Finnish Future Farm speeding up the uptake of Precision Agriculture

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Abstract

The Finnish Future Farm (FFF) is an innovative concept that seamlessly integrates a physical Smart Farm with a Digital Twin, complemented by educational programs and business development opportunities. This holistic approach aims to propel the evolution of Smart Agriculture in Finland.

At its core, FFF is a platform for co-creation with a strong emphasis on User-Centered Design. It employs a Multi-Actor Approach, bringing together companies, experts, researchers, and end users to collaborate closely in the development process. The primary focus of this collaboration is to thoroughly understand the needs and use cases of end users. This user-centric approach ensures that the resulting technologies, education packages, and business models are tailor-made to meet the specific requirements of those who will use them. This, in turn, enhances their acceptability and adoption, thus accelerating innovation in Smart Agriculture.

FFF is the culmination of several research and development projects. These projects have led to the establishment of the physical Smart Farm, which serves as a real-world testing ground complete with a Smart Bioeconomy Testbed. Additionally, FFF boasts the BioBoosters business accelerator, strategically located in Saarijärvi, Central Finland. This accelerator collaborates with an international network to nurture and boost innovative agricultural startups.

A crucial component of FFF is its Digital Twin, which utilizes data generated by the Smart Farm itself, the participating companies, and a network of selected farms. This digital counterpart enables precise monitoring, analysis, and optimization of various farming processes, contributing to increased efficiency and sustainability.

In parallel, FFF prioritizes education and training by offering specialized programs closely integrated with the Smart Farm and Digital Twin. This unique learning experience benefits students, researchers, and agricultural professionals, providing them with hands-on exposure to cutting-edge practices and technologies in Smart Agriculture.

In essence, the Finnish Future Farm is a comprehensive initiative built on collaboration, data-driven insights, and a strong commitment to meeting the needs of end users. Through its multi-faceted approach, FFF is driving forward the frontiers of smart agriculture and bioeconomy in Finland, fostering innovation and sustainable growth in the sector.

Key words: Smart Farming, Testbed, Digital Twin, Education, Business Accelerator

1. Introduction

Technologies related to sustainable development in agriculture have existed for a long time, but their practical application has been slow (Haapala, 2013). For example, technologies necessary for precision farming have been available since the 1990s (Haapala, 1995), but only a few have been widely adopted (Anand et al., 2023). Precision farming technologies such as field navigation and yield mapping are the most utilized, but site-specific control of production inputs is relatively underutilized (Talero Sarmiento, Parra-Sánchez & Lamos-Diaz, 2022). Smart farming, which utilizes precision farming technologies and intensive data processing, has gained attention in recent years. However, the adoption of smart farming also faces new obstacles, such as poor data availability and practical challenges of a fair data economy.

Failure to use technologies that promote sustainability leads to unrealized potential and unmet Sustainable Development Goals (SDGs). Additionally, if there is a failure in the adoption phase, all the effort put into developing these technologies is virtually wasted. Thus, promoting adoption is desirable and economically viable.

Overcoming this challenge requires actions to eliminate obstacles to the adoption of smart technologies. These barriers exist in various areas related to the acceptability of solutions (Nielsen, 1993), not solely economic, which is often cited as an explanation for poor adoption (Haapala, Pesonen & Nurkka, 2006; Haapala & Pasila, 2009). In agriculture, the end users of innovations are primarily farmers, who are often conservative and cautious adopters of new technologies. Fundamental reasons are related to lacking trust and a low level of willingness to take risks (Wielinga et al., 2017). New technology itself induces fear and uncertainty, leading to reluctance in investment. Uncertainty rises often since decision-making suffers from a lack of reliable and unbiased information regarding the effectiveness of alternative solutions.

Two projects were initiated to address these challenges. The goal of the development project for the Smart Farm at the Bioeconomy Campus (2021–2023) was to establish a unique hub for smart agriculture technology expertise in Tarvaala, Saarijärvi, in Central Finland. The resulting Smart Farm would provide an opportunity to test, develop, and demonstrate near-market (TRL 7-) technologies and services. The aim was to remove barriers to their adoption and accelerate innovation in the sector, significantly increasing the benefits for farmers and the related agricultural industry.

The Smart Farm project laid the groundwork for the Finnish Future Farm (FFF) project that commenced immediately after it. The FFF (2023-2026) involves a physical Smart Farm linked to a digital twin of the farm and extensive education and business acceleration sections (Fig. 1).

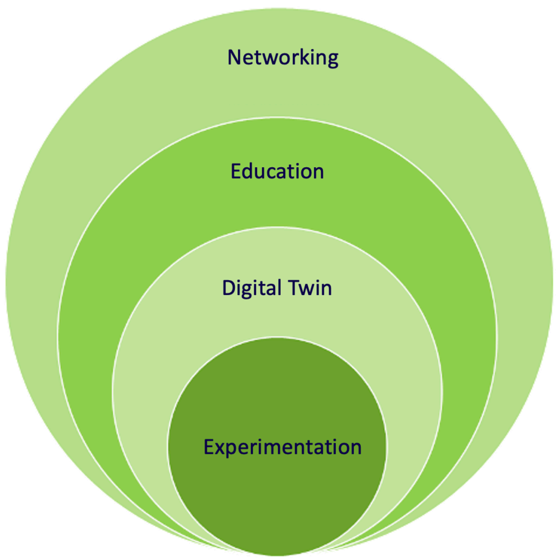

Figure 1. FFF project structure. The Smart Farm forms the foundation for experimentation upon which a virtual digital twin is created, along with an educational and networking component that utilizes them (Haapala et al. 2024).

The primary goal of FFF is to accelerate the adoption of Smart Farming technologies, contributing to the realization of the UN Sustainable Development Goals (SDGs). The Smart Farm, along with a network of partner farms, will analyze these technologies through a heavily instrumented setup. The Digital Twin will involve integrated use of GIS data and a metaverse environment.

In this paper, the FFF project's development route is reported, including the Smart Farm and the Smart Bioeconomy Testbed, a member of the Nordic Testbed Network since 2022. Conclusions regarding the potential establishment of a future center of excellence are outlined.

2. Materials and Methods

The establishment of the Smart Farm commenced in 2021 with an extensive needs assessment, recognizing the critical requirement for abundant, high-quality data, as Smart Farming fundamentally relies on the generation and utilization of big data (Wolfert et al., 2017). The primary objective was to optimize the functionalities necessary for the Smart Farm by leveraging various essential data types, thereby laying the foundation for future operations aimed at promoting broader adoption.

Given the pivotal role of precision farming in achieving Sustainable Development Goals (SDGs), the project prioritized the collection of sensor data essential for its implementation, along with data generated by tractors and machinery. Additionally, the performance of data transmission was rigorously measured, which is expected to become increasingly critical with the advancement of automation technologies.

During the growing seasons of 2022 and 2023, intensive data collection was conducted on approximately 16 hectares of experimental plots where barley was cultivated. Barley was selected as the test crop due to its prevalence as a typical cereal crop in the region. Regular measurements were obtained from the soil, crops, and machinery equipped with ISOBUS technology.

The implementation of precision farming practices was systematically compared to traditional farming methods at the Huipuri test plot, characterized by its highly variable and challenging conditions. Half of the plot was subjected to precision fertilization and field navigation techniques, while the other half was managed using a standard fertilization approach and no navigation aids in use. The Maatalo plot was designated as an experimental control area (Figure 2).

Figure 2. Test Plots. On the left, a drainage map; on the right, the division of the Huipuri field for precision farming and traditional cultivation.

Various measurement instruments were employed in the test plots, including 20 wireless soil sensors (Figure 3), drone imaging equipped with RGB, multispectral, and thermal cameras, soil scanning equipment, satellite imagery, and tractor telematics data. Soil compaction was measured using positioned penetrometer measurements.

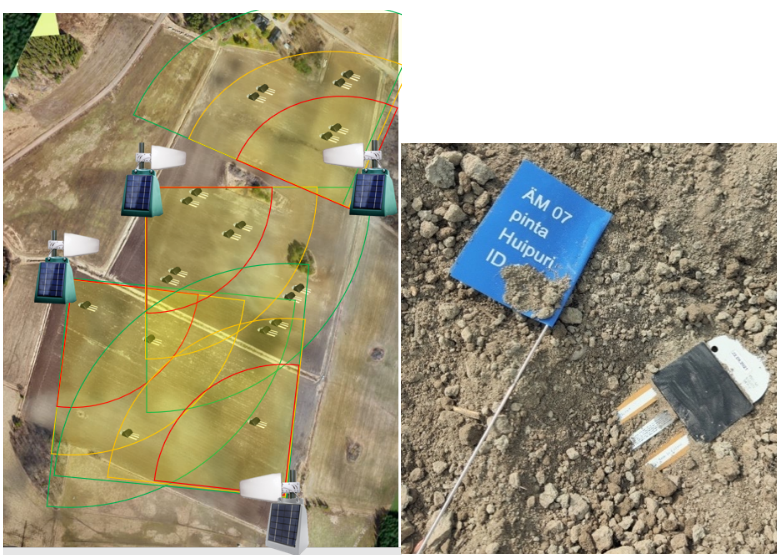

Figure 3. Placement of wireless soil sensors and repeaters in the experimental plots (left). The sensor and its labeling (right).

3. Results and discussion

Automated field navigation with headland automation was systematically compared to traditional manual driving methods (Figure 4). Utilizing Geographic Information Systems (GIS) and advanced data analysis techniques, various maps were generated from the collected data. These maps included detailed assessments of profitability and energy consumption, providing critical insights into the operational efficiencies and economic viability of the implemented technologies.

Figure 4. Route map during the sowing process. Automatic steering on the left, manual steering on the right.

Precision fertilization was applied. Based on soil measurements (including soil sensors, soil scanning, soil sampling, and drone imaging), the selected fertilizer levels were selected (Figure 5).

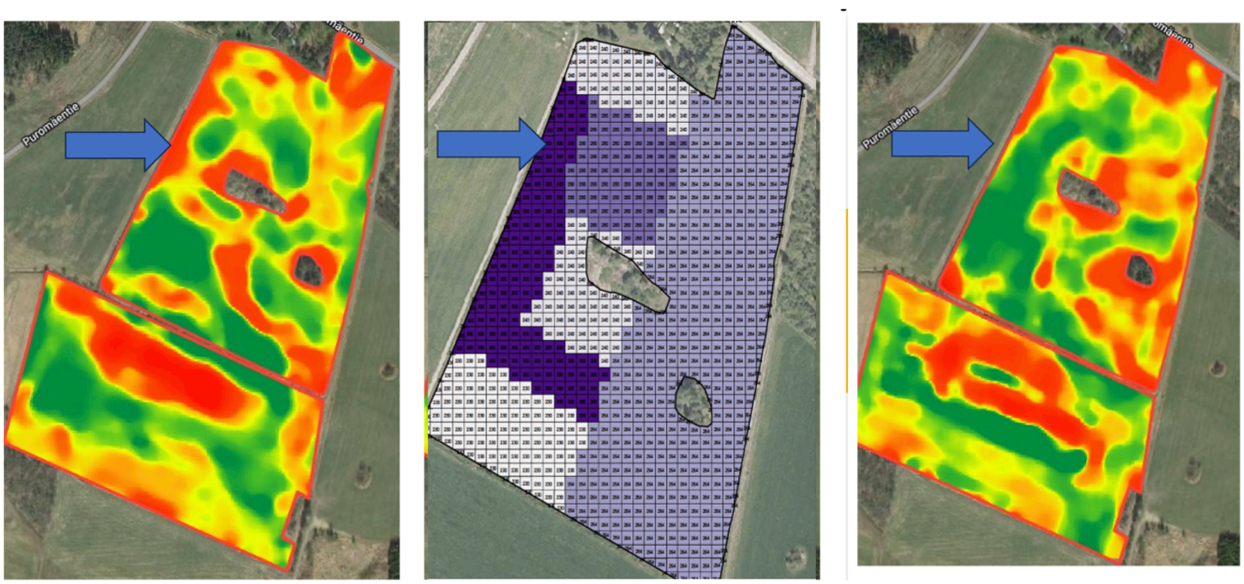

Figure 5. Precision farming in the experimental plots in 2022 and 2023. On the left, the yield map for 2022; in the middle, the fertilization map for 2023; on the right, the yield map for 2023.

To ensure that data remains under the farmer's control and is accessible to various stakeholders, a dedicated Farmer's Data Warehouse was developed. This system enables farmers to license their data to specific destinations via a data intermediation service. The implementation of the Farmer's Data Warehouse was demonstrated using example datasets, including drone imagery and soil sensor-produced data (Figure 6).

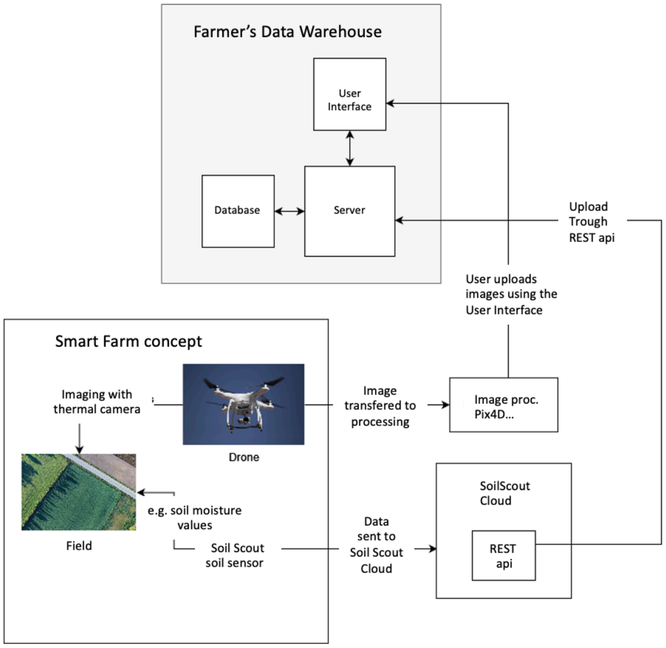

Figure 6. Farmer's Data Warehouse, featuring drone images and soil data produced by soil sensors.

To test the fluency of data transfer between the Farmer's Data Warehouse and auxiliary systems, the operation of a novel data intermediating system compliant with the new EU data regulations was demonstrated in collaboration with partner companies (Dataspace Europe, Soil Scout and Yield Systems).

Usability of 5G in machinery control was measured. In the 5G measurements performed, the signal coverage and usability were verified through field measurements and simulations. These measurements demonstrated if the tested measurement method, terminal devices, and measurement software were feasible. Test setups validated the effects of buildings, forest canopy, and varying terrain elevations on the coverage of the 5G network signal (Figure 7).

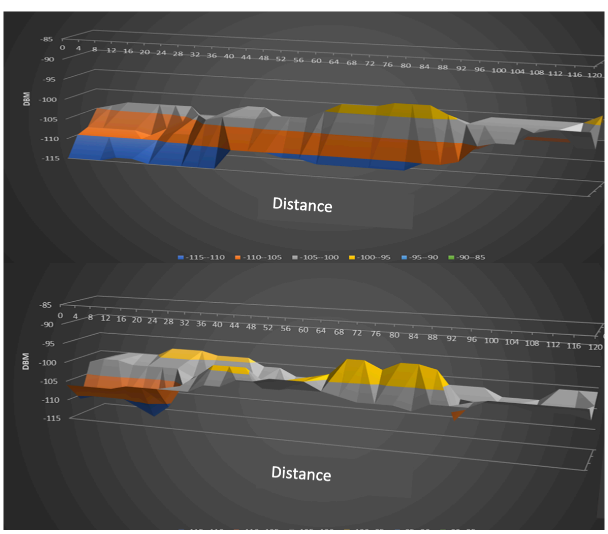

Figure 7. Field strength values (dBm) in terrain measurements at antenna heights of 2 and 3.5 meters. The yellow color indicates best values.

Economics maps were generated from the data using GIS software. All costs and income were calculated for defined grids, e.g. 10x10 meters. The data also included the work time spent in each grid point since it was available from the telemetry data of the tractor. These maps are useful tools for precision agriculture, allowing for targeted interventions based on the specific conditions of different parts of the field. (Figures 8-9)

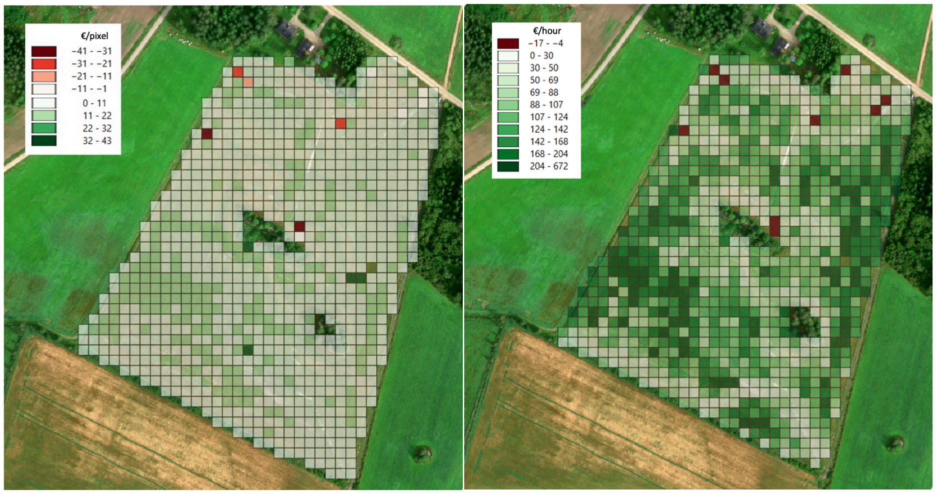

Figure 8. Economic maps. On the left: return map: on the right hourly wage map. Both presented on a 10x10 meter grid.

To fulfil the requirements set by the use cases, the Finnish Future Farm (FFF) employs a Multi-Actor Approach, engaging experts and users in collaborative efforts to enhance the acceptability of solutions. The project focuses on near-market technologies (Technology Readiness Level 7+), developed in collaboration with leading companies such as Valtra Inc., AgcoPower Inc., and Neste Inc., as well as innovative start-ups. These near-market solutions are analyzed to identify adoption challenges, followed by the application of Research, Development, and Innovation (RDI) actions, and supporting measures. Tailored education for users, designers, and marketers is provided as needed. Business development and acceleration services are offered through the BioBoosters acceleration program, which includes investors and venture capital.

In the FFF project, the development of the digital twin began with selecting the development environment, opting for a metaverse alongside related GIS software. These components are being integrated into a visually feasible solution with the assistance of gaming and data analytics experts. The resulting digital twin will encompass the smart farm described previously.

Incremental use cases are utilized to build the system, mirroring the step-by-step approach used for the physical farm. The solution incorporates open-source features from public sources such as the National Land Survey and the Finnish Meteorological Institute and includes simulation models of plant growth and other biological systems. The heavily instrumented smart farm serves as the primary data source, while a network of partner farms is also used to gather independent data (Figure 10).

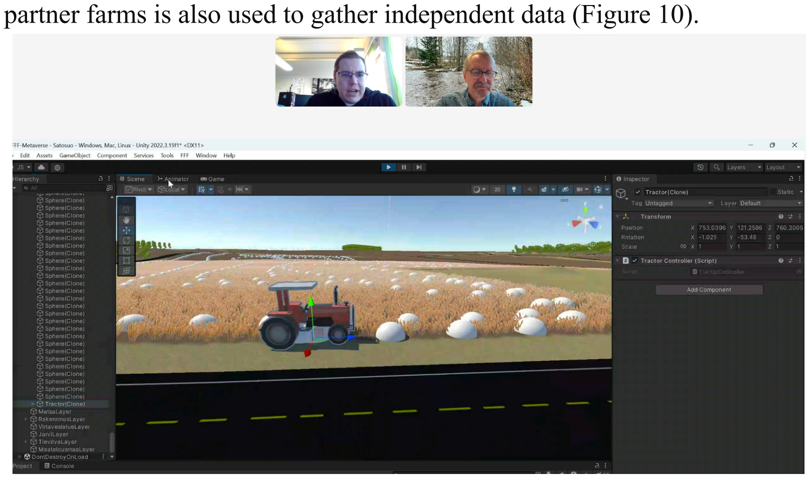

Figure 10. Developing the Digital Twin of the Tarvaala Smart Farm. GIS features are presented in a multiverse environment.

In the Finnish Future Farm (FFF) project, there are two work packages that build on the physical smart farm and the digital twin: the Education and Networking work packages (see Fig. 1).

The Education package develops simulation pedagogies that utilize the measured and simulated data to create use cases for profiled learners. The goal is to produce effective tools for different kinds of educational customers. To achieve this, four pilot groups will be run during the project.

The Networking package includes the further development and application of the existing BioBoosters business accelerator by Jamk. In addition to business acceleration cases with innovative start-ups and leading companies, bootcamps, hackathons, and other innovation events will be organized (Fig. 11).

Figure 11. Smart Bioeconomy Bootcamp in May 2024, with 22 participants from 14 nationalities.

The primary objective of the projects was to establish a foundation for a Smart Farming competence hub aimed at accelerating the adoption of smart technologies on farms, aligned with the United Nations Sustainable Development Goals (SDGs). Achieving this required understanding the types of data collected on farms and determining the Smart Farm's data handling capabilities. This was successfully addressed using available example data. Various data types, including sensor data, telemetry data, and drone imagery, were made accessible to the Smart Farm through the developed Farmer's Data Warehouse. Data transfer to external systems was achieved in various ways, incorporating fair data economy principles in accordance with forthcoming EU regulations. This was demonstrated for the first time in Europe with an official data intermediation service (Tritom by Dataspace Europe Ltd). While 5G data transmission presented challenges, it was functional in some cases, aligning with current research (Heikkilä et al., 2022).

Intelligent data analysis derived various metrics from the Smart Farm's data, which could be presented in map format. These metrics can be used to demonstrate and evaluate the benefits of SDG technologies in the future. The economic maps of precision farming were the first reported in the literature, emphasizing economic benefits as a powerful motivator for farmers to invest in smart farming technologies (Garcia et al., 2023).

The developed Smart Farm concept is international. The Nordic Testbed Network provides a valuable channel to connect with experts in smart agriculture and other related smart technology application fields. The concept is closely associated with R&D and education services, which will be offered through a Digital Innovation Hub (DIH) in the future. DIH services were developed simultaneously with the EU-funded SAH project (SAH 2024), where Jamk laid the groundwork for defining the necessary services for various target groups.

4. Conclusions

The core of the established Smart Farm concept lies in the physical Smart Farm with continuous comprehensive measurements and monitoring, allowing extensive use for testing and further development of Smart Farming technologies and practices. Based on the presented measurements and analyses, the physical smart farm was evaluated to be suitable for being a comprehensive testing environment. The extensive variability in soil and resulting yields presents a sufficiently challenging site for site-specific control.

The partner farm network under construction enables real-life experimentation in a Living Lab style, providing insights into end-users' scenarios and requirements for new technologies. This collaborative network is an integral part of the Smart Farm concept. Through collaboration, the Smart Farm has been involved in other networks promoting agricultural data economy, leading to collaborative projects where the connection between the Smart Farm and the agricultural data space is tested and developed concretely.

The Finnish Future Farm (2023–2026) commenced based on the foundation of the physical Smart Farm, incorporating a digital twin. Both the physical farm and its digital counterpart will be utilized for research, development, innovation activities, and education. The developed Smart Farm concept has contributed to the formation of an expertise hub that significantly improves the profitability and environmental sustainability of farms. The commitment of companies to continue the project indicates its success in meeting its primary objectives. The expanding startup network, in conjunction with leading companies, ensures the concept's viability in the future.

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References

Anand, J., Yusoff, N., Ab Ghani, H. & Thoti, K. 2023 Technological Applications in Smart Farming: A Bibliometric Analysis. Advanced and Sustainable Technologies (ASET) eISSN 2976-2294. Volume 2, No 2, December 2023. pp. 30-40.

Garcia, D., Cangirana, L., Queiroz, R. & Gimenes, R. 2023. Precision Farming technologies adoption: A state of the art survey. Boletim de conjuntura, 16(47), pp. 284–304.

Haapala 1995. Position Dependent Control (PDC) of Plant Production. Agric.Sci. in Finland 4: 239-350.

Haapala, H., Pesonen, L. & Nurkka, P. 2006. Usability as a Challenge in Precision Agriculture - case study: an ISOBUS VRT. Agricultural Engineering International: the CIGR Ejournal. 9 p.

Haapala, H. & Pasila. A. 2009. Agro Living Lab - an R&D platform- ensuring acceptability of new technology among farmers. 67th International Conference on Agricultural Engineering LAND.TECHNIK AgEng 2009. Hannover. Germany.

Haapala, H. 2013. Speeding up innovation in agricultural IT. Journal of Agricultural Engineering. Vol XLIV. p. 137-139.

Haapala, H., Kataja, J., Pirttiniemi, J., Sarvela, K., Ludwig, G., Appelgrén, I., Kalmari, J., Taavitsainen, M. & Vesiluoma, S. 2024. How and why we built our Smart Farm. In. Maataloustieteen päivät 2024. Suomen Maataloustieteellisen Seuran Tiedote 42. 8 p.

Heikkilä M, Suomalainen J, Saukko O, Kippola T, Lähetkangas K, Koskela P, Kalliovaara J, Haapala H, Pirttiniemi J, Yastrebova A, Posti H. Unmanned Agricultural Tractors in Private Mobile Networks. Network. 2022; 2(1):1-20. https://doi.org/10.3390/network2010001

Nielsen, J. 1993. Usability Engineering. Academic Press Inc. 362 p.

SAH 2024. Unleashing the innovation potential for the digital transformation of the European Agrifood Sector. https://www.smartagrihubs.eu/. Cited 29.2.2024.

Talero Sarmiento, L., Parra-Sánchez, D. & Lamos-Diaz, H. 2022 Opportunities and Barriers of Smart Farming Adoption by Farmers Based on a Systematic Literature Review. In: Int. conference on innovation, documentation and education. https://doi.org/10.4995/INN2022.2022.15746

Wielinga, E., Koutsouris, A., Knierim, A. & Guichaoua, A. 2017. Generating space for innovations in agriculture: the AgriSpin project. Studies in agricultural economics, 119 (1). pp. 26-33.

Wolfert, S., Ge, L., Verdouw, C. & Bogaardt, M-J. 2017. Big Data in Smart Farming – A review. Agricultural Systems 153. pp. 69-80.