3	3	3	3	3	3
Automation Integration	4	4	2	2	3	4	4	4	2	2	2	3
Crop Monitoring Effectiveness	4	2	4	5	2	4	1	1	2	4	4	2
Time Savings	4	3	3	5	3	4	3	3	3	3	3	3
Costs	Gård i Blekinge	Bärodling	IoT sensors	Robot-utveckling	Rådgivning	Gårds-arbetare	Odling	Odlar grödor	Automation	Stads-odling	Automations-lösningar	Rådgivare
Initial Investment	4	4	3	4	3	4	4	4	3	3	4	3
Maintenance Costs	2	2	2	2	3	2	2	2	2	2	2	3
Cost Savings Over Time	4	4	4	5	4	4	4	4	4	4	5	4
Energy Consumption	3	2	3	3	4	3	2	2	3	3	3	4
Financial Risk	3	2	3	3	5	3	2	2	3	3	3	5
Sustainability	Gård i Blekinge	Bärodling	IoT sensors	Robot-utveckling	Rådgivning	Gårds-arbetare	Odling	Odlar grödor	Automation	Stads-odling	Automations-lösningar	Rådgivare
Water Efficiency	4	5	2	3	4	4	5	5	2	3	3	4
Soil Health Improvement	3	4	3	3	3	3	4	4	3	3	3	3
Reduction in Pesticide Use	3	3	3	3	4	3	3	3	3	3	3	4
Carbon Footprint Reduction	3	4	3	3	4	3	4	4	3	3	3	4
Biodiversity Support	2	2	3	3	3	2	2	2	3	3	3	3

The results presented in Table 2 can be seen in Figure 2 (productivity), Figure 3 (costs) and Figure 4 (sustainability) below.

4.2.1 Productivity

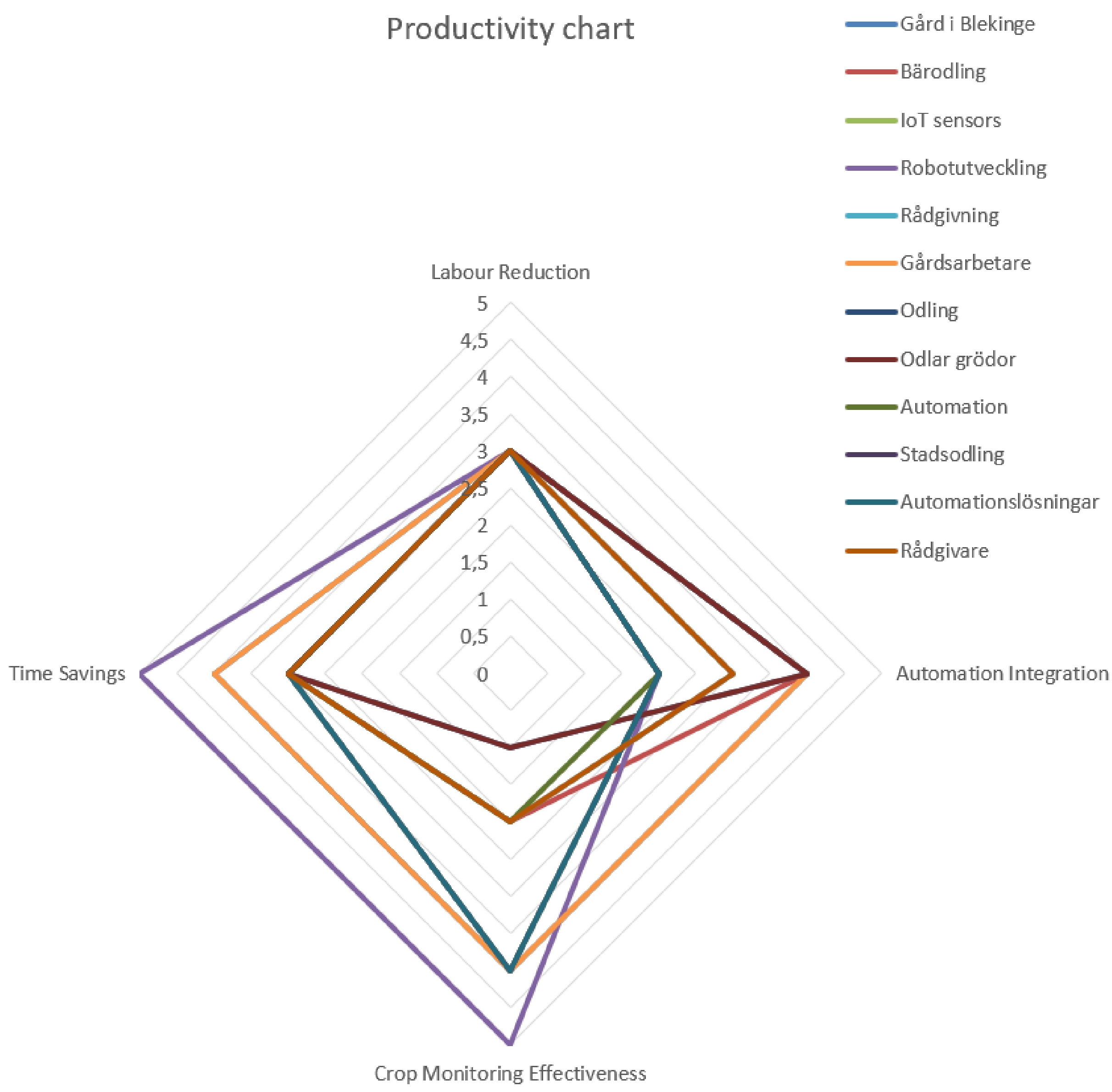

Figure 5 - productivity radar chart, with the Swedish names of the respondents

The following can be said about the responses for the productivity questions, see Figure 2 and Table 2:

Yield Efficiency – Median: 4. There is strong agreement across respondents that automation contributes positively to yield efficiency. Scores range between 2 and 5, with only one low score of 2, suggesting that is generally perceived as a good thing.

Labour Reduction - Median: 3. All respondents scored exactly 3. This reflects a consensus on whether automation reduces labour needs. Either the perceived effect is moderate or respondents are unsure about automations effects on labour in farming.

Automation Integration - Median: 3. Responses range from 2 to 4, with many giving midrange scores. This indicates that automation is somewhat integrated but not widely or consistently implemented as of yet.

Crop Monitoring Effectiveness - Median: 3. A highly varied set of responses, a range of 1 to 5, suggests that experiences with monitoring tools vary widely. Some find them very effective, others not at all, indicating inconsistent implementation or suitability in Swedish farming.

Time Savings - Median: 3. Responses are relatively consistent, 3 to 5, indicating that time savings are acknowledged by most, though not extremely impactful in all instances.

The radar chart in Figure 2 shows a clear gap when it comes to labour reduction.

4.2.2 Costs

Figure 6 - the costs radar chart, with the Swedish names of the respondents

The following can be said about the responses for the costs questions, see Figure 3 and Table 2:

Initial Investment - Median: 4. Relatively high scores may indicate that automation is seen as requiring a significant upfront investment. No extreme values, answers of 3 and 4 from all respondents, suggest this perception is broadly shared.

Maintenance Costs - Median: 2. Maintenance is not considered overly expensive, with most of the respondent scoring 2. A couple of higher scores, of 3, hint at some variation in opinion or use cases.

Cost Savings Over Time - Median: 4. There is a strong belief in long term economic benefits. Most gave 4 or 5, indicating this is a key strength of automation for many.

Energy Consumption - Median: 3. Mixed views. Some see no major issue with scores of 2, others give 4, indicating concern about increased consumption or variability depending on system type used by the respondent.

Financial Risk - Median: 3. Moderate concern with financial risk. Scores vary slightly more, of 2 to 5, indicating that financial exposure depends on the type of automation and farm size.

The radar chart, see Figure 3, shows a clear gap when it comes to maintenance costs.

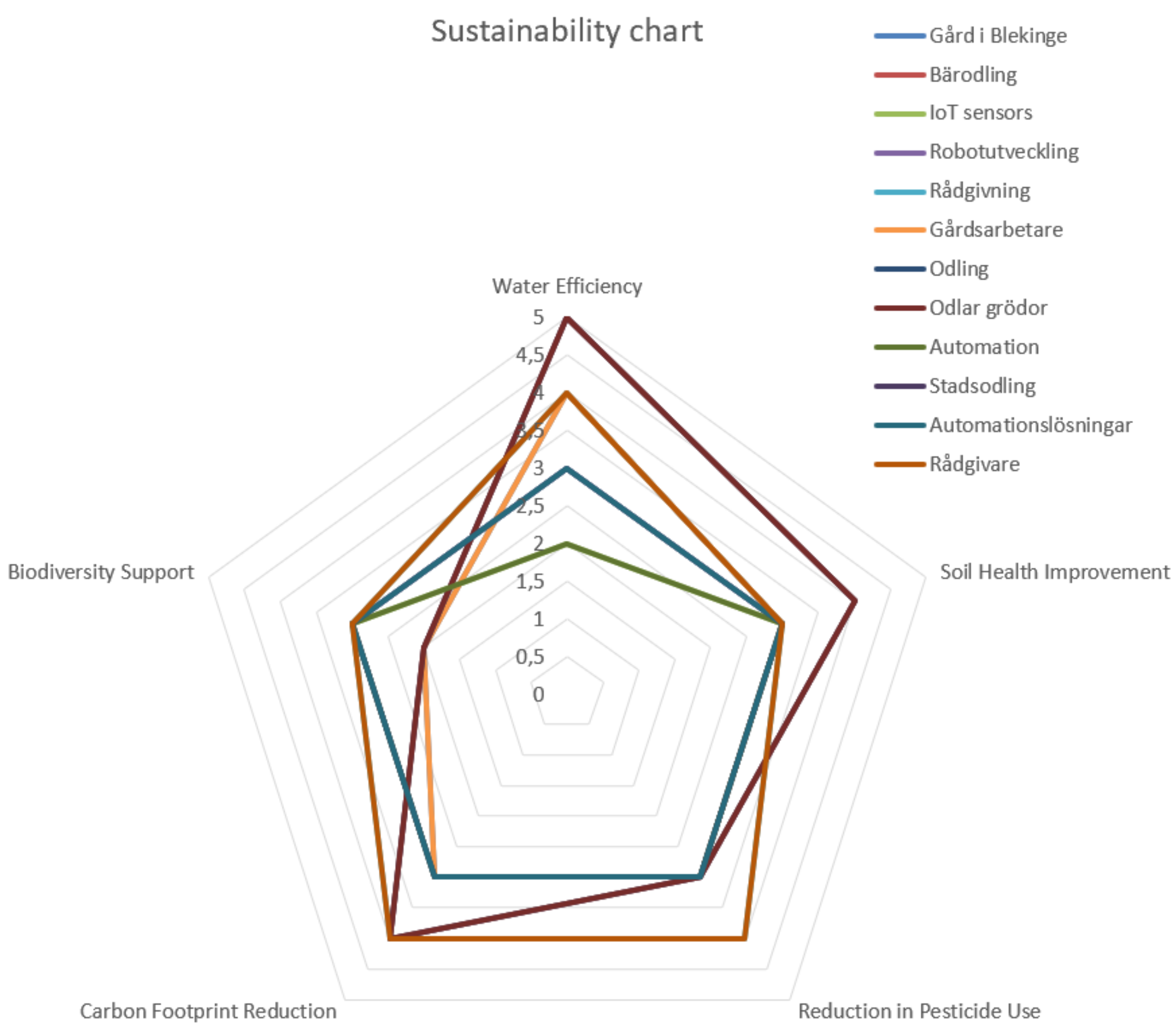

Figure 7 - the sustainability radar chart, with the Swedish names of the respondents

The following can be said about the responses for the productivity questions, see Figure 4:

Water Efficiency - Median: 4. There is generally a positive view of automations role in improving crop water efficiency, with only a few respondents assigning lower values. This indicates effective irrigation.

Soil Health Improvement - Median: 3. Consistent scores suggest a modest perceived benefit, but automation is not seen as a primary driver for better soil health.

Reduction in Pesticide Use - Median: 3. There is a consensus here, on a score of 3. This may indicate a minor or uncertain impact on pesticide reduction.

Carbon Footprint Reduction - Median: 3. Scores point to some belief in automation helping climate goals, though this effect is perceived as moderate.

Biodiversity Support - Median: 3. This is one of the the lowest score across the sustainability section. It implies automation is not widely perceived to support biodiversity directly, or its impact here is unclear.

The radar chart, see Figure 4, shows a clear gap when it comes to biodiversity support.

4.2.3 Open ended question answers

As seen in Appendix 2, according to the respondents, automation has had a significant impact on agriculture, mainly improving efficiency, productivity, and working conditions. Some mention that without automation, managing water and nutrients precisely would be difficult. However, some respondents feel that the current level of automation is still limited and could develop much more, especially since the technology potential exists but is not yet fully utilised. Costs and technical knowledge barriers slow down adoption for some. Overall, automation is making farming smoother and more effective, especially in irrigation and fertilization.

The biggest benefit stated in the answers, presented in Appendix 2, is increased productivity, including better yield and resource use. The precision of applying water and nutrients is also a key advantage, reducing waste. Challenges include the high cost of initial investments, technical difficulties such as poor user interfaces, lack of technological experience among farmers, and slow adoption due to these factors. Many note that these systems are still quite expensive and that better support or lower costs could help increase uptake.

The future is seen as promising and likely to bring more and faster automation developments, as presented in Appendix 2. Respondents expect more automation in all types of farming, driven by technological advances and the need for sustainability and efficiency. There is hope that automation will attract younger generations to farming and improve gender balance. However, financial risks and high costs are concerns that might slow progress. The overall outlook is positive, with increasing adoption expected as technology improves and becomes more affordable.

4.3 Prototype for Agricultural Automation Gaps in Sweden

Taking the results from the survey, there are gaps and potential improvements that could be filled by future automation solutions in agriculture. The gaps and potential improvements for the *productivity sector* can be summarised as follows. Labour Reduction is the lowest scoring productivity factor. It indicates that automation currently does not reduce manual labour significantly. Hence, there is clear potential to improve labour use by developing more autonomous solutions that take over repetitive manual tasks. Automation integration is not yet fully implemented or effective in many areas. This shows a gap in combining technologies smoothly or deploying them broadly on farms. Crop Monitoring Effectiveness is inconsistent and could be improved, especially by integrating better sensors and data analytics to provide timely insights. While time savings exist, this is not yet maximised, suggesting room for optimisation of processes and more autonomous scheduling. Yield Efficiency is a strength, showing that automation helps increase yields well.

For *costs* the gaps and potential improvements could be the following. Maintenance costs are relatively low, which is positive. However, this might reflect underuse of equipment or simple systems. Initial investments remain a barrier to adoption. Solutions need to be more affordable or have financing/support models to lower upfront cost for farmers. Financial Risk perception varies, the higher risk scores suggest uncertainty about returns or technology reliability. Energy Consumption shows that there is potential for improving energy efficiency, especially with renewable energy powered systems. Cost Savings Over Time are a strong motivator, but these depend on overcoming initial cost and risk barriers.

Sustainability gaps and potential improvements are summarized below. Biodiversity Support is the weakest sustainability aspect, showing little benefit or focus on supporting biodiversity through automation. Water efficiency is good in some cases but inconsistent. More precise irrigation and water management automation could help. Soil Health Improvement shows moderate results, more attention could be paid to minimising soil compaction or improving organic matter. Reduction in Pesticide Use has some impact on reducing chemicals, but potential exists to improve further with precise weeders or integrated pest management robots. Carbon Footprint Reduction has moderate benefits, this could mean that there are opportunities to design low emission autonomous machinery and optimise fuel or energy use.

A summary of the of insights from the automation gaps per category productivity, costs and sustainability would be that *productivity* is where automation shows the most positive impact, especially for yield efficiency and time savings. At the same time, for *costs* the cost savings over time is a major driver, although initial investments remains a barrier. *Sustainability* benefits are modest and vary by environmental factor, with water efficiency scoring highest and biodiversity support lowest. These results can be presented in a table, as seen below in Table 3. In the table the highest scores and the lowest scores are presented.

Table 3 - summary of gaps found for the three categories productivity, costs and sustainability

Category	Highest	Median	Lowest
Productivity	Yield Efficiency	4	Inconclusive
Costs	Initial Investment (negative) and Cost Savings Over Time	4	Maintenance Costs (positive)
Sustainability	Water Efficiency	4	Inconclusive

As seen in Table 3 above Yield Efficiency, Cost Savings Over Time, low Maintenance Costs and Water Efficiency currently has a high impact with current automation tools. The median show that most responders viewed automation of these areas positively, suggesting these are the areas where automation is seen as most beneficial. The Initial Investment is the largest gap in the current automation tools, giving that it is a high initial investment to get started.

4.3.1 Minimum viable product

Based on this, a prototype suggestion could be a modular unit för irrigation and fertilizing. This unit would move autonomously across fields, combining precision irrigation with real time crop and soil monitoring. It would reduce manual labour improve water efficiency and improve sustainability, if driven via solar power.

The prototype supports and potentially enhances yield efficiency by targeted irrigation based on soil moisture and crop growth data, ensuring optimal water supply. Real time monitoring of crop health using integrated sensors. Process automation via scheduling or sensor activation, that ensures operations are carried out at ideal times, reducing human error or delay. Since there is already effective tools for this in todays automation, it would be reasonable to build on that and integrate the already existing technology.

The Initial Investment for such a unit would normally be significant, particularly due to sensors and autonomous control systems. To address this, the prototype could be designed modularly, allowing farms to adopt it in stages, or offered via a leasing model to reduce upfront costs. This gradual implementation could also address the current gap in technological knowledge with the personnel operating the equipment.

Cost Savings Over Time could be realised through reduced labour needs, lower water and energy consumption, fewer losses due to poor watering schedules.

The unit could be specifically designed to enhance water efficiency by using soil moisture sensors to irrigate only when and where needed, adjusting water flow based on real time environmental conditions, logging and analysing water use to optimise irrigation schedules over time. The simplicity of using solar energy and modular hardware can help keep maintenance minimal. The prototype keeps with the current low concern around maintenance and ensures it stays low despite technological complexity.

4.4 Prototype of control system

Using the knowledge acquired from the previous section, a prototype can be presented. The core goal of the prototype is to enable a targeted, efficient irrigation of crops. The primary purpose is to irrigate plants only when and where it is needed. The prototype has been made using various sensors and output functions connected to an Arduino Uno rev3.

The idea is to place the prototype in the field or connected to some sort of growth point or pot where the crop is growing and stationarily monitor the crop at its location.

The Arduino Uno is a microcontroller base used to connect and code components for different use cases. [82]

The prototype can be seen below in Figure 6.

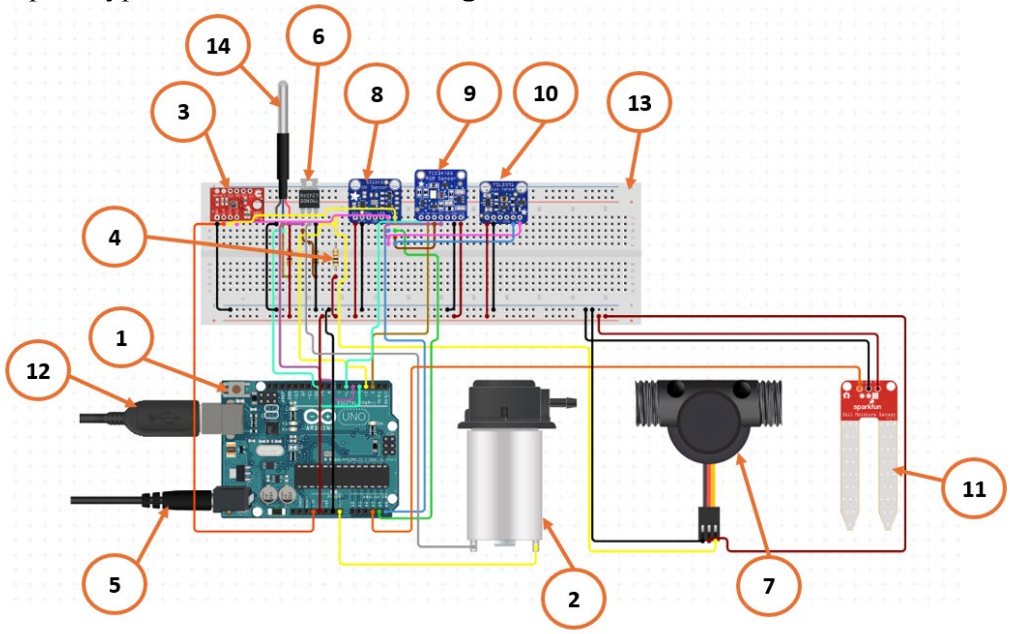

Figure 8 – Prototype circuit, based on the Arduino microcontroller

The following components in Table 4 have been used, and their position can be seen in Figure 6:

Table 4 - the components of the prototype and their positions in Figure 6 as well as their functions in the system

Position	**Name**	**Function**
1	Arduino Uno	Microcontroller base
2	Peristaltic Liquid Pump	Water pump for watering crops.
3	Atmospheric Sensor SparkFun BME280	This sensor provides detailed atmospheric conditions: air temperature, relative humidity and atmospheric pressure
4	4.7K Ohm Resistor	Necessary electrical component.
5	Power Supply 12VDC 2A	Necessary electrical component.
6	MOSFET Switch 60V 30A	Necessary electrical component.
7	Water flow sensor	Measures the water flow used for irrigation.
8	Light sensor SI1145	Measure the visible light, the different wavelengths of light including IR and UV index.
9	Colour sensor TCS34725	Measures the colour of the crop. Intended to react to the colours green, yellow and brown throughout the growth cycle.
10	Full spectrum light sensor TSL2591	This is a more advanced light sensor that provides very accurate readings of full spectrum light. It measures the light intensity in Lux and offers finer detail for monitoring light

		conditions critical for crop health and growth phases.
11	Soil moisture sensor	A crucial component for measuring the water content in the soil and deciding when to irrigate the crop.
12	Cable for signals	Necessary electrical component.
13	Breadboard	Necessary electrical component.
14	Waterproof temperature sensor DS18B20	Measures the soil temperature.
	Wires	Necessary electrical component.
	Electrical connectors	Necessary electrical component.

The prototype will measure the health data of the crop and take action only when and where it is needed. The multiple sensors provide detailed data for the different conditions:

- Light conditions
  - Helps determining the need for water volume of the irrigation system. The UV index helps assess sun exposure, which can indicate higher water demand. The visible light sensor gives essential information for photosynthesis and overall plant growth and alerts of poor crop placement. The IR light can indicate plant heat stress or simply presence of light, indication the quality of the crop placement. The full spectrum light sensor gives finer detail for monitoring light conditions critical for crop health and growth phases.
- Soil moisture
  - This is the most crucial sensor for irrigation decisions. It measures the water content in the soil and helps determining the need for water volume of the irrigation system.
- Air temperature
  - It is important for understanding evaporation rates and plant stress.
- Relative humidity

    - Measures evaporation and plant transpiration in the direct vicinity of the crop.
- Atmospheric pressure
    - Contributes to providing a full picture of the crop environment. Can be used with a prediction tool to predict future weather conditions.
- Soil temperature
    - Contributes to providing a full picture of the crop environment. Gives early indication for an oncoming frost or draught (alongside the air temperature measurements).
- Water flow
    - Controls the pump in relation to the need signalled by the other sensors.
- Colour variations in the crop
    - Measures the colour difference over time. Sends signals to fertilizing pump if the crop changes colour from green to yellow or brown, over time.

The prototype can be used for both watering and liquid fertilization. It can be used in multiples for multiple functions at once for one single crop. Since it is based on a modular system, the prototype can be adjusted as needs presents themselves and the investments in new technologies can be made gradually.

4.5 Prototype usage

The prototype can be programmed to be used as shown in the Figures 9-11 below. The Figures are to be seen as indicators of the useability of the prototype and how the sensors will interact with each other and the user.

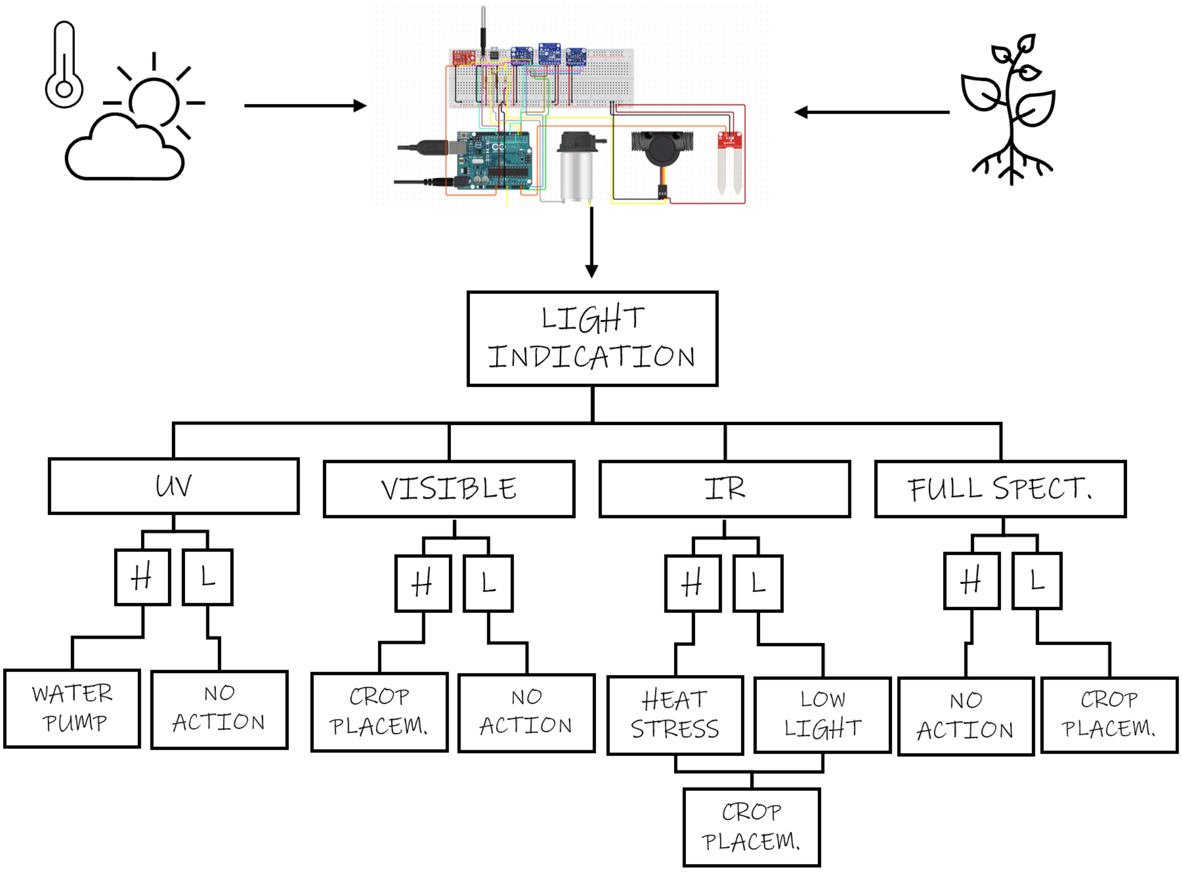

Figure 9 - Light indication chart

Figure 9 shows how the light sensors act depending on if the interpreted value is high (H), or low (L). Some light sensors can indicate issues with the crop placement, in this case the user will be alerted and appropriate action can be taken. If the chart leads to the water pump it is indicated that the crop requires additional watering and the prototype will signal to the water pump.

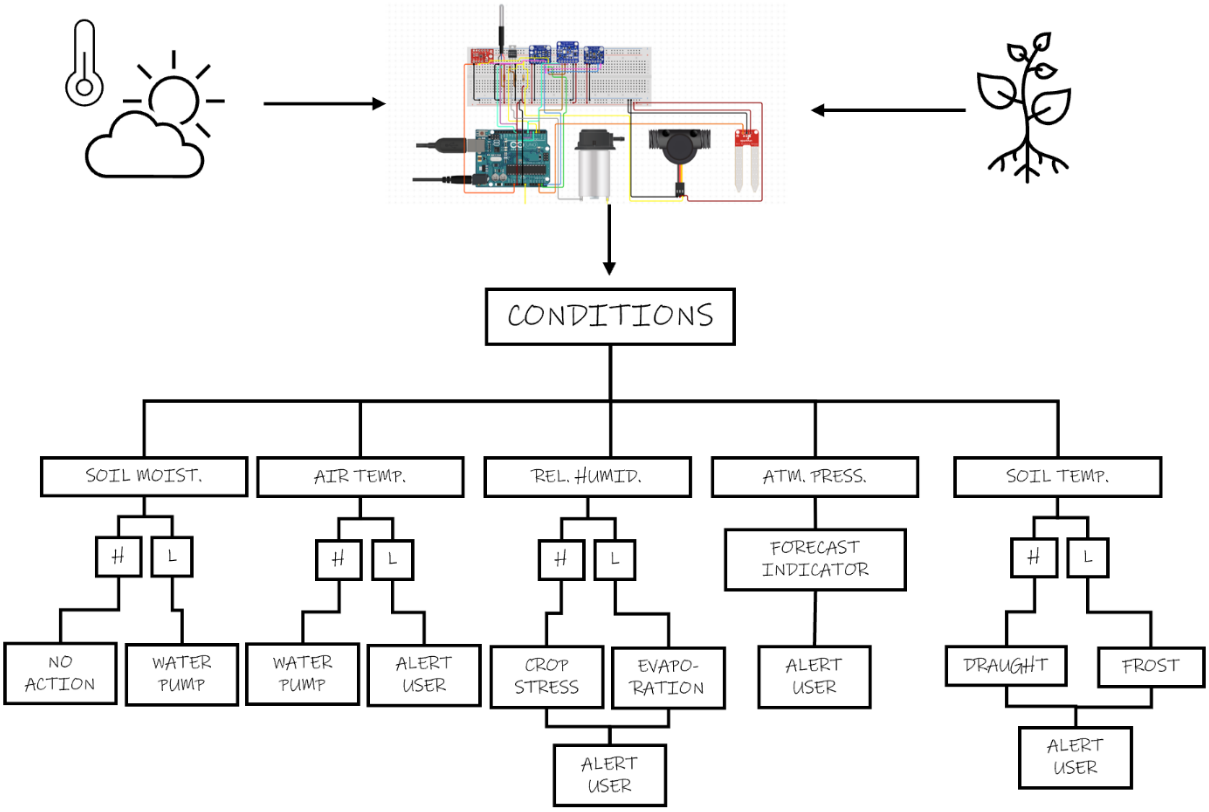

Figure 10 - Conditions chart

For the outer conditions, shown in Figure 10, the sensors also indicate high (H), or low (L) values. Depending on the indication, different action is taken. If the chart leads to the water pump it is indicated that the crop requires additional watering and the prototype will signal to the water pump.

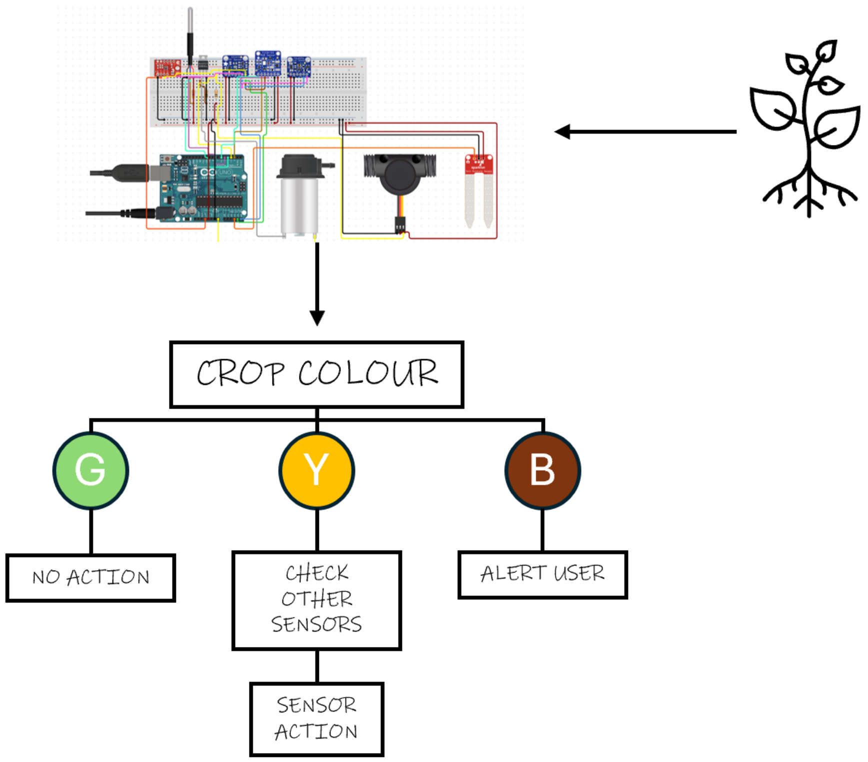

Figure 11 - Crop colour chart

In the crop colour chart, seen in Figure 11, the colour sensor will give indication for the colour of the crop itself. If the crop is green, no action is required. If the crop is yellow, input from the other sensors are required. If the crop is brown, the user is alerted to the crop health concerns.

5. Discussion

This discussion looks at the current state of agricultural automation in Sweden and how a recommended prototype could help solve some of the problems that farmers face today. The analysis is based on survey results and focuses on the three main areas of productivity, costs and sustainability. It also explains how the current state of farming shows important gaps in these areas and suggest how new innovation could support better use of automation in the future.

5.1 Automation implementations in Swedish agriculture

Despite the growing significance of automation in agriculture, finding specific sources on its implementation in Sweden proved challenging. This lack of readily available research may indicate that automation in Swedish agriculture is an emerging field with considerable opportunities for further exploration.

Swedish agriculture is undergoing a change due to fast growth in technology, new business models, and a stronger focus on environmental protection. These trends match the goals of Agenda 2030, which aims to achieve a more sustainable world. To reach these goals, Sweden is turning to digital and automated farming solutions. This includes using advanced technologies like robotics and smart systems to improve efficiency and reduce environmental impact.

In recent years, crop production has become more focused on growing single crops in large areas. This is mainly to fit the size and needs of modern farming machines. While this helps with higher food production, it also leads to negative effects such as less biodiversity and poorer soil health. The use of digital tools and data driven decisions in farming can help fix these problems. Technologies make it possible to use water, fertiliser, and pesticides in more exact amounts. This means less waste, better protection of the environment, and lower costs.

One big challenge is that many small and medium sized farms in Sweden cannot afford these new tools and technologies. Without help or support, they risk falling behind larger farms in other countries. This affects their chances to compete and produce food. Still, smart tools can bring many benefits like better crop yields, healthier soil, and fewer harmful chemicals. Even though some people are unsure about automation, these systems can make farming more efficient and reduce environmental harm.

Smart irrigation is a good example of using technology to help. It uses sensors and control systems to give crops water only when needed. This saves water and improves growth. Swedish companies like Vultus and IRRIOT are leading this area. Vultus uses satellite data to guide farmers on how much fertiliser and water to use. IRRIOT offers smart systems that use wireless technology and soil sensors to help farmers water more wisely and grow more crops.

Another company, Spowdi, helps small scale farmers in India with drip irrigation powered by solar energy. This system uses less energy and gives water directly to the plant roots. It saves water, improves crop growth, and is easy to move and share. This makes farming more efficient in rural areas.

Hydroponic farming is also growing in Sweden. This type of farming does not use soil and is often done indoors with water and nutrients. It is helpful in cities and areas with little farmland. One example is eSoil, developed by Linköping University. This new growing material helps plants grow better using small electric signals and is more sustainable than older materials. Other Swedish companies, like Swegreen and Grönska, grow vegetables indoors using hydroponics. Their systems use little water, no pesticides, and avoid long transport. This helps the environment.

Soil health is still a key concern. New tools like drones, satellites, and sensors help farmers measure things like soil moisture and nutrients. These tools give better data for farming decisions. Some systems are also linked to irrigation to use water only when needed. This helps protect soil and saves resources.

Research is also moving forward. RISE, a Swedish research institute, is testing electric and autonomous machines that can lower emissions and reduce soil damage. Smaller self driving machines can help small farms and reduce the need for heavy equipment. The EU is also funding a project to improve soil health in Europe. Sweden is part of this and is testing new ways to improve soil health in areas with a lot of land use.

Living labs like Finngarne farm are important for testing new ideas in real farm settings. These places work with companies and researchers to try out new tools and methods. This teamwork helps make sure the tools are useful and work well for farmers.

5.2 Current status of agricultural automation in Sweden and evaluating the Impact of Automation on Swedish Agriculture

The results from the survey help explain how different people see the pros and cons of using automation on Swedish farms. The results show that automation in Swedish agriculture is seen as most useful when it comes to improving productivity. Most of the participants believed it helps increase yield and save time, which suggests that automation is viewed as a good way to make work more efficient. When it comes to costs, many pointed out that automation can lead to savings over time, which makes it attractive in the long run. But the high cost of getting started is still seen as a problem for many. Views on sustainability were more mixed. Some thought automation had environmental benefits, but these were not as strong or consistent. Water efficiency was rated quite high, meaning people do see a link between automation and smarter use of water. On the other hand, biodiversity support got a lower score, showing that this is not a main focus or outcome of current automation solutions.

5.2.1 Productivity

Farmers and stakeholders generally seem to think automation has a positive influence on yield efficiency. Most respondents indicated that automation has enabled them to improve output. Although there were some differences in opinion, the overall answers suggests that automated systems have helped them get better harvests. This shows that the value of automation for increasing productivity can be great.

With regard to labour reduction there was a shared view that automation does ease some labour demands, but not substantially. This indicates that while machines and systems may reduce the time spent on tasks, they do not entirely remove the need for human involvement.

The reality is that automation is not yet fully implemented in Swedish agriculture. The results suggest that while some farms are making progress, widespread integration of automation is not yet the case.

Some participants reported that automation provides precise data that supports crop health and decision making. Others said it had limited use. This range highlights that while the potential of automated monitoring is widely recognised, its effectiveness still depends on factors such as equipment quality and the ability to interpret and act on the data generated.

Time savings were noted by most respondents. The respondents felt that automation allowed for faster execution of certain activities. These technologies helped reduce the time required for repetitive manual labour, freeing up resources for more strategic planning or specialised work.

5.2.2 Costs

Initial investment emerged as a common concern among respondents, with many indicating that adopting automation requires a considerable financial commitment. This reflects the cost of acquiring advanced equipment, installing necessary infrastructure, and training staff to use new systems.

Maintenance costs were seen as relatively low. Most participants reported that once systems are installed, the cost of keeping them functional remains manageable. This may be due to the durability of the technology, the availability of support services, or the simplicity of routine upkeep. This could indicate that the installation may be expensive but the ongoing financial burden does not increase as much over time, making automation more reasonable in the long run.

Respondents showed strong agreement on the when it came to long term cost savings. Almost all participants noted that automation eventually leads to financial efficiency. Reduced resource usage, improved productivity, and more targeted decision making makes this an important factor in automated farming.

Energy consumption attracted more mixed responses. While some participants were satisfied with the energy demands of their automated systems, others noted concerns about increased consumption.

The question of financial risk yielded a wider spread of answers. While some viewed automation as a good investment, others were more cautious, citing uncertainty about returns or the potential for costly system failures. This variation likely reflects differences in experience, economic stability, and the nature of the automation used.

5.2.3 Sustainability

Participants were generally optimistic about the potential of automation to improve water efficiency. Many noted that automated irrigation and sensor systems made it possible for them to better manage when and how water is used for crops. This contributes to resource conservation and more stable yields. Not all respondents reported the same level of improvement, but there was a clear sense that automation supports more responsible water use.

While automation may support better soil conditions the technology is not seen as a major driver for this. While the technology is helping farmers use pesticides more efficiently, significant reductions may require broader changes.

Opinions on carbon footprint reduction were cautiously positive. Many participants noted that automation might help lower emissions, particularly by replacing older equipment with more efficient machines or by optimising transport and fuel use. Nevertheless, these improvements appear incremental rather than transformative. The sustainability benefits of automation are present, but not consistently strong across all farm activities.

Support for biodiversity was one of the least recognised benefit among respondents. Most viewed automation as having little or no direct impact in this area.

5.3 Prototype for Agricultural Automation Gaps in Sweden

Yield Efficiency, Cost Savings Over Time, low Maintenance Costs and Water Efficiency as well as the Initial Investment are the largest gaps in the current automation tools.

To address these gaps and potentials an automation tool for irrigation and fertilisation is recommended. The prototype developed in this project shows good potential to help with some of the current gaps in farming automation, especially for targeted irrigation and crop monitoring.

Using the Arduino Uno microcontroller made it affordable and flexible to connect different sensors. These sensors measure things like soil moisture, light, temperature, humidity, and crop colour etc. This helps the system water the plants only when and where it is needed, saving water and helping crops grow better. The modular design is also a strength because farmers can start small and add more features later, which makes it easier and less expensive to adopt (smaller initial costs). Having many sensors gives plenty of useful information that could help improve the system further in the future.

There are some limitations to the system. The prototype is still at an early stage and was made mainly for prototyping/testing, and not for real farm use. The current hardware setup, like open wiring and breadboards, is not strong or weatherproof enough for outdoor farming conditions long term. Some sensors are basic, that might not always give reliable or accurate readings over time, which could be a problem in real life during prolonged testing.

5.4 Future studies

In my study, many participants chose the midpoint (3 out of 5) on the interview scale, which made it difficult to draw clear conclusions from their answers. Midpoints often reflect uncertainty or neutrality, offering little insight into the participant's actual opinion. For future studies, I recommend using a scale without a midpoint to encourage participants to take a clearer stance. This could lead to more meaningful and informative results.

Another improvement for future studies would be to group respondents in a more meaningful way, based on relevant factors such as their role, experience, or level of involvement with the topic. This would make it easier to identify patterns or differences between groups and allow for more targeted analysis, rather than treating all responses as equally representative.

The prototype needs to be tested over time in order to further determine its potential for monitoring crop health. The test should be conducted with two control groups, one crop left alone and one taken care of by traditional methods (ocular control). The prototype should be used side by side with the control groups and the crop health compared between the groups. This is recommended for further studies.

Real life application of the prototype is recommended for future studies in the field. The user interface must be adopted for the intended user base.

6. Conclusion

- Sweden is exploring digital and automated technologies in agriculture to improve productivity and sustainability.
- Productivity is where automation shows the most positive impact, especially for yield efficiency and time savings. Cost savings over time is a major driver, although initial investments remain a perceived barrier. Sustainability benefits are modest and vary by environmental factor, with water efficiency scoring highest and biodiversity support among the lowest
- An automated irrigation and fertilisation system based on the Arduino Uno is the recommended prototype.

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Appendix 1 - Survey questions

Avsnitt 1 av 5

Automation inom odling av grödor i Sverige

Denna undersökning genomförs inom ramen för ett kandidatarbete vid Sveriges lantbruksuniversitet (SLU) och syftar till att undersöka automationens roll inom svenskt jordbruk. Fokus ligger specifikt på växtodling och hur automatiserade system påverkar produktivitet, ekonomisk lönsamhet och hållbarhet. Studien omfattar inte djurhållning eller automation kopplad till animalieproduktion.

Formuläret innehåller både flervals- och öppna frågor. Flervalsfrågorna använder en femgradig skala där du bedömer olika aspekter av automation i din verksamhet. De öppna frågorna är frivilliga och ger dig möjlighet att dela med dig av dina erfarenheter och perspektiv i större detalj.

Alla frågor besvaras subjektivt och utifrån din egen uppfattning.

Undersökningen tar cirka 5–10 minuter att genomföra.

Tack för din medverkan!

Vilken typ av verksamhet är du aktiv inom? *

Lång svarstext

Jobbar du med automationslösningar inom jordbrukssektorn? *

- ◯ Ja
- ◯ Nej

Vilken åldersgrupp tillhör du? *

- ◯ 1-17 år
- ◯ 18-25 år
- ◯ 26-35 år
- ◯ 36-45 år
- ◯ 46-55 år
- ◯ 56-65+ år

Könstillhörighet *

- ◯ Man
- ◯ Kvinna
- ◯ Vill inte ange

Avsnitt 2 av 5

Produktivitet

Beskrivning (valfritt)

Hur förbättrar automationslösningar effektivitet inom jordbruket? *

- Inte alls effektivt
- Lite effektivt
- Varken effektivt eller ineffektivt
- Ganska effektivt
- Mycket effektivt

I vilken utsträckning har automation bidragit till att minska behovet av arbetskraft inom jordbruket? *

- Inte alls
- I liten utsträckning
- Till viss del
- I hög utsträckning
- I mycket hög utsträckning

Hur väl är automation integrerat i jordbruksverksamhet? *

- Inte alls integrerat
- Till viss del integrerat
- Måttligt integrerat
- Ganska väl integrerat
- Fullt integrerat

Hur effektiva är automatiserade system för att bevaka grödor? *

- Inte alls effektiva
- Mindre effektiva
- Varken effektiv eller ineffektiva
- Ganska effektiva
- Mycket effektiva

Hur mycket tid sparar automatiserade teknologier i arbetsmoment inom jordbruket? *

- Ingen tidsbesparing
- Liten tidsbesparing
- Måttlig tidsbesparing
- Betydande tidsbesparing
- Mycket stor tidsbesparing

Avsnitt 3 av 5

Kostnader

Beskrivning (valfritt)

Hur betydande är den initiala investeringen som krävs för automation inom jordbruket? *

- Obetydlig
- Mindre betydande
- Måttligt betydande
- Ganska betydande
- Mycket betydande

Hur kostsamt är underhåll av automatiserat jordbruk? *

- Inte alls kostsamt
- Låga kostnader
- Måttliga kostnader
- Höga kostnader
- Mycket höga kostnader

I vilken utsträckning har automation lett till kostnadsbesparingar över tid? *

- Inte alls
- I liten utsträckning
- Varken stor eller liten utsträckning
- I hög utsträckning
- I mycket hög utsträckning

Hur mycket har automation påverkat energiförbrukning inom jordbruket? *

- Ingen påverkan
- Liten påverkan
- Måttlig påverkan
- Stor påverkan
- Mycket stor påverkan

Hur stor finansiell risk förknippar du med att implementera automation? *

- Ingen risk
- Låg risk
- Måttlig risk
- Hög risk
- Mycket hög risk

Avsnitt 4 av 5

Hållbarhet

Beskrivning (valfritt)

Hur har automation förbättrat effektiv vattenansvändning för bevattning av grödor? *

- Inte alls
- I liten utsträckning
- Varken stor eller liten utsträckning
- I hög utsträckning
- I mycket hög utsträckning

I vilken utsträckning har automation bidragit till bättre jordhälsa? *

- Inte alls
- I liten utsträckning
- Varken stor eller liten utsträckning
- I hög utsträckning
- I mycket hög utsträckning

Hur mycket har automation minskat användningen av bekämpningsmedel inom jordbruket? *

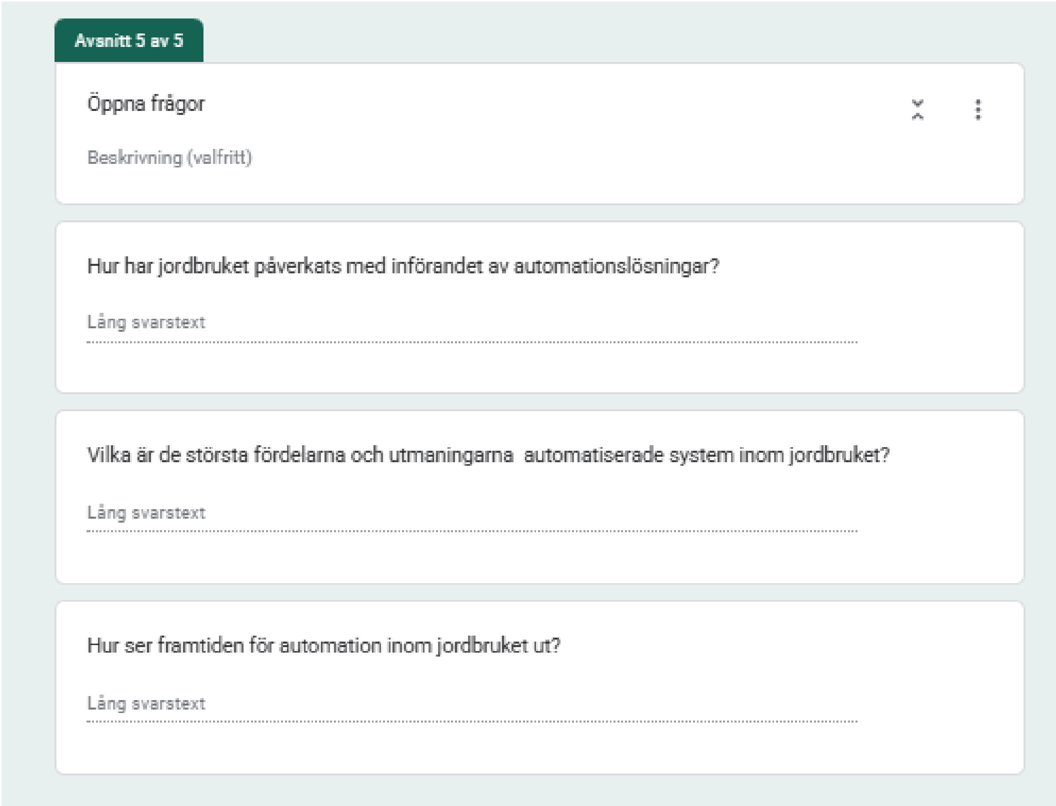
- Inte alls
- I liten utsträckning
- Varken stor eller liten utsträckning
- I hög utsträckning
- I mycket hög utsträckning

Hur väl har automation bidragit till att minska jordbrukets koldioxidavtryck? *

- Inte alls
- Till viss del
- Måttligt
- Ganska väl
- Mycket väl

Hur har automation stöttat biologisk mångfald inom jordbruket? *

- Ingen påverkan
- Liten påverkan
- Måttlig påverkan
- Stor påverkan
- Mycket stor påverkan



Avsnitt 5 av 5

Öppna frågor

Beskrivning (valfritt)

Hur har jordbruket påverkats med införandet av automationslösningar?

Lång svarstext

Vilka är de största fördelarna och utmaningarna automatiserade system inom jordbruket?

Lång svarstext

Hur ser framtiden för automation inom jordbruket ut?

Lång svarstext

Appendix 2 - Survey answers

Vilken typ av verksamhet är du aktiv inom?

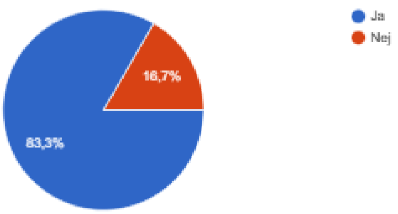
12 svar

- Sensorer och automation
- Rådgivning
- Arbetar på gård i Blekinge
- Rådgivare
- Gårdsarbetare
- Jag jobbar på en odling
- jobbar med automationslösningar i stadsodling
- robotutveckling
- Internet of things or sensors

Jobbar du med automationslösningar inom jordbrukssektorn?

Kopiera diagram

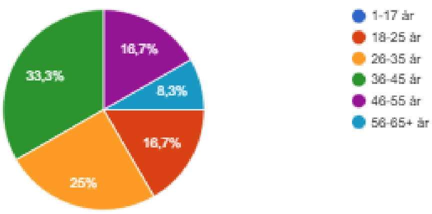
12 svar



Vilken åldersgrupp tillhör du?

Kopiera diagram

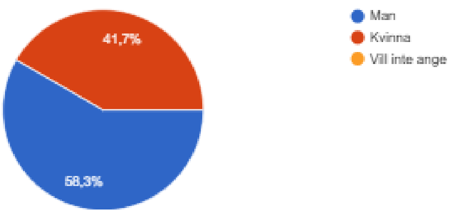
12 svar



Könstillhörighet

Kopiera diagram

12 svar

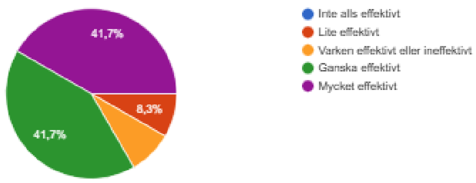


Produktivitet

Hur förbättrar automationslösningar effektivitet inom jordbruket?

Kopiera diagram

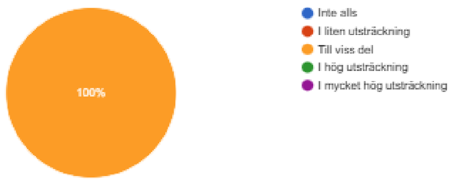
12 svar



I vilken utsträckning har automation bidragit till att minska behovet av arbetskraft inom jordbruket?

Kopiera diagram

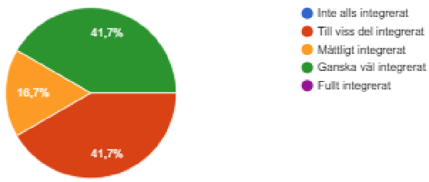
12 svar



Hur väl är automation integrerat i jordbruksverksamhet?

Kopiera diagram

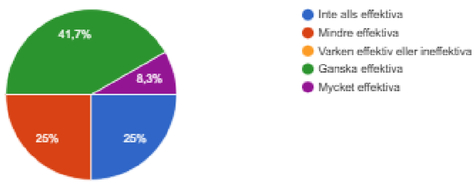
12 svar



Hur effektiva är automatiserade system för att bevaka grödor?

Kopiera diagram

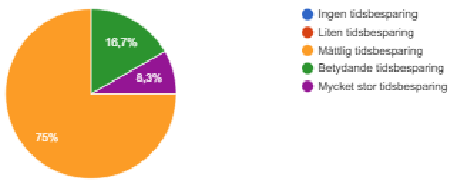
12 svar



Hur mycket tid sparar automatiserade teknologier i arbetsmoment inom jordbruket?

Kopiera diagram

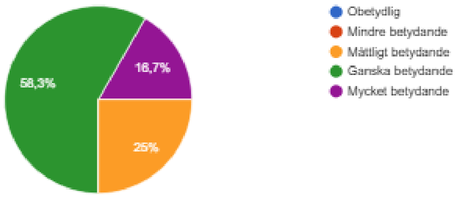
12 svar



Kostnader

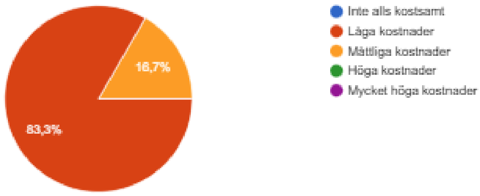
Hur betydande är den initiala investeringen som krävs för automation inom jordbruket? Kopiera diagram

12 svar



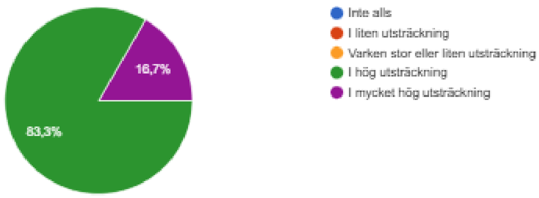
Hur kostsamt är underhåll av automatiserat jordbruk? Kopiera diagram

12 svar



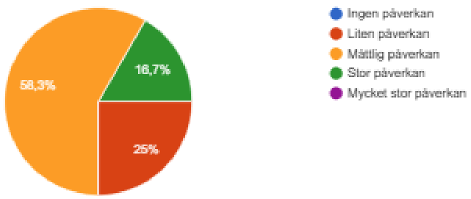
I vilken utsträckning har automation lett till kostnadsbesparingar över tid? Kopiera diagram

12 svar



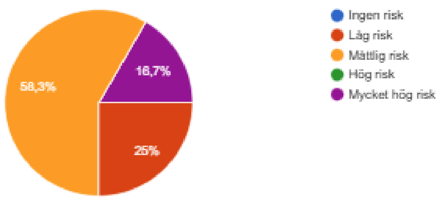
Hur mycket har automation påverkat energiförbrukning inom jordbruket? Kopiera diagram

12 svar



Hur stor finansiell risk förknippar du med att implementera automation? Kopiera diagram

12 svar

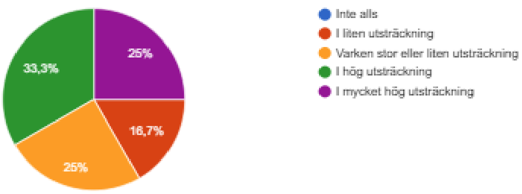


Hållbarhet

Hur har automation förbättrat effektiv vattenansvändning för bevattning av grödor?

Kopiera diagram

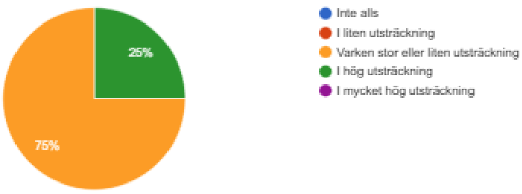
12 svar



I vilken utsträckning har automation bidragit till bättre jordhälsa?

Kopiera diagram

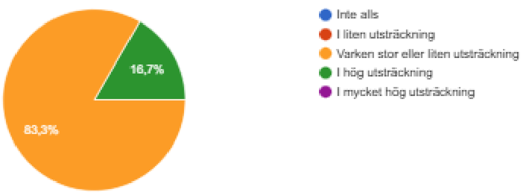
12 svar



Hur mycket har automation minskat användningen av bekämpningsmedel inom jordbruket?

Kopiera diagram

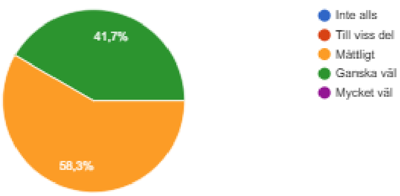
12 svar



Hur väl har automation bidragit till att minska jordbrukets koldioxidavtryck?

Kopiera diagram

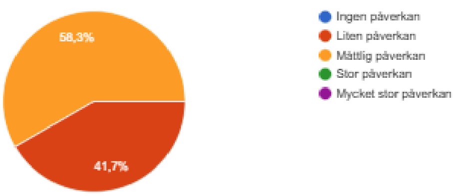
12 svar



Hur har automation stöttat biologisk mångfald inom jordbruket?

Kopiera diagram

12 svar



Öppna frågor

Hur har jordbruket påverkats med införandet av automationslösningar?

11 svar

Just nu har det inte skett en så stor påverkan. Det hade kunnat vara mycket mer, potentialen finns med tekniken men det används inte. Det är också rätt dyrt.

Införandet av automationslösningar har haft en stor inverkan på jordbruket. Tex Ökad effektivitet och produktivitet och förbättrad arbetsmiljö

Det har blivit mer effektivt

Det känns som att effektivitet och så vidare har blivit bättre mer mer automation. Det har skett en stor förändring de senaste åren. Även arbetsmiljön har blivit bättre.

Det har gjort det så mycket smidigare att bedriva vår verksamhet! Speciellt automatiserad bevattning och gödning

om det inte vore så dyrt så skulle det nog ha påverkat mer

inte mycket än

Vilka är de största fördelarna och utmaningarna automatiserade system inom jordbruket?

11 svar

De största fördelarna är att produktiviteten ökar. Men det är svårt att få användarna att komma igång just nu, det är gamla interface och en rätt dyr initialkostnad. Det kanske blir bättre när det är mer etablerat.

Ökad produktivitet är en stor fördel. En stor nackdel är de höga investeringskostnaderna.

Det är dyrt men funkar bra

Det är rätt dyrt att komma igång men allting går bättre och snabbare.

Det har skett en effektivisering när det gäller bevattning och gödning. Det känns hållbart. Allt får precis det som behövs, inte mer. Det gör att man sparar på både klimat och pengar.

många som jobbar med jordbruk har inte så bra datavana, det är dyrt att komma igång

ger bättre uppfattning om hur det går och vad som behöver göras

Utmaningarna är många som IT vana, dåliga användargränssnitt och än så länge dyra system, men när konkurrensen ökar och användarna blir mer erfarna, så kommer hållbarheten bli bättre och produktionen

Hur ser framtiden för automation inom jordbruket ut?

11 svar

Det kommer bli mer och mer, men bara om intresset för det fortsätter att växa

Framtiden för automation inom jordbruket ser lovande ut, med en allt snabbare utveckling av teknik som kan göra jordbruket mer effektivt, hållbart och lönsamt.

Det ser positivt ut, trenden går åt rätt håll

Jag tror att framtiden är ljus, utvecklingen går snabbt och det känns som att det driver allting framåt i rätt riktning

Det kommer att utvecklas till ännu mer automation inom all typ av jordbruk.

om fler företag använder sig av det kommer det att driva utvecklingen

långsamt införande på grund av finansiella risker ej önskade och hanteras ej av staten

Den är viktig också för att attrahera en yngre generation och en ökad jämställdhet.