Towards sustainable and highly productive farming systems – strategic research and development needs for ICT, automation technologies and robotics in agriculture

Annett Latsch[1]*, Martin Holpp[1], Markus Lötscher[2], Elke Saggau[3], Till Schneider[3], Iver Thysen[4], Jürgen Vangeyte[5], Koen Mertens[5], Stephanie Van Weyenberg[5]

[1]Agroscope Research Station ART, Tänikon 1, Ettenhausen,8356, Switzerland
[2]Federal Office for Agriculture, Mattenhofstrasse 5, Bern, 3003, Switzerland
[3]Federal Agency for Agriculture and Food (BLE), Deichmanns Aue 29, Bonn, 53179, DE
[4]Danish Agency of Science Technology and Innovation, Bredgade 40, Copenhagen, 1260, Denmark
[5]Institute for Agricultural and Fisheries Research (ILVO), Vangansberghelaan 115, Merelbeke, 9820, Belgium
**Corresponding author. E-mail: annett.latsch@art.admin.ch*

Abstract

Innovative information and communication technologies (ICT), automation and robotic technologies will be a key base for the development of more sustainable and efficient farming systems (European Commission, 2010; SCAR, 2011). The European research area network 'ICT and robotics in agriculture and related environmental issues' (ERA-Net ICT-AGRI) identified goals for a sustainable and highly productive European agriculture, particularly depending on the mentioned technologies. The research and development (R&D) needs were determined by an online-consultation carried out by ICT-AGRI. Results show, that generally improvements in terms of technology aspects and agronomic knowledge are required in all domains. The need for compatible and user-friendly solutions at farm level is also stressed. As the solution domains are strongly interlinked, a cross-thematic research approach is promoted.

Key words: ICT, automation, robotics, agriculture, environment

1. Introduction

European agriculture is facing conflicting future challenges: Global needs for food and bio-energy, consumer demands for food quality and security, animal welfare, reduction of the environmental footprint, diminishing rural populations and international competition (SCAR, 2011). Advancements in ICT and automation technologies are rapidly emerging and might be capable to reform farming in the near future. Common solutions are required, but European research and innovation is fragmented. The cross-thematic ERA-Net ICT-AGRI contributes to the development and implementation of these new technologies for a competitive and environmentally friendly agriculture. Within the ICT-AGRI Strategic Research Agenda (SRA), serving as a common research agenda based on shared priorities and supporting the coordination of European research and innovation efforts, strategic research and development needs in ICT and robotics in agriculture were worked out.

2. Materials and methods

Future challenges for a sustainable European agriculture were identified by an extensive analytical review of about 20 recent foresight studies. In order to tackle these challenges specific goals have to be formulated. ICT-AGRI identified goals where ICT, automation and robotics can play a major role in terms of solutions (Fig. 1). This solution concept comprises several solution domains to cover nearly all contributions of ICT and robotics to primary agricultural production and to agriculture related environmental issues. The basis for the

design of the solution concept was a review of current technologies used in plant and animal production and for farm management.

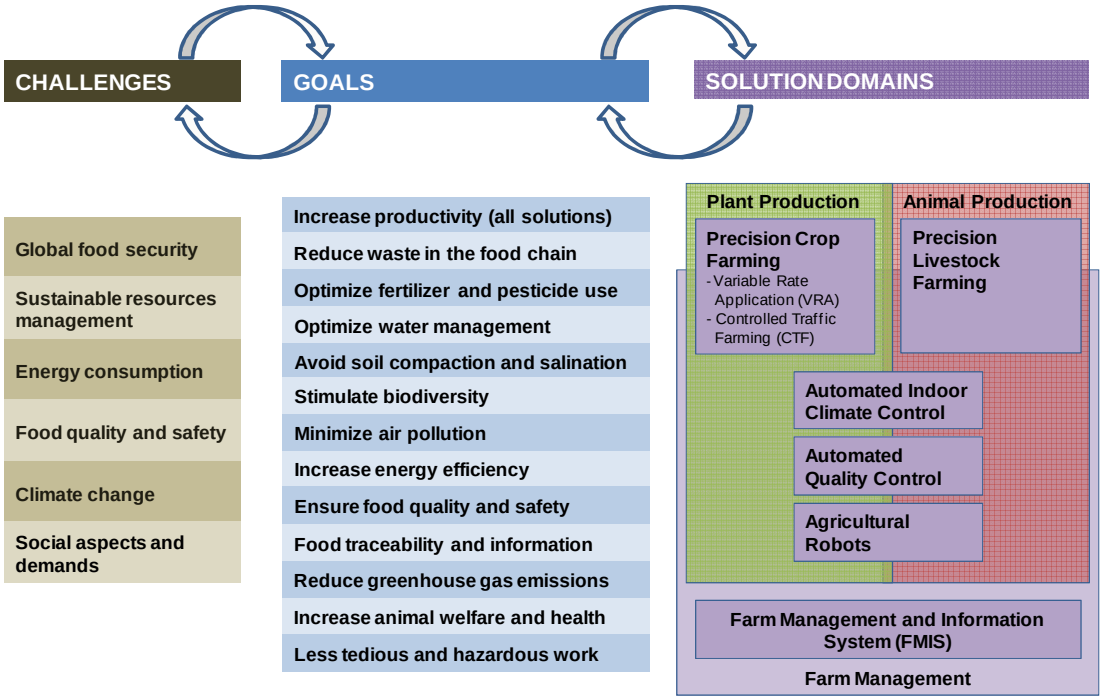


FIGURE 1: Challenges, goals and solution domains for a sustainable European agriculture, identified by the ERA-Net ICT-AGRI. The solution domains were designed to cover nearly all contributions of ICT and robotics to primary agricultural production and to agriculture related environmental issues. Short descriptions of the solution domains are given in Table 1.

TABLE 1: Solution domains of the ICT-AGRI solution concept

Solution domain	Description
Precision Crop Farming: Variable Rate Application and Controlled Traffic Farming	Precision Crop Farming addresses optimization of inputs to sub-areas of fields to increase the total efficiency as well as to eliminate or reduce the negative effects on the environment. Variable Rate Application as one focus of precision crop farming is the site specific application of fertilizers, pesticides or water. Controlled Traffic Farming as another subarea is the geo-positional control of field operation traffic to optimize yields and input (including fuel and labor) and to reduce negative environmental impacts.
Precision Livestock Farming	The main goals of Precision Livestock Farming are the improvement of profitability, work ergonomics and animal health and welfare based on sensor measurements and advanced information and communication technologies. However, livestock production today is not limited to these goals. Modern society is concerned about food safety and quality, efficient and sustainable animal farming and acceptable environmental impact of livestock production, too (Berckmans, 2004).
Automated Indoor Climate Control	Advanced systems for Automated Indoor Climate Control should help to reduce energy consumption and GHG emissions.
Automated Quality Control	Quality, safety and traceability of food and feed are the main goals of Automated Quality Control. This is essential to assure high quality and safe food produced under animal and environment friendly

	conditions for a continuously increasing market.
Agricultural Robots	Agricultural robots can substitute manual work, in particular hazardous or tedious work, to improve work safety, labor efficiency, product quality and environmental sustainability.
Farm Management and Information System	The Farm Management and Information System (FMIS) is defined as the backbone system for all other ICT and robotic solution domains. FMIS provides a common user interface to solution domains and a repository for farm information (fields, crops, buildings, facilities, inventories, animals, past operations, goals, quality measures etc.). FMIS also includes tools for communication and information exchange with external bodies, e.g. providers, food chains and authorities.

Every solution domain is characterized by six different solution components, describing the requirements necessary for making a solution domain work at farm level (Table 2).

TABLE 2: Components of the ICT-AGRI solution domains

Solution component	**Description**
Agronomy	Required agronomic knowledge (agricultural research)
Economics	Knowledge about profitability and non-economic values (economics and social science)
Environment	Knowledge about the effects on the environment (environmental research)
Inter-Operation	Compatibility of hardware components, information exchange (computer science)
Operation	Feasibility and user-friendliness (agricultural research and engineering)
Technology	Mechanics, electronics, buildings, hardware (engineering)

An online-consultation was carried out to indentify the research and development needs for the solution domains and their components, necessary to meet the challenges facing European agriculture. Via e-mail-listings the call for participation was widespread.

The online-consultation was designed as real time Delphi survey, so participants could see the R&D voting results and comments of the other responders. The descriptions of the solution domains and the solution components could be modified. There was also the possibility to create and comment additional solution domains, but all of them turned out as sub-cases of the ICT-AGRI solution domains with more narrow scopes. Thus, the new ideas were integrated into the solution domains defined by ICT-AGRI.

For the graphic presentation of the R&D voting results the absolute voting numbers were weighted with triple, double or single value. Table 3 (chapter 3) shows weighted averages of the R&D voting.

Voting on Research and Development (R&D) needs

- High - Important component and lack of knowledge
- Medium - In between
- Low - Less important component and/or less lack of knowledge

Weighting of absolute voting numbers

- High - triple value
- Medium - double value
- Low - single value

$$\frac{\sum \text{weighted voting numbers}}{\sum \text{absolute voting numbers}}$$

3. Results

A total of 185 participants with expertise or profound interest in ICT-AGRI from 21 mainly European countries responded to the online consultation. Table 3 summarizes the R&D voting results and specifications of the participants.

Variable Rate Application: The research and development needs are voted relatively high for all components of this solution domain. Especially the agronomic knowledge has to be improved.

Controlled Traffic Farming: The techniques for determining geo-positions and control of traffic are well known, but research and development needs are high concerning agronomic, environmental and inter-operational aspects.

Precision Livestock Farming: There is a lack of agronomic knowledge and a substantial need for technology advancements in this field.

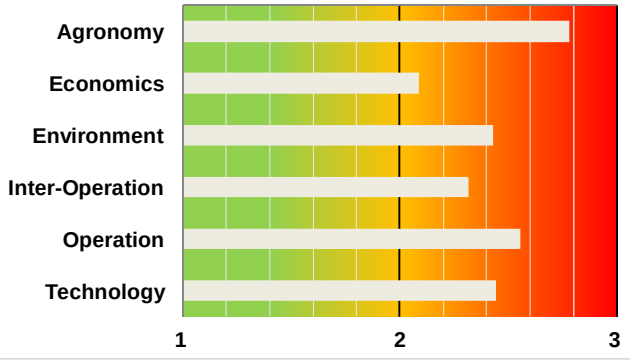
Automated Indoor Climate Control: The research and development needs for this solution domain are voted medium to high with focus on technology.

Automated quality control: The highest research and development needs are seen in the fields of agronomy and technology.

Agricultural Robots: Responders of the consultation obviously see a great potential for agricultural robots. According to the voting there is a great need for research and development in all fields of this area, especially in the fields of technology and operation.

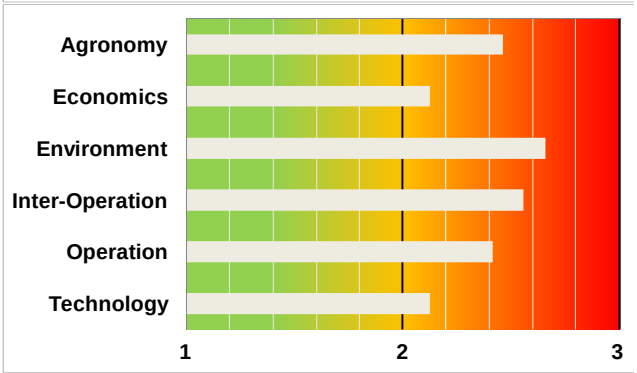
Farm Management and Information Systems: Research and development needs are especially seen in the fields of inter-operation and technology.

TABLE 3: Research and development needs for the different solution domains – Voting results (weighted averages; Low = 1; Medium = 2; High = 3) and specifications of the online-consultation.



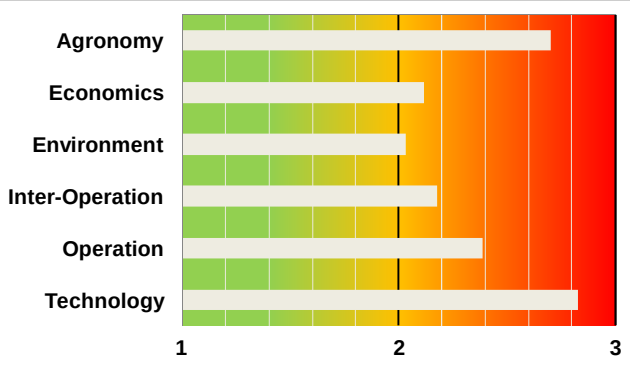
Variable Rate Application – Needed improvements

- proximal sensing technologies for plant nutrient status
- detection of biotic and abiotic stresses: weeds, fungal diseases, water stress
- mapping of soil characteristics (new and improved sensors)
- remote sensing
- information management, farm management and (weather based) decision support
- cost-benefit analyses



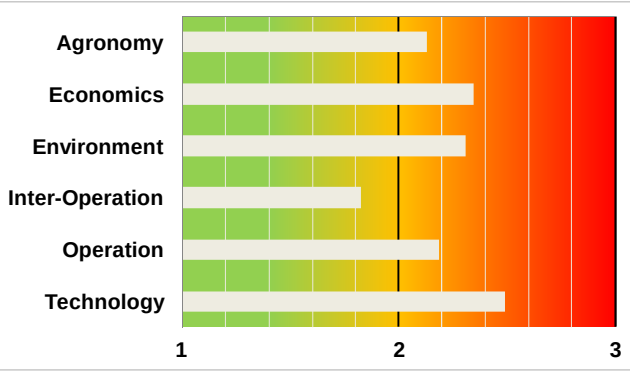
Controlled Traffic Farming – Needed improvements

- long term experiments (soil compaction, GHG, crop development etc.)
- operation and traffic planning (information exchange, representation protocols)
- feasibility and cost-benefit assessments
- compatibility between products from different vendors



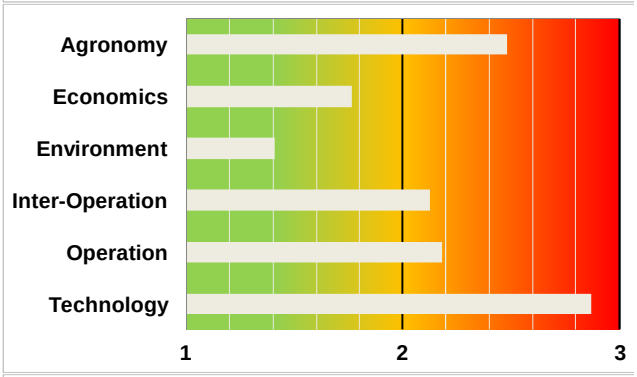
Precision Livestock Farming – Needed improvements

- biosensors: higher sensitivity and specificity
- improved decision support
- management of GHG emissions
- disease risk assessment and modeling
- feeding systems
- compatibility between products from different vendors



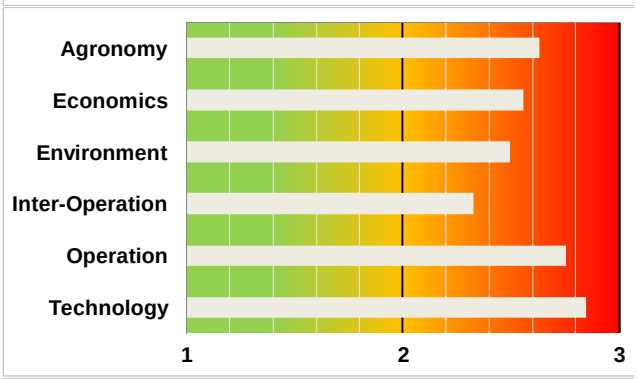
Automated Indoor Climate Control – Needed improvements

- reducing energy consumption and GHG emissions
- improved regulation and management
- integrated / coupled heating-ventilation systems
- automated natural ventilation systems



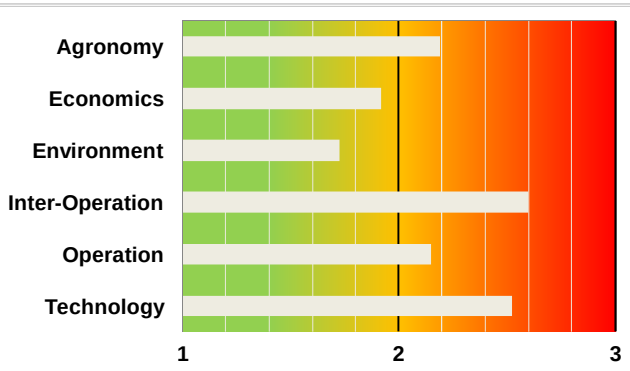
Automated Quality Control – Needed improvements

- traceability: inspection principles
- sensors for quality and contamination control in plant and livestock production
- control of each individual product instead of sample based quality control
- interoperability of products through the entire food chain



Agricultural Robots – Needed improvements

- safety issues
- fast and effective “eye-hand” coordination
- multi-disciplinary approach (technology, agronomy, economy, farm logistics etc.)
- transfer of engineering methods to the context of agriculture and robots
- intensive information exchange with FMIS



Farm Management and Information Systems – Needed improvements

- automated information collection and storage
- communication between research institutions, end-users and manufacturers
- (open) standards to obtain interoperability
- web-based approaches for farm management and decision support
- interfaces as easy to use
- added value for farmer

4. Conclusions

All solution domains require further research and development, although there are already good technical solutions for Automated Quality and Indoor Climate Control and for Farm Management and Information Systems available. Innovations are needed for Precision Livestock and Precision Crop Farming with Variable Rate Application and Controlled Traffic Farming. Agricultural Robots are seen as the solution domain with the highest R&D needs. This might be due to the fact, that use of robots in agriculture is rather little progressed and experience with technology application is not high yet.

Due to the strong interaction between the solution domains as well as the components it is quite difficult to prioritize the R&D needs. Sensing devices developed for variable rate application might be also used in precision livestock farming or automated quality control. Robots generally need sensors and actors from other solution domains. FMIS as backbone system depends on all other solution domains. A look at the interactions between goals and solution domains gives a similar picture of interlinked effects and thus a prioritization of research and development needs is not suggested.

However there are two components showing very strong R&D needs: Agronomy and Technology. In spite of all agronomical research efforts we still lack more reliable knowledge about the complex function of agricultural biosystems in plant and animal production. And despite all technological progress during the last decades, technology is still not sophisticated enough for the precise management of biosystems. This underlines the necessity to bring together interdisciplinary knowhow from ICT and agricultural experts enabling the creation of new, innovative solutions.

Thus, future ICT-AGRI research especially needs to focus on a coordinated cross-thematic research approach. Substantial and imminent progress can only be expected with close inter- and transdisciplinary collaboration. The need for compatible and user-friendly solutions at farm level calls for collaboration between public research, industry, providers and farmers on a European level.

5. Acknowledgements

This work was executed within Work Package 4, Elaboration of a Strategic Research Agenda, of the European Research Area Network (ERA-Net) ICT and robotics in agriculture and related environmental issues (ICT-AGRI), funded by the EU with Grant Agreement No. 235460.

6. References

Berckmans, D. (2004). Automatic on-line monitoring of animals by precision livestock farming. In Animal production in Europe: The way forward in a changing world (pp. 27-30). International Society for Animal Hygiène. Saint-Malo, France.

European Commission (2010). Europe 2020 – A strategy for smart, sustainable and inclusive growth. Communication from the commission. Brussels, Belgium.

SCAR – Standing Committee on Agricultural Research (2011). Sustainable food consumption and production in a resource-constrained world. The 3rd SCAR Foresight Exercise. Luxembourg: Publications Office of the European Union, (232 pp.).