Agtech competence: urgent needs and possible pathways

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During the 19th century, it took approximately 4,200 minutes to harvest and thresh one ton of grain thanks to the invention of the knife bar, the steam engine, and the threshers. But today, with the biggest combine harvesters, such as the John Deere X9, the farmer can harvest and thresh one ton in just 2 minutes (fig. 1). It illustrates a fabulous productivity development in agriculture (Frankelius, 2019a).

The technological milestones have been many over the years. While Google launched its self-driving car Waymo in 2009, agriculture has had self-driving tractors since at least 2002. Regarding robots, it can be mentioned that ABB and others relatively recently launched robots that can interact with biological agents (in that case humans). ABB launched one in 2019 (Svanström, 2019). But agriculture had robots that can interact with biological beings, namely cows, already 1992 thanks to the Lely's Astronaut. DeLaval had a patent before Lely but launched its robot later, in 1998.

Figure 1. This X9 combine from John Deere can harvest 100 tons per hour. Photo: Per Frankelius.

But despite all the progress in agriculture, there is cause for concern. Some current observations: David Beasley, UN World Food Program, declared on 6 May 2022 that 276 million people worldwide are already facing acute hunger at the start of 2022 (World Food Programme, 2022). On 7 May we were reached by the news that Sri Lanka has declared a state of emergency due to lack of food, fuel, and medicines (McLaren-Kennedy, 2022).

The world faces huge challenges regarding food needs in relation to food supply. According to estimates by the Food and Agriculture Organization (FAO), we need 60 percent more food in 2050 than today (United Nations, 2019). The expanding food needs are not only connected with population growth, but as much with changing food habits in Asia and elsewhere (Silva, 2018). Because agricultural production is vital for food production, many challenges must be handled through developing agricultural tools and methods.

At the same time food production needs to be boosted, there are many other kinds of challenges for agriculture, like threatened biodiversity (Secretariat of the Convention on Biological Diversity, 2020), sealing of arable land (Mission Board for Soil Health and Food, 2020), climate change (IPCC, 2019), soil compaction (Montanarella, 2015), lack of manpower (Rosenblatt, 2021), and spreading of animal diseases (FAO, 2017). On the shoulders of farmers are also changing regulations and expanding administrative complexity. To conclude, agriculture has many challenges to cope with at the same time, and these include contradicting goals.

Three pathways

In principle there are three pathways: evolution, imitation, and innovation (Frankelius & von Rosen, forthcoming). Evolution and imitation are much needed. But neither evolutionary changes nor imitation will be enough to cope with all challenges and the contracting goals. We need more revolutionary changes (Frankelius, 2019b). In other words, we need more innovation. But what kind of innovations do we need, and how can we secure innovation success? There are signs that agriculture is approaching a new technology era in agriculture (Frankelius & von Rosen, forthcoming). The new agtech era includes, among others, these areas:

(1) New crop and cultivation concepts that includes concepts such as
- high-speed phenotyping breeding,
- sensor and AI-aided precision,
- novel no-chem weed management,
- field vegetation combinations,
- compaction reducing concepts,
- subsurface drip irrigation,
- subsurface drip irrigation.

(2) Field robotics that includes concepts such as
- small and big field robots,
- robot swarm concepts,
- robot mode functions,
- master and servant concepts,
- autonomous drone scouting.

(3) Climate-smart energy and products that includes concepts such as
- carbon-free farm energy concepts,
- carbon-free necessities,
- crop-based biofuel production,
- fossil-free substitutes production.

(4) Smart connected systems that include concepts such as
- predictive maintenance,
- remote support,
- connected farm systems,
- traceability customer value.

(5) Animal welfare technology systems that include concepts such as
- AI-aided animal monitoring all around the clock,
- prevention of antibiotic usage,
- sex detection during incubation,
- sensor-aided breeding on new targets.

One example of new technology in group (1) New crop and cultivation concepts is singulation for ordinary grain crops (by means of for example the Proceed machine from Väderstad). This means precision planting of seed along the moving direction. Another example is underground drip irrigation, also called surface drip irrigation (SDI) such as concepts proposed by the company Netafim. A key concept in this area is "fertigation" or "nutrigation" i.e. irrigation with nutrient-enriched water. One of Netafim's most important inventions is a small device made of plastic that allows the same amount of drops to come out even if the pressure in the hose varies between 0.4–4 bar. Still another example is precision machines with variable row spacing (like the Flexrow concept, fig. 2). That concept builds on new technology originally intended for airplanes. One big problem in modern agriculture is soil compaction. Concepts such as Compaction Prevention System (CPS) can help farmers to avoid this huge problem. The system gives farmers decision support regarding soil compaction risk. It helps deciding where and when to work on the fields and vehicle configuration. An algorithm creates an index out of information about wheels/tracks pressure on soil, soil type, soil moisture and field status. Maps of the compaction risk level are provided as well as real-time information on a meter as the vehicle moves. (The CPS concept won silver medal in Agritechnica innovation award 2022.)

Figure 2. The Flexrow concept paving the way for pure flexible row distances. Photo: Per Frankelius.

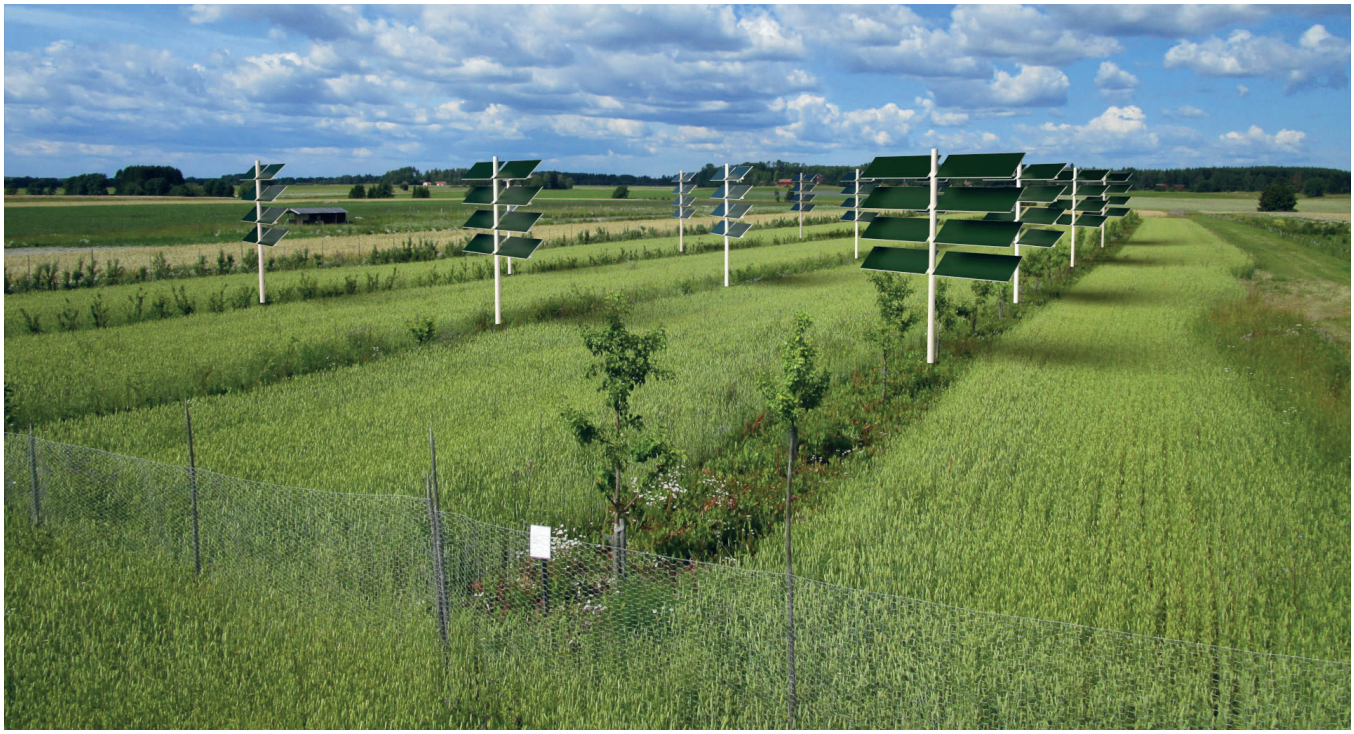

Figure 3. The Agrosolary concept. Image: Gustav Näslund/Kurt Hansson.

Regarding new technology in group (2) Field robotics there are probably more than 40 robot concepts already out on the market. Still many are in concept state like the tank carrier robot Fieldgofer. The centerpiece of Fieldgofer is a U-shaped robot that can carry special tanks and is equipped with a three-point lift. Furthermore, at least three loose tanks and a road transport trolley are included. The robot is transported out to the field. There it can, for example, spread mineral fertilizer or granulated biofertilizer itself. When the tank is empty, the robot itself switches to a refilled tank and continues until the job is done. The farmer can devote him- or herself to fetching more fertilizer for the field, but no one needs to drive a tractor for spreading. In addition, the equipment weighs less than a classic tractor with a fertilizer spreader, which reduces soil compaction.

One example of new technology in group (3) Climate-smart energy and products is biogas tractors with electric drivelines (like the one from the farm company AUGA Group). Another concept is Agrocolary including solar cell path in the fields (fig. 3). This area is in strong development mode right now (Frankelius and Lindahl, 2021). One shall have in mind that agricultural production is very much related to energy production, because fertilizers are produced by means of natural gas, grain drying needs lots of energy – and tractors or other farming machinery also need huge amounts of energy. Unlike road transport vehicles, it has been shown that battery operation is not sufficient for the heavy work in fields required in agriculture. At the same time, many actors in society want agriculture to switch to fossil-free energy. And even if it had been possible to switch to electric power, the problem remains that the electricity must be fossil-free produced for there to be any meaning to it all. Today, less than 30 percent of the world's electricity is fossil-free produced. Regarding fertilizers fossil natural gas is the main energy source today and many are struggling in finding alternatives.

One example of new technology in group (4) Smart connected systems is the Expert Alert system by John Deere launched in 2018. Expert Alert is a remote service concept that shows how sensors, communication, AI and organizational arrangements can create interesting values for farmers as well as for the machine company. The machine, such as a tractor or combine, is, via telematics, in constant communication with a global command center at John Deere in Germany. There, the system can warn that e.g. a layer in the combine is going hot. The key is that the command center collects lots of data from many machines and

then, with the help of AI, can identify patterns and define combinations of conditions that are likely to lead to an injury or even downtime. The dealer then receives info and can inform the customer so that they put in service before an accident occurs.

One example of new technology in group (5) Animal welfare technology systems is animal data transmitting sensors such as SenseHub Feedlot from Allflex/Merck, or camera-based observation of animal breathing (like the concept from Saab/Agtech 2030).

Increased demands for new skills

All these areas and concepts increase the demand for new skills. That was the background to a multiyear investigation project framed by The Royal Swedish Academy of Agriculture and Forestry. The work within KSLA's Committee for Technology in the Green Industries began in 2017. The assignment from KSLA was to "work to highlight challenges and opportunities in the introduction of new technology in agriculture and forestry". The Academy believed that it was important for the committee to be able to point out the problems and the need for knowledge that existed in the green industries and that could be solved, among other things, with new technology. There was also hope that the committee's work would promote the introduction of new technologies in practical contexts. One way to implement this was to create increased communication between stakeholders and actors in the field. Finally, the Academy expected the committee to provide concrete proposals and measures to support the introduction of new technologies in the industries. This gave the committee in the field of technology a fairly free rein to shape its activities. It was interpreted as meaning that one should start by adjusting the situation with regard to both applied and new technology in agriculture, forestry, and horticulture. Then you should create an overview of the need for and access to technology-related advice and experimental activities. Based on these insights, the committee would identify the most important challenges in the technical development of agriculture, forestry, and horticulture in Sweden.

The results of the Committee for Technology in the Green Industries was presented in a report at the end of 2021 (Emgardsson, Frankelius & Martiin, 2021). The committee worked at a time when the winds of change were blowing in agriculture. Among the proposals put forward were these three:

Proposal 1:

Countries should invest in international cooperation and a national forum. All countries need to take action to improve the development of skills in agricultural technology. For small countries like Israel, Georgia or Sweden cooperation is extra important to maintain and strengthen competence. To enable cooperation, all countries must have competent actors with the ability to "give" something in exchange for what we want to "get" from other countries. Significant parts of the knowledge associated with new technology are advanced, so a key to success is that we strengthen academic educations focused on interdisciplinary competence in physical and digital agricultural technology.

Proposal 2:

Independent technical advice needed. There is a need for commercially independent actors to whom agricultural professionals can turn for objective advice on technology issues. Today, both farmers and advisers are largely in the hands of actors who directly or indirectly represent manufacturers of the technical alternatives available. Therefore, farmers need a function that captures and structures national and international experiences of applied physical and digital agricultural technology. One can observe such functions in some countries. This feature should include the ability to quickly evaluate whether and for which farms a particular new technology can become profitable. The need for a forum increases when the creation of knowledge is spread over many organizations in different places.

Proposal 3:

New data platform. Data is becoming increasingly important in agriculture. But agriculture is lagging behind in terms of manufacturer-independent structures for managing and sharing data. The committee concluded that data management of the future in agriculture should be internationally compatible and based on sophisticated object models, i.e. standards. Farmers should seek cooperation with farmers' organizations in other countries with the aim of influencing the machinery industry's systems and creating their own cross-border and farmer-controlled management systems for agricultural data.

To secure innovation success

How then can we secure innovation success? Among the success factors are farm-based development centers – concepts beyond test farms because testing is only one part of what can be done by farmers at farms. Another success factor is cooperation strategies alongside facilitators for collective innovation efforts. One example of innovation promotion is Volcani Center – Agricultural Research Organization in Rishon, Israel. Volcani Center is an impressive research and innovation environment hosted by the Israeli Ministry of Agri-

culture and founded as early as 1921. The focus is on developing agriculture in practice. Today they have about 200 researchers who must all draw their own research funds. The list of clients includes Walmarks, Cargill, Pepsico, Unilever, Dow, Coca-Cola, Burger King, DuPont, Syngenta, General Mills, Monsanto, P&G, and Bayer.

Another example of innovation promotion is the research and innovation program, Agtech 2030, hosted by Linköping University in Sweden. The purpose of Agtech 2030 is to stimulate sustainable growth through innovation processes supported by dynamic innovation environments. Focus is directed towards sensors, digital technology, AI and the Internet of Things. About 90 partner companies and organizations have conducted approximately 30 innovation projects during the last three years. Research by Agtech 2030 has been published in journals like Agronomy Journal, The Lancet, Journal of Cleaner Production, Journal of Agricultural and Environmental Ethics, Journal of Service Management and International Food and Agribusiness Management Review. Agtech 2030 has resulted in many patents and innovations. Some got international recognition.

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