AGRICULTURAL KNOWLEDGE AND INNOVATION SYSTEMS TOWARDS THE FUTURE

A Foresight Paper

Standing Committee on Agricultural Research (SCAR)
Strategic Working Group AKIS-3 Report

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Research and Innovation

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Directorate-General for Research and Innovation
Directorate F — Bioeconomy
Unit F.3 — Agri-Food Chain

Contact: Hans-Jörg LUTZEYER

E-mail: RTD-PUBLICATIONS@ec.europa.eu

European Commission
B-1049 Brussels

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FOREWORD

Many uncertainties question the way we produce, process and consume food. We are challenged to reduce the climate footprint of our food systems. Citizens and consumers are demanding more information on how food is produced, while food systems have to remain competitive on quality and costs in an open world. Business as usual is not an option, which is why research and innovation (R&I) is so crucial in helping future food security and competiveness.

European farming and agro-food systems need knowledge from many different sources to compete with quality products and services in a globalised world. New knowledge is generated by farmers, researchers, companies and citizens. The old 'linear' model of technology transfer (from scientists to the users) is gradually being replaced by an interactive model of systems which integrates knowledge production, adaptation, advice and education. Using an open innovation approach provides opportunities to leverage research into a new setting. It was on this basis that the Standing Committee on Agricultural Research (SCAR) began working on Agricultural Knowledge and Innovation Systems (AKIS) in the SCAR-AKIS Strategic Working Group in 2010.

Over this time the group has built up an impressive intelligence portfolio on the results of various EU-projects dealing with agricultural innovation systems, such as: SOLINSA, JOLISAA, FarmPath, and IMPRESA. Two projects contributed with studies to this report: VALERIE and PRO-AKIS.

Not only does the SCAR-AKIS group give advice to the Commission and Member States, it also acts as a platform for exchanging views on new policy concepts. The European Innovation Partnership on Sustainable Agriculture (EIP-AGRI) is such a concept which aims to link knowledge from practice and research across the different regional, national and European levels of policies and implementation.

It thus gives us great pleasure to present here this publication, which marks the continuing contribution SCAR-AKIS has made to progress in this area and highlights the results and conclusions of the group for the period 2014 to 2015. This period also coincided with a strong contribution from the SCAR-AKIS group to the work leading to the SCAR Bioeconomy Foresight, a timely and insightful report investigating the challenges to European Agricultural Knowledge and Innovation Systems towards 2030, also highlighting research needs and trends in the agriculture sector up to the year 2050.

Innovation in Food Systems is a global challenge, and R&I needs to be Open to the World. In this respect SCAR-AKIS also began a debate on the experiences of Open Innovation in the European and African context, which will be further expanded upon under the emerging EU-Africa long-term partnership on Food, Nutrition and Sustainable Agriculture and in the next SCAR-AKIS mandate.

Furthermore, under the SCAR-AKIS interactive innovation models the implications for 'Big Data' and Information and Communication Technology revolution were investigated. The Open Science approach offers many new opportunities for knowledge networks and business models and is seen as an important opportunity to speed up excellence and innovation in science.

SCAR-AKIS has identified that brokers can play a key role in building successful professional relationships in multi-actor projects. This is a role which farm advisors could play, but more needs to be done to assure this as a function in public policies.

In summary we feel that not only do we have here a roadmap for implementing aspects of open innovation, openness to the world and open science, but one that will also help to boost jobs, growth and investment in rural areas.

John Bell

Director

Bioeconomy,

Directorate-General for Research and Innovation

1 INTRODUCTION

1.1 Setting the scene

Food is everywhere. European agriculture and the food chain manage to provide consumers with a cornucopia of food that is cheaper and safer than ever, despite price spikes and food scandals. It is a main exporter of quality food and drink that are sought after all over the world. These production activities provide income and employment for many, in the rural area and in cities, in farming and the food business but also in related activities such as logistics, the machinery industry, commerce, the service industry (accounting, banking etc.) and in governments.

Food is also culture. From chefs on television to mountains of books, discussing everything from urban farming and sustainability to food design. Even artists and designers have turned to aspects of food. Especially the last trend suggests that some of our thinking on agriculture and food has become problematic and needs to be reframed with the use of art.

But it is not so certain that food will stay plenty and cheap. Global food and nutrition security is one of the major challenges, due to the growth of the world population and its increased wealth. In addition, there is climate change that will affect production. And many current practices in the agricultural and food system are already not very sustainable, seeing the pollution and ethical debates they generate.

Historically innovation (in the last 200 years backed by science as well as research and development) has played an important role in keeping up with the challenges in agriculture. Seeing the future challenges, we will need this more than ever. Science has in recent years generated new technologies such as in genetics, information and communication technology (ICT) and nanotechnology, that could be beneficial in this endeavour to cope with the challenges.

Given the organisation of the sector and the importance of guaranteeing the food supply in society, governments have played an essential and large role in organising innovation. In Europe this is a shared responsibility between the European Union (EU), collaborating with other countries in the European Research Area (ERA), its Member States and regional authorities.

To prepare for future government needs, foresights on the agricultural markets and food supply, as well as on how science and research and development, could contribute to coping with challenges in agriculture and these markets. In addition it makes sense to reflect on how innovation processes could and should be organised. Owing to changes among other technologies (such as ICT that makes communication easier), scarcities (that make for instance travel for scientists cheaper or more expensive) and politics (that favour central or decentralised, market or governmental solutions), the organisation and governance of science and research is not static. Policy ideas and instruments in this area develop.

Against this background the EU's Standing Committee on Agricultural Research (SCAR) has decided to reflect on the future organisation of research and innovation in the agricultural domain. The next section explains the institutional background of the SCAR and the mandate for this work. Section 1.3 guides the reader through the rest of this report.

1.2 Role of SCAR and the Strategic Working Group AKIS

1.2.1 Standing Committee on Agricultural Research

The EU's Standing Committee on Agricultural Research (SCAR) is mandated by the Council of the EU to play a major role in the coordination of agricultural research efforts across the ERA. SCAR currently represents 37 countries, the members being ministries (or other organisations such as research councils) from all EU Member States, with Candidate and Associated Countries as observers.

SCAR has grown to become a respected source of independent advice on European agricultural and wider bioeconomy research, along with being a major catalyst for the coordination of national research programmes, and has helped in the shaping of an integrated ERA. The Committee plays an important role in coupling research and innovation and in removing barriers to innovation, and aims to make it easier for public-public and public-private sectors to work together in delivering innovation that tackles the challenges faced in the bioeconomy area. This has particular relevance with respect to the new growth-oriented approach in the Horizon 2020 programme.

SCAR builds upon four main activities:

- Strategic policy advice in supporting the development of research initiatives, diverse policies and policy instruments etc.;
- Developing a strong foresight process to cope with the wide range of complex and interlinked challenges facing agriculture and the wider bioeconomy;
- Developing common research agendas as a base for further multilateral cooperation (including alignment of programmes at national and EU levels);
- Mapping SCAR member research capacities to bring about increased collaboration.

These activities are established through the various groups within the SCAR governance structure: the plenary meeting, secretariat, working group, foresight group, strategic and collaborative working groups and dedicated task forces. The strategic working groups (SWG) – such as the SWG AKIS – were established to discuss strategic matters for which there is insufficient time or opportunity in the plenary meetings. The strategic matters cover broad issues with a specific remit, described in the terms of reference, and approved at the plenary meeting. Membership in these groups is voluntary and is financed through national resources with European Commission (EC) staff also being actively involved.

1.2.2 Background on the work on AKIS

The SCAR activities on Agricultural Knowledge and Innovation Systems (AKIS) started in 2010 as a consequence of multiple drivers:

- The informal Council of the ministers of agriculture (Krems, 2006) recommended "[SCAR to] include questions of advisory services, education, training and innovation in their discussions";
- A SCAR workshop under the French Presidency of the EU (2008) pointed out that European farming and agro-industry need knowledge from many different sources to compete with quality products in a globalised world. New knowledge is generated by farmers, researchers (basic and applied) and

private companies. The old 'linear' model of technology transfer (from scientists to the users) is therefore outdated and should be replaced by an interactive model of networking systems which integrates knowledge production, adaptation, advice and education.

- The Communication "Towards a coherent strategy for a European Agriculture Research Agenda" (2008) indicated that "the [European] Commission intends to make use of SCAR to identify agricultural knowledge structures in each Member State, with a view to eventually creating a corresponding Collaborative Working Group";
- While the first SCAR foresight (2007) indicated that "the mounting challenges facing the agri-food and rural sectors in Europe calls for a review of the links between knowledge production and its use to foster innovation", the second SCAR foresight stressed the need for renewed political attention to the effectiveness, relevance and scale of Europe's AKIS and for a redefinition of AKIS.
- A Swedish Presidency of the EU conference (2009) dwelt on the importance of a well-functioning knowledge triangle (education-research-innovation) for Europe, in a situation where the EU's research and higher education system is perceived as fragmented and called for intensified interaction between policy areas, notably higher education, research and innovation.

The SCAR plenary meeting of December 2008 endorsed the proposal to look into the possibility to set up a CWG. France and the Netherlands started a CWG (CWG AKIS – nowadays the SWG AKIS) and the group started its work in 2010. The first report "*Agricultural Knowledge and Innovation Systems in Transition – a reflection paper"* was published in spring 2012. This gave an overview of the thinking on innovation policy, the concept of AKIS and drew attention to the concept of social innovation. It documented experiences in the EU Member States and looked to the future.

Since then, the issue has become even more relevant in the changing European policy context, with, for example, the EU 2020 strategy for a smart, sustainable and inclusive growth, the European Innovation Partnership (EIP) and the reform of the Common Agricultural Policy, CAP (including the role of innovation). The second AKIS mandate therefore focused upon the collection and analysis of national and European experiences with interactive methods useful for fostering agricultural innovation. Elements in the discussion were – among others – innovative innovation policies, cross-border collaboration and incentivising stakeholders. Experts also provided papers on incentivising researchers and the role that ICT could play in innovation. The findings are reflected in the report "*Agricultural Knowledge and Innovation Systems Towards 2020– an orientation paper on linking innovation and research*".

1.2.3 Mandate and working methods of the SWG AKIS

Because of the widespread interest among the SCAR members and the participants of the SWG AKIS, new terms of reference for a third period of AKIS activities were drafted in 2013. It was proposed to focus the mandate on four items, namely:

- Supporting the implementation of the EIP through the follow-up of activities, exploring the interaction between the EIP and Horizon 2020, sharing EIP experiences at national level, developing linkages between different instruments, etc.;
- Co-learning on interactive innovation with counties beyond Europe;

- Foresight as regards matters of relevance to the EU and national AKIS;
- Exploration of the possibilities of ICT and open data for agriculture.

SCAR members endorsed the continuation of the AKIS SWG with a new mandate and stated their commitment to participate. After the chairmanship by France and the Netherlands under the first two mandates, the SWG AKIS 3 was coordinated by the Netherlands and Belgium. The group's activities started with a first workshop in December 2013.

The SWG is a network of civil servants (and some counterparts from research and advisory organisations) from the Member States and the EC. The SWG has exchanged experiences on the implementation of the EIP, but also reflected on the international dimension, the role of ICT and conducted an AKIS foresight. More details on the SWG, its composition and the way it carried out its work are given in Annex 2 "The Making Of". The EC also requested the FP 7 projects PRO AKIS and VALERIE to make a small budget available to carry out studies on e-science and the design of networks and the role of the government. The outcomes are included in this end report.

1.3 Structure of the report

Chapter 2 of this report explains the AKIS and their role in innovation, including the policy context of the European Innovation Partnership "Agricultural productivity and sustainability". The text is a synthesis of the first two AKIS reports (EU SCAR 2012; 2013) and readers familiar with these reports can easily skip this.

Chapter 3 discusses the relation in a globalised world between Agricultural Research (AR) and Agricultural Research for Development (ARD). This is followed by two chapters that focus on ICT-trends: chapter 4 discusses ICT in the food chain and its implications for research and innovation. It is followed by a chapter on E-science to see how ICT and "Big Data" could support the interactive innovation model. These trends are one of the inputs for a scenario analysis in chapter 6 on the future developments in AKIS. Chapter 7 focusses on policy recommendations for AKIS and especially on its advisory services. The report ends with recommendations for the SCAR (EU and Member States) and the AKIS stakeholders. This chapter also functions as a summary of the findings of the Strategic Working Group.

2 INNOVATION AND THE ROLE OF AKIS

By Anne Vuylsteke (ed.)

This chapter introduces the general aspects of innovation (especially interactive innovation) and the role of AKIS and AKIS-actors. The text is a synthesis of the first two AKIS reports (EU SCAR, 2012; 2013), which respectively discuss the state of play of AKIS throughout Europe and the interactive innovation model (especially in the context of the European Innovation Partnership "Agricultural productivity and sustainability"). For more detailed information, we refer to the full reports.

2.1 Innovation

The (societal) challenges described in section 1.1 ask for solutions on multiple levels, but research and innovation certainly have a role to play when it comes to feeding nine billion people in 2050 in a sustainable way. This calls for more investments, system innovation and a transition of the food system. But at the same time, there is also need for an evaluation and possibly an update of the organisation of the Agricultural Knowledge and Innovation Systems (AKIS).

2.1.1 Definition

Innovation is a broad concept. The OECD defines innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations (OECD and Eurostat, 2005). This implies that innovation activities are all scientific, technological, organisational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovations. Innovation is often linked to businesses, but the public domain (which is the other 50% of the European economy) can innovate too. This includes the public aspects of agriculture ('multifunctionality'). And there is social innovation, a term that not only refers to the social aspects of innovation, but also to innovations in social life.

2.1.2 Role of research

This definition of innovation implies that research certainly contributes to innovation. The development of new technologies such as genetics, robotics, ICT and nanotechnology are examples. However, more research implies not necessarily more innovation. To realise innovations, additional activities are for example needed if working methods have to be changed or new products or services have to be marketed. For farmers and small businesses such innovation activities are full of risks that have to be managed. Collaboration with partners or support and feedback from colleagues or experts can help. Traditionally farmers depend on AKIS and their food chain partners to realise the innovation process.

The difference between innovation and research means that governments have more instruments than research to promote innovation. Extension and education, fiscal measures, credit guarantees, innovative procurement, inducements such as prizes and other incentives can help too. Thus it makes sense to have an innovation policy in addition to a science and research policy. There is also an important European dimension to innovation and innovation policy. Where cross-border collaboration in research clearly exists and increases, cross-border collaboration in innovation should be improved. This seems to be even more of an issue as the research networks are biased to the oldest EU

Member States / north-western Europe, and widening participation is a policy objective.

2.1.3 Stimulating innovation

More innovation is desirable, at least from a societal point of view. Some firms and farms are very dedicated to innovation, but others are more conservative or realise that innovation has winners and losers, especially if innovation is disruptive. Working methods and institutional arrangements have to be changed, which is difficult, risky, and sometimes needs changes with business partners and in regulations too. This tension between the actual and desirable level of innovation is an incentive for policy makers actively to stimulate innovation.

- Role of innovation policy

The thinking on AKIS is based in the so called 'Systems of Innovation' thinking concerning innovation policy. Smits *et al*. (2010) distinguish two views on innovation policy: the systems of innovation approach versus the macro-economic approach.

Table 2.11. Two views on innovation policy

	Mainstream macro-economics	Institutional and evolutionary economics: System of Innovation
Main assumptions	Equilibrium	Dis-equilibrium
	Perfect information	Asymmetric information
Focus	Allocation of resources for intervention	Interaction in innovation process
	Individuals	Networks and frame conditions
Main policy	Science / research policy	Innovation policy
Main rationale	Market failure	Systemic problems
Governments intervene to	Provide public goods	Solve problems in the system
	Mitigate externalities	Facilitate creation new systems
	Reduce barriers to entry	Facilitate transition and avoid lock-in
	Eliminate inefficient market structures	Induce changes in supporting structure for innovation: create institutions and support networking
Main strengths of policies designed under this	Clarity and simplicity	Context specific

paradigm		
	Analysis based on long term trends of science-based indicators	Involvement of all policies related to innovation
		Holistic approach to innovation
Main weaknesses of policies designed under this paradigm	Linear model of innovation	Difficult to implement
	(Institutional) Framework conditions are not explicitly considered	Lack of indicators of analysis and evaluation of policy

Source: Smits *et al*. (2010)

The macro-economic view tends to see innovation as a linear process from (basic) research via R&D to a commercial application. The main rationale is market failure and the main policy instrument is science or research policy. As there is also a risk of government failure, the choices on the direction of innovation should – in this view – be left to the market as much as possible: the market organises the allocation of resources. It leads to a fairly clear policy that can be monitored by trends in science-based indicators.

The systems of innovation view has a more complicated approach to innovation and innovation policy. The focus is on interaction between different stakeholders in the innovation process. The main rationale is that there are systemic (network) problems or that the creation of new innovation systems is necessary. Therefore an innovation policy is needed, which makes choices and is context specific. In the systems of innovation view, a well-developed knowledge and innovation system has seven functions (Bergek *et al*., 2010):

1. Knowledge development and diffusion;
2. Influence on direction of search and identification of opportunities;
3. Entrepreneurial experimentation and management of risk and uncertainty;
4. Market formation;
5. Resource mobilisation;
6. Legitimation;
7. Development of positive externalities.

Innovation systems can be analysed according to these functions. But it is also possible to identify blocking mechanisms to develop or improve these functions. Such analyses can be a basis for policy intervention.

- Drivers of agricultural innovation

The challenges for the agricultural sector in Europe are significant and result in drivers of agricultural innovation at the farm level and society.

In the first case, innovation is a strategy to address the challenges related to the existence of many agricultural producers, increasing liberalisation of trade in agricultural policies, strict environmental policies and the possible future decreasing influence of agricultural producers. Innovation in this context has the target of lowering cost prices or introducing new products of new markets.

Society is also an important driver of innovation, as agricultural production has an impact on the physical environment. Governments have different instruments for protection of the environment. Many of these instrument are implementations of the EU directives, such as the Nitrate Directive. These policy instruments influence the production possibilities of the agricultural sector. Innovation is a possible remedy to improve or increase agricultural production within the framework of the environmental regulations.

- Barriers for innovation in the agricultural sector

Barriers can be categorised in different ways. The barriers which are external or exogenous to the producer and the barriers which are internal or endogenous are a frequently used division.

Exogenous barriers can be supply, demand or environmentally related. Supply barriers can be for example the difficulty of getting certain materials. Demand barriers are the possible absence of a market and environmental barriers are environmental regulations, policy actions or antitrust measures.

Endogenous barriers show a more diverse picture. They cover for example resource-related barriers, lacking technical expertise or management time and culture- and system-related barriers. Resource-related barriers are for example the lack of resources, technical expertise is for example the lack of knowledge, cultural-related barriers are for example avoiding risks and system-related barriers are for example market characteristics such many small players for which the transaction cost for innovation are rather high (Hadjimanolis, 1999).

- The role of governments

Innovation is first of all the responsibility of businesses. But it is a government responsibility too. Innovation has not only benefits for those who innovate, but others also win: future innovators as well as the clusters of business and the economy at large with a stronger competitive position and in the long run more employment and higher incomes. These are so-called positive externalities (spill-over effects) that an investor in innovation does not take into account and lead to underinvestment in innovation. Agriculture is furthermore confronted with the fact that the agricultural market provides too little R&D because agricultural producers perceive the chance of success to be too low or the costs of innovations and experimentations too high, in relation to the benefits that quickly erode due to spill-overs to others.

A second reason for governments to promote innovation is that this is one of the policy instruments to reduce negative external effects such as environmental pollution in agriculture and food production.

Four types of policy instruments are available to the government stimulate agricultural innovation:

- Government R&D that provides spill-overs to the private sector;
- Targeted or more generic subsidies for public R&D or subsidies to speed up the innovation process (such as financing innovation brokers, innovation boards, networks of firms etc.);

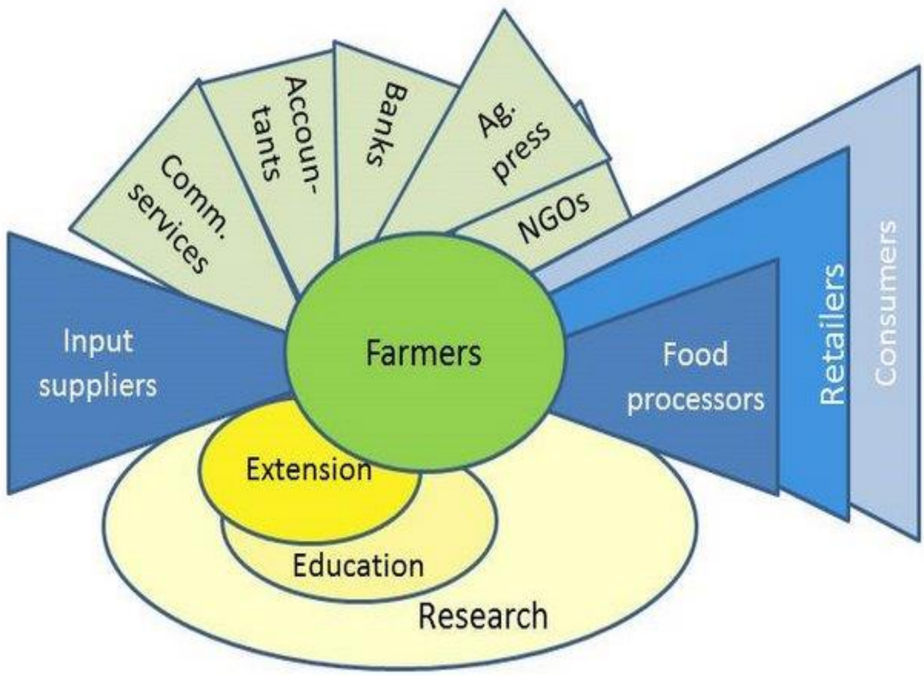
- Awards to successful R&D efforts (prices, innovation vouchers, SBIR) and
- Non-financial instruments such as changing laws which hamper innovation or addressing cultural issues.

2.2 AKIS to support the innovation process in the agri-food sector

The concept of AKIS was originally defined as Agricultural Knowledge and Information Systems. The term referred to "a set of agricultural organizations and/or persons, and the links and interactions between them, engaged in the generation, transformation, transmission, storage, retrieval, integration, diffusion and utilization of knowledge and information, with the purpose of working synergistically to support decision making, problem solving and innovation in agriculture" (Röling and Engel, 1991). Later, this concept developed into the notion of AKS, emphasising the process of knowledge generation and includes actors outside the research, education and advice sectors. More recently the AKIS concept has evolved as it has acquired a second meaning (*innovation*) and the AKIS was opened up to more public tasks and to the support of innovation (Klerkx and Leeuwis, 2009). Important characteristics of an innovation system are the institutional infrastructure, funding mechanisms, network characteristics and market structure (Klein Woolthuis *et al*. 2005).

The first AKIS-report (EU SCAR, 2012) showed that AKIS is a useful concept to describe a system of innovation, with emphasis on the organisations involved, the links and interactions between them, the institutional infrastructure with its incentives and budget mechanisms (Figure 2.1). Although different AKIS-components – Extension, Education and Research – are often stressed, it is important to realise that there are many more actors in the food chain that directly influence the decision making of farmers and their innovations.

Figure 2.1	Actors in the AKIS directly relevant to agricultural innovation in the food chain



Source: SCAR (2012)

Note: Commercial services include laboratories, veterinarians, management software, notaries, land brokers etc. Accountants have been mentioned separately as being in some countries very influential on strategic decisions

The first AKIS reflection paper draws seven conclusions based on the confrontation between AKIS in Europe and the theory.

- AKIS is originally a theoretical concept (based in observations) that is relevant to describe national or regional AKIS: they exist. The AKIS concept can be used to describe national or regional systems and to reflect on the relevant policies;
- AKIS are quite different between countries and/or regions. There is no "one size fits all" formula on what the ideal AKIS is. Especially the link between (applied) research and farmers via extension is very different, covering a range from mainly privatised systems via co-managed systems to management by the state. Within a country or region there can be quite different AKIS between sectors. The obligatory Farm Advisory Service (FAS) for advice on cross compliance has been implemented in different ways, in line with EU member states' AKIS and the perceived needs of the sector.
- AKIS are dynamic and change over time. Some countries have restructured their AKIS considerably to address new needs and challenges (both in the agricultural sector and the government);
- AKIS components are governed by quite different incentives. Although the communication and collaboration between the different components is seen

as crucial, the components are driven by different incentives. Research is often evaluated in terms of publications, citations, and 'excellence', while education is often funded on student numbers. In extension there is a wide variety of incentive mechanisms. These differences do not favour the multi- and trans-disciplinary approach needed to overcome systemic problems in agriculture;

- AKIS are governed by public policy but consistent AKIS policies are not apparent. There are policies for agriculture, for education and for research, sometimes governed by different ministries. The interaction with innovation in the private sector (such as the food industry) is often weak and not very clearly taken into account in designing policies. Questions can also be raised on the relationship between agricultural innovation instruments and general innovation policy. Only exceptionally such discussions on policy coherence are tabled;
- Monitoring of AKIS (input, system, output) is fragmented. There seems to exist a major inconsistency between the high level of attention to "innovation" in the policy domain and the lack of data and research for evidence-based policy. Statistics and other data gathered mainly focuses on R&D in the food industry, on patents and the number of publications of the research system and their citations. In some cases, policy analysis of innovation programmes has been carried out and made public;
- In general, it is concluded that – although AKIS are changing and diversity is useful in innovations and transition – the future of AKIS is unclear as it faces uncertainty. There is no guarantee that they are fit to answer the challenges posed by the need to increase productivity and sustainability in agriculture and food production.

2.3 The interactive innovation model

Innovation starts with mobilising existing knowledge. The AKIS concept underlines that innovation is a social process, more bottom-up or interactive than top-down from science to implementation. Even pure technical innovations are socially embedded in a process with clients, advisors etc. Very often partners are needed to implement an innovation.

In recent years, more and more emphasis has been put on this interactive innovation model, whereby the linear model of innovation has progressively been replaced by a participatory or 'side by side' approach, in which innovation is 'co-produced' thanks to interaction between farmers, firms, researchers, intermediate actors (advisors, input providers, experts, distributors, etc.) and consumers in concrete projects. Cooperation which is result oriented and generates co-ownership for the solutions commonly developed are key in the interactive innovation model. Intermediate actors such as farm advisors and innovation brokers may play an important facilitating role in bridging between science and practice, and between specific in-depth knowledge and a holistic entrepreneurial approach. Farm advisors also have the potential to analyse and funnel practical problems from various farmers into project development and afterwards broadly communicate the project results to their clients.

Networking is supportive for starting up such interactive innovation projects. As innovation is a risky business and benefits from the exchange of ideas, learning and innovation networks have proven to be an adequate vehicle for empowering groups of farmers to investigate new options to make their business more viable or sustainable. This implies policy instruments that finance cooperation projects and collectives in networks, including food or non-food chain partners, non-governmental organisations (as advocates of sustainability), extension and research.

2.3.1 Two types of research

This evolution towards interactive innovation can be better understood by distinguishing two types of research based on their different motives: science-driven research and innovation-driven research (Table 2.2). They represent two extremes on a scale, but many hybrids can occur in between.

Table 2.2. Two types of motivation for research

Aspect	Science driven research	Innovation driven research
Incentive to programme a topic	Emerging science that can contribute to solving a societal issue (or a scientific question)	An issue / problem in society that can be solved by new research, or a new idea to solve an existing issue
Participation of users	In demonstration phase / via research dissemination	In agenda setting, defining the problem and during the research process
Quality criteria	Scientific quality	Relevance (for the sector or a region)
Focus	Research organisations	Networks of producers and users of knowledge
Diffusion model	Linear model	System (network) approach
Type of government policy	Science / Research Policy	Innovation Policy
Economic line of thinking	Macro-economics	Systems of innovation
Finance	To a large extent public money: more speculative and large spill-over effects	Public-private partnerships very possible / advantageous
The role of the EU	Efficiency of scale (member states are often too small), smart specialisation between EU Member States, create European research market with harmonisation of hard- and soft infrastructures	Stimulate interaction and learning in Europe between national/regional AKIS. Enable in CAP innovation by networks with farmers
Typical EU examples	Horizon 2020, FP7, ERC, some ERA-NETs, Joint Programming Initiatives	CAP: European Innovation Partnership, LEADER, European Technology Platforms, EIPs, some ERA-NETs
Type of research	Interdisciplinary with absorption capacity in AKIS (to work with material science, ICT, chemistry etc.)	Transdisciplinary and translational with close interactions

Science-driven research is the classical hierarchical flow from science to societal impact. Emerging science developments are important for research planning. Themes can be set centrally with stakeholder involvement as is currently done in Horizon 2020, Joint Programming Initiatives or Technology Platforms. This is likely to be more efficient on EU level than in 27 member states plus their regions. Note that in agriculture and food many new technologies have always come from other science fields such as chemistry and engineering. Genetics is at the moment perhaps the exception to this rule. So for agriculture and food it is important to look where developments in certain disciplines can be fruitfully linked to the problems in agriculture. Cross-pollination can be fruitful here and the government might thus be active in linking sectors that not normally co-innovate. Absorption capacity, having the competences to learn from other sectors, is an important aspect of the AKIS for such collaboration.

Innovation driven research is much more linked to empowerment of the potential innovators themselves. The freedom to choose topics and partners is important. Choices will depend on the strategy of the actors and regional circumstances. Some regions heavily invest in agriculture and food, while others emphasize the multifunctional role of agriculture. Where science driven research is mainly evaluated by impact in science (publications, citations etc.), innovation driven research should as much be evaluated on its relevance. Quality of research at the researchers level can probably still be judged by classical output criteria, but the performance evaluation of research groups and institutes should include relevance as an important item. This calls for the development of evaluation criteria that are more suited than the current ones.

2.3.2 EIP as an concept to stimulate interactive innovation

At a European level, the innovation-driven research approach and the interactive innovation model are promoted through the European Innovation Partnership "Agricultural Productivity and Sustainability" (EIP-AGRI). The focus is on bottom-up approaches and cooperation between farmers, advisors, researchers, businesses and other actors in operational groups to realise innovations. It is expected that this knowledge "exchange" will generate new insights and ideas and mould existing tacit knowledge into focused solutions. Such an approach should stimulate innovation from all sides and should help to target the research agenda.

- Main characteristics

EIPs have been started on several societal challenges, including agricultural productivity and sustainability. They are challenge-driven, focusing on societal benefits and rapid modernisation. EIPs streamline, simplify and better coordinate existing instruments and initiatives and complement them with new actions or a more coherent policy framework where necessary. EIPs should provide favourable conditions for research and innovation partners to co-operate and achieve better and faster results compared to existing approaches.

The EIP-AGRI aims to foster a competitive and sustainable agriculture and forestry that 'achieves more from less' input and works in harmony with the environment. It will contribute to ensuring a steady supply of food, feed and biomaterials (both existing and new ones) in harmony with the essential natural resources on which farming depends. For achieving this aim, the EIP wants to build bridges between research and farming practice and involve farmers, businesses and advisory services, and others as actors in operational groups.

The content and priorities to be pursued by the EIP will emerge in an open manner and reflect the need for diverse solutions. Translating new technologies, methods and processes into farming practice and creating a space for practical questions requires a bottom-up approach, combined with effective networking. Several areas for EIP innovative actions have been selected on the basis of input and exchange with stakeholders. The EIP Commission Communication[1] lists these possible fields of innovative actions. This list however is non-exhaustive, as EIP actions will emerge bottom up:

- Primary production: technical solutions to increasing productivity and economic viability;
- Resource management: ecosystem services, soil functionality, water management and genetic resources ("public goods");
- Bioeconomy: innovative technology for the bio-based economy, bio-refinery, new products, reduction of post-harvest loss;
- Supply chain: integrated supply chain solutions, new services, logistics and management systems;
- Quality and consumers: food quality, food safety and healthy lifestyles (consumer information and consumer choice).

Operational groups (OGs) are the key acting entities in the EIP and gather farmers, advisors, researchers, businesses, and other actors (e.g. civil society including NGOs and governmental bodies). The forming of OGs takes place on the initiative of innovation actors. No specific conditions are laid down by the EC as regards the size, the composition and the specific undertakings of an OG. OGs have to draw up a plan, describing their specific project and the expected results of the project. Furthermore, the OGs have to disseminate the results of their project, in particular through the EIP network. The exact content of a project plan depends on the actors involved and the problem, issue or opportunity to be tackled. Innovation brokerage can help to find innovative ideas, help partners to connect and set up an OG formed around concrete projects.

- Policy frameworks

For funding concrete innovative actions, the EIP-AGRI is implemented through actions that are mainly supported by two EU policies: Rural Development Policy and Horizon 2020. Funding, implementation and prioritisation of actions take place through the delivery mechanisms embedded in the respective policies.

Several measures under the Rural Development Regulation 2014-2020 can be used to stimulate innovation and the activities of OGs. The co-operation measure (Article 35) plays a key role in the implementation of the EIP. Support can be given both for the establishment and operation of OGs of the EIP, and for the implementation of their projects. This support can also be combined with support under other measures such as training (Art.14), advice (Art.15), investments (Art. 17), etc. The Rural Development programme can fund bottom-up innovation projects with a 100% support rate.

[1] COM (2012)79

Within the societal challenge "Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy" of Horizon 2020, two new instruments were developed that support the EIP: multi-actor projects and thematic networks. The key feature of multi-actor projects is to address the needs, problems and opportunities of end-users and to generate the necessary interaction between researchers and end-users such as farmers/producers, advisors and enterprises by attributing a clear role for the different actors in the work "all along the project". This combination of practical and scientific knowledge should generate innovative solutions that are more likely to be applied thanks to cross-fertilisation of ideas between actors, the co-creation and the generation of co-ownership for eventual results[2].

Thematic networks mobilise all concerned actors on specific thematic areas. The aim is to develop end-user material to facilitate the discussion on, sharing and dissemination of knowledge in an easy accessible way, providing input for education and a research database for end-users and making results long term available. Next to the newly developed EIP instruments, a range of existing instruments will continue under Horizon 2020 (collaborative projects, ERA-NETs, JPIs and COST actions).

The concept of OGs may also be applied within various funding sources. The EIP-AGRI is not exclusively linked to Rural Development Policy and Horizon 2020. There are also potential synergies with other policies like the EU Regional Development Fund, national or regional funding schemes, private funding etc.

- More information

More information on the EIP-AGRI is available in the second AKIS report (EU SCAR, 2013) and the dedicated website of the EIP-AGRI: http://ec.europa.eu/eip/agriculture/

2.3.3 Experiences with the interactive innovation model

Although the term 'operational group' is new, some initiatives in European countries already apply an interactive innovation approach. These initiatives were the basis of the discussion within the SWG AKIS-2. The main findings of the discussions can be summarised as follows:

- The initiatives started for diverse reasons and address specific questions or challenges. On a more general level, four main groups of drivers can be identified: a problem, risk or challenge; realising public good aspects or reaching societal goals, an opportunity and a strategic (policy) choice.
- The key success factors strongly depend upon the specific context, challenge and constitution of the group. They concern: the composition and the way of working within the group; the (effective) outcomes of the group; the presence of a (legal) framework and the availability of tools and learning methods; an appropriate mix of (public and private) funding and support.
- Public policies and funding schemes are important in most cases. The governmental actions can take different forms, but funding is by far the most important one. Other examples of government actions incentivising interactive innovation are the promotion of projects with specific

2 Definition of multi-actor approach in H2020 Workprogramme 2016-2017 (page 10): http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-food_en.pdf

characteristics, active involvement in projects, the provision of scientific advice or technical support, changes of legislation or the identification of national priorities (which is often linked to funding).

- The process of finding the right partners and establishing a suitable basis for cooperation is very important. Innovation brokers can play a role in this process with activities such as demand articulation, network composition and innovation process management (Klerkx and Leeuwis, 2009).
- National and regional governments can stimulate innovation by implementing the EIP through multi-actor operational groups that work in a participatory way. This can be realised through an instrument portfolio that:
    - Gives incentives for research, development and innovation;
    - Stimulates knowledge exchange, adoption of innovation and technical application in the production process;
    - Supports the activities of facilitators, innovation brokers and tutoring paths for farmers to implement innovations;
    - Value the input and knowledge of farmers;
    - Supports operational groups to develop cross-border interactions;
    - Invests in AKIS-subsystems that have been underdeveloped in the specific national or regional situation.

2.3.4 Incentivising relevant actors

As the involvement of all relevant actors is crucial for the interactive innovation approach, special attention is needed for the incentives that can stimulate those actors to get involved. The second AKIS report discusses how to incentivise actors to participate in the innovation process. Such a reflection was needed, as the first AKIS-report clearly showed that the different parts of the AKIS are governed by different incentives, which threatens the synergy and cooperation between the AKIS subsystems.

National experiences show that financial incentives are the most important group of incentives to get actors involved. They are mainly used to stimulate different actor groups to work together in the realisation of common objectives. But the government can also push (by an obligation) or stimulate collaboration by adopting the framework conditions. Finally, interaction and collaboration can be stimulated through the establishment of joint boards and other multi-actor networks. Unfortunately, there are also barriers to interactive innovation. A number of barriers have been identified. Actors groups for example have the (normal) propensity to look after their own interests and not those of the other groups or the community. Other barriers are the restrictive eligibility criteria in funding schemes (hampering participation of necessary actors), administrative and bureaucratic burden, flaws in the AKIS (absence of actors or broken links between subsystems), differences in cultures or "languages", lack of experience with interactive approaches etc.

Next to the general incentives and barriers, specific attention was given to the incentives for research to be responsive to the innovation processes in addition to scientific excellence (Home and Moschitz, 2013). Six potential changes at the level of research policy were identified. They concern the creation of evaluation criteria that stimulate transdisciplinary and interactive research, the involvement of practitioners in research funding and evaluation processes, the support for sabbaticals and short-term visits to stimulate exchange of practices between stakeholders, the creation of funding for projects that involve science and practice on an equal footing and the establishment of an easily accessible data base for high quality non-academic publications/articles. Research institutions should develop targeted training courses to enhance the skills for effective science-practice interaction, create specialised centres for and a new discipline of Integration and Implementation Sciences, establish a database with information about institutions, methods, tools, publications and training courses on interactive research and, finally, include a researcher's (non-academic) societal impact into the overall evaluation of his/her performance.

2.3.5 Cross-border collaboration

A specific issue when it comes to interactive innovation approach is cross-border collaboration as each country has its own science and rural development policy to address specific issues and challenges. A major challenge to realising the European Research Area (ERA) is to move to common rules and procedures between EU Member States for commissioning research and innovation programmes, and in that way create a real European 'market' for science as well as research and development. That does not mean that national or regional authorities should give up their strategy- and agenda-setting processes. On the contrary, for successful cross-border cooperation these processes are essential and should in some cases even be strengthened. But the commissioning of the research based on that agenda should be organised in such a way that the best results are obtained. That includes an optimal level of international collaboration, to prevent overlap and duplication of research (and investment in research infrastructure), to benefit from efficiency of scale and spill-overs and to create further specialisation in the research system. To organise the research in such a way is helped by the pooling of resources (such as in ERA-NETs and JPI). It would also benefit from common rules and procedures in commissioning research (e.g. making it easier for research institutes to match proposals from different programmes) and by opening the market to institutes and actors from other countries (e.g. allowing institutes to work in a national project with a foreign partner with which they team up in a European project).

2.3.6 Role of ICT and social media

Multi-actor innovation might benefit from modern ICT support, comparable to how ICT is changing working processes and collaboration in the rest of the daily life. There is a great potential for using existing social software tools and platforms for communication, interaction, knowledge sharing, preservation of information and as such stimulate multi-actor innovation.

A special analysis for the SWG AKIS 2 (Jespersen *et al*., 2013) shows that there is a great potential for using existing social software tools and platforms for communication, interaction, knowledge sharing, preservation of information in the agricultural sector and, as such, stimulate multi-actor innovation. However it is not possible to predict which ICT tools that will be best to use in a given situation, but focus should be on the end user and the purpose of the network. Regular updates on the content of the ICT tools, selecting first movers, ambassadors etc. may play an important role in a successful application.

The analysis has identified some important barriers which need to be overcome to obtain the full potential of the use of social media and other ICT tools in the agricultural sector The present lack of use of social media for innovation may be overcome by stepwise promotion and tailoring of social software systems and testing of crowdsourcing and innovation brokers in Horizon 2020 or in OGs under the EIP. Lack of reliable and fast Internet connections are crucial barriers for virtual collaboration and innovation. This barrier may be reduced by rural development funding of broadband infrastructure in regions with no or slow access to the Internet. The price of hardware and broadband subscription may also be an obstacle in poor regions, but rural funding programmes may also assist here. Also cultural aspects may also be a barrier – almost one-third of EU farmers are above 65 years of age and probably not familiar with PCs, smartphones and ICT tools. Promotion of easy access ICT tools, courses and demonstration of good examples may reduce the problem. Another cultural barrier is the lack of engagement of researchers in social media for farmers. A change in the system for rewarding researchers may solve this problem. Risk of overload and misinformation of farmers, participating in multi-actor social media platforms may also be a barrier. Use of Twitter for following reliable experts may be used as a filter for overload and misinformation or it may be built into the software tools used for the virtual networking. The lack of maintenance of networks beyond research project periods is a barrier for the establishment of stable and lasting collaborative networks within different fields of the agricultural sector. Increased use of already established ICT tools and well-established virtual social networks such as AgChat may change that.

2.4 Are AKIS fit for purpose?

The first AKIS report already indicated that AKIS are not fixed systems, but that they are continuously evolving. Given the dynamic challenges described in the first section and the increasing focus on interactive innovation, it can be questioned if AKIS are fit for purpose. Will AKIS in the future be ready to deliver on the three dimensions of sustainability (People, Planet and Profit) and be resilient towards several possible scenarios? And are the necessary monitoring and evaluation systems in place to examine of current policies are performant or need to be altered?

The next chapters will investigate these questions by examining possible scenarios, but information on future directions and important issues is also available from recent European projects. The PRO- AKIS project[3] focused upon the advisory services as a key player in AKIS, in order to investigate how and from what sources farmers can get reliable and relevant knowledge, orientation and support to continuously evolve, to solve problems and to respond to external expectations and development opportunities. The project formulated policy recommendations (Knierim *et al*., 2015) on the policy design, the governance of AKIS and support to specific actors. They are the following:

- Policy design
    - To support innovation processes in agriculture, policy measures should take into account the diversity of AKIS and ensure that measures target the appropriate level (national, regional) and type of intervention (e.g. structural funding, incentives);
    - Policies should encourage systematic evaluation to allow for comparative appraisal of knowledge systems and advisory services;

[3] Prospects for Farmers' support: advisory services in European AKIS. EU FP 7, GA n° 311994. www.proakis.eu

- Governance of AKIS
    - The AKIS concept should be promoted for national- and regional-level use as a diagnostic tool for knowledge exchange by public actors and policy makers. Utilising the AKIS concept will allow to identify strengths and weaknesses of knowledge flows and interaction in national and regional AKIS;
    - Policy should encourage research practice which values knowledge exchange with end users, especially farmers, and the orientation towards their needs. translation' and 'adaptation' measures and services are necessary to provide practical knowledge;
- Support to specific actors
    - A long-term perspective is required to maintain advisory services that provide public goods where there is no other funding mechanism for their provision. Advisory service infrastructure or public support of independent private advisory services should be maintained;
    - Support training and education for AKIS actors and the development of certification schemes to create transparency about the quality of advisory services;
    - Specific medium-term approaches are required to enhance the potential of small-scale farms;
    - Rural multi-actor innovation networks are complementary to professional advisory services and should be supported accordingly. Multi-actor networks are able to deliver advisory services with innovative formats that overcome some of the limitations of conventional advisory systems.

This policy recommendations are also supported by earlier findings of the Solinsa[4] project. Burkart *et al*., 2014 also stress for example the importance of appropriate support to AKIS actors and networks, the importance of recognising networks and their knowledge, the need for more cooperation in the AKIS and the funding of practice-related research. Additionally, the training of actors and their networks to realise transitions is stressed, just as cross-sectoral activities and intermediary persons.

These research findings all illustrate that the AKIS are on the move to adapt to a changing world. AKIS have long been able to take up new agricultural challenges, be it for instance mechanisation, introduction of chemicals, the green revolution or environmental aspects. But it seems that now the way AKIS are organised themselves has become an issue. Partly this has to do with changes in the food chain (Figure 2.1) where input firms and food processors have become bigger, and farmers more educated and integrated in society. In last decennia there are also new ideas on the role of the state versus the private

[4] Agricultural Knowledge systems in Transition: Towards a more effective and efficient support of Learning and Innovation Networks for Sustainable Agriculture. EU FP 7, GA n° 266306, www.solinsa.org

sector. And now it seems that also ICT is going to play a role. This aspect is in depth discussed in chapters 4 and 5 of this report, followed by a foresight analysis to investigate potential future scenarios to which the AKIS has to be made more resilient. But seeing the more interconnected world we are living in and the role of the developing and middle-income countries on the world's food security, the next chapter firstly investigates synergies between agricultural research (AR) and agricultural research for development (ARD).

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3 AR AND ARD: WORLDS THAT COULD COME TOGETHER

By Krijn Poppe, Anne Vuylsteke, Hans-Jörg Lutzeyer, Alex Percy-Smith, Patricia Wagenmakers and Wolfgang Kasten, based on joint sessions of SWG AKIS and the SWG ARCH[5]

3.1 Fading differences between ARD and AR

Agricultural Research (AR) focusses on national needs within Europe whereas Agricultural Research for Development (ARD) is dedicated to collaboration with and in developing, countries working towards the Millennium Development Goals. Historically research and innovation processes for agriculture have been implemented by the EU's Member States rather differently from research for agriculture in development cooperation. Target groups, issues and governance have been quite different. In many EU Member States the Ministries for Development Aid or Foreign Affairs and their agencies are responsible for ARD whereas AR for Europe is mostly driven by Ministries of Science or Agriculture.

There are reasons to revisit the communality between AR and ARD:

- It has become clear, especially through the global challenges that the two domains have much in common. Both now address global challenges such as climate change, sustainable agricultural production and use of natural resources, food and nutrition security, poverty and social equity and demands for energy.
- The world has become smaller in recent decades as food systems between the continents are now more integrated by international trade and foreign direct investment. But continents are also connected through the use of natural resources, environmental trade-offs, ecosystem services etc.
- There is more south-south interaction in trade and foreign direct investment. For instance in Africa the role of China as a client and investor, also in rural infrastructure such as roads, has increased.
- A number of activities on the political agenda stimulate the opportunities for cross-liaison and co-learning. The EU-Africa high-level policy dialogue on Science, Technology and Innovation for example identifies securing food and nutrition security and sustainable agriculture development, including water management, as the first priority. Climate change and food transport are also associated with the spreading of (new) pests and diseases.

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[5] The Joint EIARD SCAR Strategic Working Group – ARCH [European Agricultural Research towards greater impact on global CHallenges]

3.2 Bridging AR and ARD

As the differences between AR and ARD are fading, it appeared to be necessary to link between SCAR and EIARD[6] to realise a better coordination between both. In 2013, ARCH (European Agricultural Research towards greater impact on global CHallenges) was set up as a joint EIARD SCAR Strategic Working Group. The group's aim is to improve linkages between AR and ARD aiming at identifying and working towards ways to increase the contribution of European Agricultural Research investments to the solution of global challenges. The activities focus on improving linkages between Agricultural Research and Agricultural Research for Development and include:

- Development of Mutual Learning Processes for improving knowledge exchange between AR and ARD targeting research funders, programme managers, policy makers and decision makers;
- Improving coordination between countries leading to more synergy;
- Improving efficiency of use of research funding through collaboration between European national funders and at European Commission level.

The linkages between research and innovation, the functioning of AKIS and the interactive innovation model are relevant topics for both AR and ARD. Therefore, the SWGs AKIS and ARCH joined forces in a common workshop (May 2014). The aim of the workshop was to improve the understanding on these common topics and to formulate policy recommendations to feed into policy dialogues, relevant fora, the EC and national / regional governments. After the scene had been set, the workshop addressed the opportunities to align research themes for AR and ARD, innovation partnership approaches and strategies for aligning funding for research and innovation.

The common ARCH-AKIS workshop resulted in a Policy Brief, primarily targeting the policy-makers and funders in the EC, as well as in national funding ministries and agencies. The main messages of the policy brief are reflected in the next sections.

3.3 Best strategies for intercontinental research and innovation partnerships - towards greater impact on global challenges

3.3.1 Opportunities to align research themes for AR and ARD

There are several aspects of research and innovation where AR and ARD can reinforce each other. Issues which come to mind are research themes, such as food and nutrition security, climate change, poverty alleviation and many others. At the farm level these themes are often interlinked in terms of decision making, while their interrelationships are less well recognised at the global level. As a consequence, many policy interventions for individual challenges are considered in isolation.

Multi-stakeholder collaboration is necessary to address these complex global research challenges. The global aspect means that it is not very efficient to try to solve the problem in one continent, if that means a the problem is shifted to

[6] EIARD is the European Initiative for Agricultural Research for Development and it is a permanent informal ARD policy coordination platform between the European Commission, Member States of the European Union, Switzerland and Norway.

another continent. This implies that resources should be allocated to the region where the problem can be solved most efficiently.

Many research needs are not limited to one country or continent, but should be developed in cooperation between countries, regions and continents. For example, problems such as infectious pests and diseases (e.g. avian flu or African swine fever) are 'cross-border' issues in which the problems in one continent could spread to another. In addition there are themes that are not necessarily a global challenge, but that are relevant in different continents, including rural livelihood issues or family farming.

Besides themes there are other aspects of research and innovation that can be of common interest. One is the methods that are used in research and innovation, from genetic research, multi-scale modelling or Information and Communication Technology (ICT) to participatory research and multi-stakeholder processes. In the past, several methods developed in ARD have also been taken up by AR (e.g. systems research, action research) and vice versa.

Research infrastructures (such as gene banks, expensive technical equipment or soft infrastructures including databases) are other issues in which AR and ARD could reinforce each other.

Finally, AR and ARD can reinforce each other in institutional and governance aspects. In both areas there is increasing attention being paid to new forms of public-private partnerships. Societal aspects of research (as in the GMO debate, asking for social innovation) and discussions on assessing science in terms of excellence, relevance and impact are also communalities between AR and ARD.

Of course there are also important differences, in products and context (institutional, social) and certainly in the fact that in ARD the focus is more on innovation with the poorest, to address the Millennium / Sustainable Development Goals, and so bring the developed and developing countries closer than ever before.

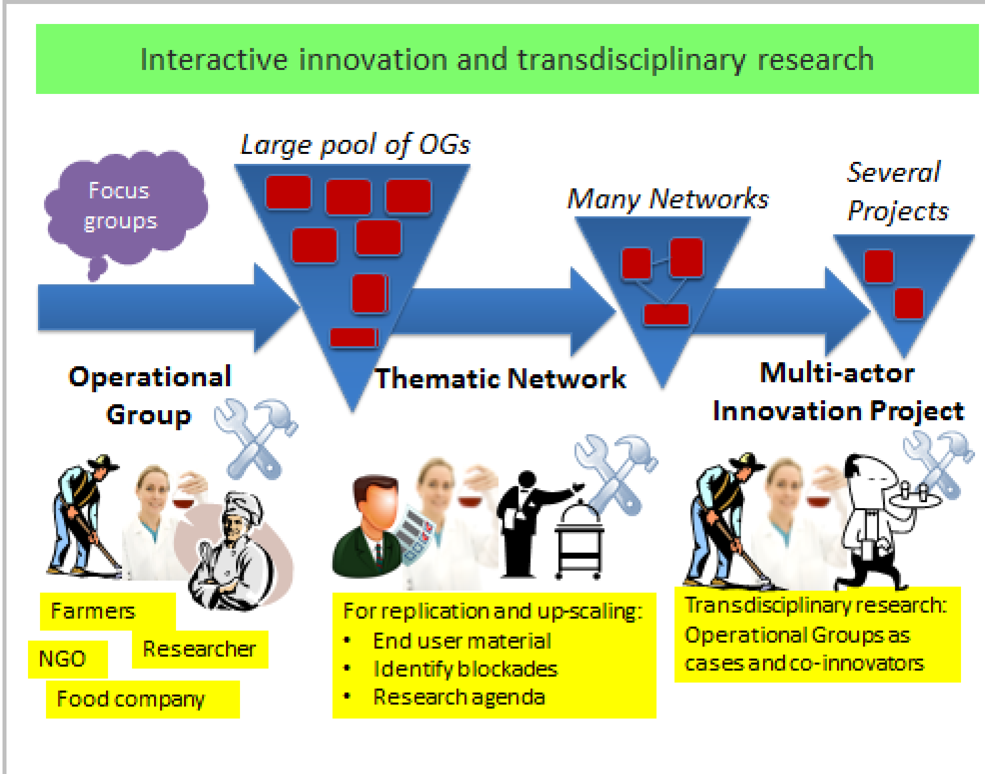
3.3.2 Innovation Partnership Approaches

In its statement on the Innovation Union, the European Union has addressed the need for more innovation. In agriculture the Innovation Union has led to the European Innovation Partnership "Agricultural Productivity and Sustainability" (EIP-AGRI) in which links between research and innovation are strengthened. The EIP-AGRI can provide a framework to connect local multi-actor groups via thematic networks on global challenges to research programmes with transdisciplinary research approaches. The agricultural policy supports so called Operational Groups (OGs), "multi-actor" groups that work locally on an innovation project. This is comparable to what is done in many multi-stakeholder development projects (although there could be a difference in the sense that actors are expected to co-create "all along the project" as partners in the activities, while stakeholders can restrict themselves to only express their views (stakes)).

These groups are linked to the interacting global themes and research projects by thematic networks and scale-up the results of OGs by producing end-user material to induce replication of successes (and learn from failures). They also identify new bottlenecks and produce research agendas.

Research projects such as in Horizon 2020 can often be formulated as multi-stakeholder / transdisciplinary projects in which OGs and private business (SMEs or larger) take part.

Figure 3.1	**Interactive innovation and transdisciplinary research**



Source: Policy Brief AKIS-ARCH

International Innovation Partnership Approaches build on a rich experience of multi-stakeholder and participatory research in ARD. However, a new joint policy framework is needed for research and innovation policies and development cooperation policies, both on national and EU levels.

3.3.3 Strategies for aligning funding for research and innovation

Experiences shared by the countries demonstrate that there are important differences in the alignment strategies. While some countries are only taking their first steps to establish a strategy to align funding for research and innovation, there are also examples from Member States with a high level of policy coherence (e.g. The Netherlands).

Lessons on alignment and stimulation of innovation can also be learned from research projects that have recently been carried out. The FP7 project JOLISAA (Joint Learning in Innovation Systems in African Agriculture) investigated innovation in developing countries and came up with recommendations such as: Build on innovation in practical situations ("innovation in the wild"); Combine local and external knowledge and ideas to enhance innovative capacity; Encourage access to diverse value chains to lower the innovation risks; Support unpredictable innovation processes and Address the multiple dimensions of innovation.

The SOLINSA project (Support of Learning and Innovation Networks for Sustainable agriculture) found that innovation is about knowledge creation and exchange, but also about fostering entrepreneurial drive and activity, vision development, resource mobilisation, market formation, building legitimacy for change, and overcoming resistance to change. It demonstrated that, in this context, it is crucial to understand both the process that constitutes innovation as well as the context in which the process takes place. The project recommended supporting emerging learning and innovation networks by improving their organisational capacity (governance, project management, leadership, decision making and coordination), and by recognising the importance of the role innovation brokers (transition partners).

Other projects, including ESFIM (Empowering Smallholder Farmers In Markets), had similar experiences and observations.

3.3.4 Concluding remarks from the Joint ARCH AKIS Workshop

The following findings and suggestions are relevant and have been submitted to SCAR, EIARD, the Expert Group supporting the High Level Africa Initiative, the European Commission (DG DEVCO, DG AGRI and DG RTD) and the Member States' governments.

- Europe is sometimes perceived as being difficult to approach by potential partners in research and innovation and cross-border cooperation has been difficult. There seems to be a lack of unified and coherent thinking between different policies across Europe and a lack of clear vision. Policy makers at national and EU levels should seek for cross-policy collaboration.
- Many areas of joint interest have been identified and demand for collaboration between the AR and ARD domains. This can be achieved by bringing together farmer's knowledge and scientific knowledge (technological, social and economic).
- Innovation starts with producers' and consumers' needs. New bottom-up models have to be designed and technology has to be adapted and sometimes redesigned to target diverse implementation levels and reach desired outcomes.
- The approach to promote private sector involvement in developing countries - involving partners from Europe and outside Europe - should be elaborated and diversified. The role of multinationals differs from SMEs. A framework is needed that deals with diversity as an asset of public-private partnerships.
- The added value of European international research and innovation practices must be made explicit. The alignment across Member States should be strengthened and can feed into national knowledge policy as well and benefit from strategies guided by evidence. Shared visions on research and innovation will lead to more effective partnerships and a higher impact on global challenges.
- Policy makers should discuss the desired flexibility in the application of funding mechanisms (competitive calls in Europe, targeted funding to institutes in the tropics, innovation prizes, loans, public-private partnerships, etc.).
- The balance between the criteria for the evaluation of research projects (excellence, relevance and impact) should be reassessed to overcome the gap between science-driven research versus innovation-driven research.

- Policy makers, including for example the High Level Policy Dialogue on EU-Africa, and the EU-Mediterranean partnership (PRIMA), could benefit from the insights of the ARCH and AKIS groups. New intercontinental innovation partnerships should become part of a policy framework of research and innovation and development cooperation.

3.4 Additional issues

Our discussion illustrated that intermediary actors are needed to bring research results into practice. The question is then how the system can be scaled up and which instruments and framework conditions are needed. In this context, there is need for institutional innovations in order to bring people together and to come to practical implications. An important bottleneck is the complexity because of the diversity between systems and initiatives. This requires a more profound interaction between AR- and ARD-researchers and a focus on impact of research as well as scientific excellence.

In funding and agenda setting, there is a challenge in AR and ARD's aims for different outcomes, but this can be addressed through specific funding initiatives (such as the UK strategy for agricultural technologies). But other activities are also possible, including alumni activities. In the organisation of research, the demand for more collaboration between actors in and outside EU is supported by several countries.

When it comes to innovation partnership approaches, there seem to be more differences between AR and ARD. The technical institutes and intermediary actors in the EU are, for example, well organised, while in other regions there is a strong but scattered civil society. The approach can also differ in function of the final end client (private versus public sector). Despite the differences, it makes sense to strive for more alignment in the field of innovation. The Dutch Food and Business Knowledge Platform (which acts as a steering committee) and the French RITA network for knowledge transfer in the overseas regions are interesting examples.

There are different views and models to create pathways to the intensification of agriculture. While the one country may want to transform its agriculture through agro-ecology, another country might opt for a strategy based upon community-based approaches. All partners, however, wish to develop a common policy framework and a research and innovation agenda that can overarch the diversity. Diversity is considered to be an asset: it gives local actors the opportunity to choose a solution that fits best to their demand and their context.

There is a need for a better understanding of each other's' framework, e.g. through the analysis of programmes on similar topics. It could also be worthwhile to reflect upon several funding strategies with their advantages and disadvantages. It is not about creating new funding schemes, but about exploring what can be done based on the existing schemes.

Multi-stakeholder groups appear everywhere and often struggle with the same problems (How to involve SMEs? How to work with competitive funding?), but the case-specific character of these initiatives should also be respected. Innovation is a process with different actors involved, but it is not always evident for those actors to be clear on their expectations. Education can play a role, but this is also culture-related. Initiatives should for sure take the time so that people can learn to understand each other. This is the case in all multi-actor projects, but even more so in cross-cultural projects that bridge the worlds of AR and ARD.

4 ICT AS A DRIVER OF CHANGE IN THE AGRI AND FOOD SECTOR

By Krijn Poppe and Elke Saggau, based on the strategic research agenda of the ERAnet ICT-Agri and insights from the Future Internet PPP in FP7.

4.1 Summary

This chapter has been written as a Policy Brief based on inputs from experts of the Strategic Working Group AKIS and the ERAnet ICT-AGRI and some interviews. The paper primarily targets policy-makers and funders in the European Commission, as well as in national funding ministries and agencies (in and beyond SCAR), including the relevant Joint Programming Initiatives (FACCA and HDHL). In this policy brief we analyse what the developments in information and communication technologies (ICTs) mean for programming and organising agricultural research and innovation.

The Policy Brief argues that ICT dominates innovation in many sectors, including food and agriculture. It could revolutionise the sector in the same way as tractors and chemicals did in the 1950s. Programming of research and innovation in the field of ICT in agriculture is a challenging task, as ICT is an enabling technology. Based on the work in the ERAnet ICT-AGRI and in the Future Internet PPP of the EU we identify a number of topics. Many of these topics have in common that a better and easier exchange of data, between applications but especially between organisations, is needed. The so-called 'interoperability' of data and information systems is very low, but value is created by the combination of data from different sources and the use by others rather than the data-collecting apps or organisations.

The Policy Brief then reflects on the role of the governments in research and innovation with ICT for agriculture and how to organise this. In line with recent reports on AKIS it makes sense to differentiate between science, market-driven R&D and innovation. Concerning science: this is mostly taking place outside agriculture, and even outside Europe. This asks for absorption capacity in agriculture. ICT is an enabling technology, where the government could be more effective by defining the challenge (e.g. food safety) and not the solution (e.g. tracing and tracking with RFID). In market-driven R&D, multi-actor projects are preferred: many equipment companies and food processing companies are or could be involved, which asks for private-public partnerships in which the government focusses on the public issues at stake. These issues are not only in absorbing technical developments but also in interoperability with standardisation and data exchange facilities. Concerning innovation, research is not the only instrument the government has: open data, regulation, support of start-ups and innovative procurement (e.g. in the administrative processes around the CAP) are some of the others.

The European context in research and innovation on ICT in agriculture needs better utilisation of research results and a larger market for commercial products. Horizon 2020, Joint Programming Initiatives (JPIs), CAP's Rural Development (EIP) and ERA-Nets (like the ERAnet ICT-Agri) are well-suited instruments. Moreover, Entrepreneurship and Innovation Programmes and the Knowledge and Innovation Communities (KICs) funded by the European Institute of Innovation and Technology (EIT) have the potential to bring together industry, education and research, in order to enhance the entrepreneurial culture and bring innovations to market.

4.2 The importance of ICT

ICTs dominate innovation in our times. Also in the farm sector and the food chain, the use of ICT has increased strongly over the last decade. Precision agriculture techniques have been introduced successfully (Henten *et al.*, 2009) and produce much data. However this is just the start of what could become a revolution in agriculture, not unlike the introduction of the tractor and pesticides in the 1950s. It will change the way farms are operated and managed and it will change the farm structure as well as the food chain in unexplored ways – just as in the 1950s, the changes in the next three decades could not be foreseen.

In this policy brief we try to analyse what these developments mean for programming and organising agricultural research and innovation.

4.3 Topics in programming research and innovation

Programming research and innovation on ICT for agriculture and the food chain is a challenging task, as ICT is typically an enabling technology to solve other issues: innovation with ICT is not done for the sake of ICT development, but to solve issues such as resource efficiency, environmental pollution, food safety or animal welfare. ICT could support labour efficiency, resource efficiency and close the gap between the producer and the consumer. It is therefore not only relevant for conventional farming but also for organic farming and short supply chains. This means that an agenda for research and innovation topics should be based on a careful mapping of agricultural issues (challenges and opportunities) with the potential contribution of ICTs (favoured over other solutions) and to see where development of those ICTs then makes sense. The ERAnet ICT-Agri has gone through that process and has come up with the following strategic research agenda for agriculture[7]:

The **Farm Management and Information System** (FMIS) as the backbone system for all other ICT and robotic solution domains. FMIS provides a common user interface across solution domains and a repository for farm information. It includes tools for communication and information exchange, and acts as a decision support system (DSS). Time-consuming and error-prone manual data collection may be replaced by automated information collection and storage. The FMIS of tomorrow will be a modular system.

Variable-rate application (VRA) is the site-specific application of fertilisers, pesticides or water. This improves resource use efficiency and reduces the environmental impact. The incorporation of FMISs and DSSs in web-based approaches is a particularly important aim.

Controlled-traffic farming (CTF) enables the geo-positional control of field traffic in order to optimise yields and inputs and reduce negative environmental impacts. Further experiments under different soil and climatic conditions are required.

Precision livestock farming is based on sensor measurements as well as on advanced ICTs. The sensitivity and specificity of bio-sensors must be improved.

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[7] Text based on the Executive Summary Strategic Research Agenda ICT-AGRI; Didelot *et al.* (2012)

Advanced systems for automated **indoor climate control** reduce energy consumption and greenhouse gas emissions, as well as improve the environment in greenhouses and buildings for livestock.

Quality, safety and traceability of food and feed are the main objectives of **automated quality control**. Sample-based quality control is currently common practice, but future technologies should enable close monitoring of individual product quality.

Agricultural robots can replace humans in the performance of manual labour – notably for hazardous or tedious work – in order to improve safety at work, labour ergonomics and efficiency, product quality, and environmental sustainability. Advances in robotic engineering must be applied in the agricultural sphere in order to step up innovation.

In addition to these points, the EU's Future Internet Public Private Partnership has stressed the fact that the use of ICT will accelerate due to **cloud technology** that makes digital exchange of data easier. **Open data** (in which governments or others share their data free of charge) can be seen as an example. Together with the **Internet of Things** (using data from sensors, machines and other devices) and the use of data from social media this contributes to the era of **big data**.

As the strategic agenda of the ERANet ICT AGRI suggests, this asks for a better and easier exchange of data. Especially between organisations the so called 'interoperability' of data and information systems is very low. This holds for SME-to-SME or SME-to-government communication as well as SME-to-big company communication. The issue is even more complex if one realises that the data exchange between, for example, farmers and their cooperative or robot supplier, leads to digital data that can be fruitfully used by third parties. The accountant requires access to the electronic invoices of the cooperative, while the farm management system, the veterinary and the herd book need access to the data from the cows milked by the robot. The PRO-AKIS study also suggested the need for integration of databases and to organise the governance of this integration.

Such interoperability asks for common standards and an **Agri-Business Collaboration and Data Exchange Facility** (an ABCDEF) is required as an infrastructure for data exchange (Poppe *et al*., 2015). Investing in compatible systems to harness the full potential of the technology through a European-wide effort is needed.

Identifying the topics for research and innovation in agriculture is one aspect of policy making. The other one, to be carried out in parallel, is identifying how to organise the research and innovation: which policy instruments should be chosen? Here we turn to the organisation of the research and innovation.

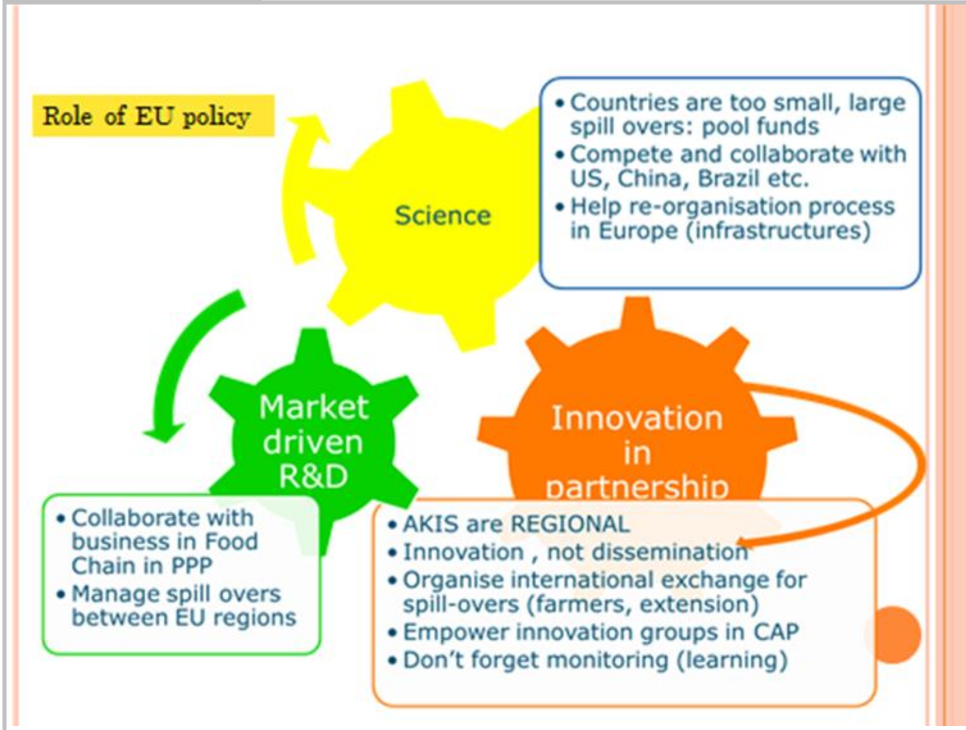
4.4 Organising research and innovation on ICT

As argued in chapter 2, research and innovation are different concepts, but need to be strongly interconnected. Links can be strengthened through better collaboration with the private sector (including SMEs), with NGOs and with other relevant players. The process should be driven by bottom-up identification of issues, challenges and needs. Several actors in the food chain are important in innovation, and this makes an interactive innovation model attractive (Figure 2.1).

This model raises the question why public support for ICT in agriculture is needed. There are big input suppliers (such as the machinery industry) and food processors (that need tracing and tracking) who have the capacity to promote the use of ICT, adapt their products to the needs of farmers and sell their hardware, software and services. A government intervention with research or innovation support should be evaluated ex-ante on its impact on these market processes. In case of ICT, the following reasons for intervention could play a role:

- Public objectives including food security, employment and regional development are not automatically guaranteed by the market. More uptake of ICT as a result of innovation and research could deliver such objectives.
- There are many SMEs in agriculture, the food and the machinery industry that underinvest in knowledge. Investment costs can be (too) high and IPR cannot easily be protected: it is quickly copied in the market. Pooling of funds make sense.
- There could be systemic bottlenecks hampering the collaboration between agriculture and the ICT-sector.
- There is a need for common pool investments (infrastructure like ABCDEFs, standards for data exchange etc.) that individual companies will not create.
- There could be (negative) external effects of ICT that need attention: privacy, data ownership, potential discrimination by software algorithms, power balance in the food or software chain, effects on small farms and on remote regions etc.
- There are negative external effects in agriculture that can be more attractively solved by ICT than by regulation (e.g. precision agriculture should benefit the environment, food safety, animal welfare etc.)
- The government is a user of ICT: for example, the simplification issue in the CAP could benefit from better ICT between government and farmers; Governmental supported research could be more efficient with e-science. Public extension services could work more effectively with ICT.
- In promoting the uptake of ICT in agriculture (or reducing its negative effects) with research and innovation, it makes sense to differentiate between science, market-driven R&D and innovation, as has been argued in previous AKIS reports (Figure 4.1).

Figure 4.1	Science, R&D and Innovation



Source: Report AKIS-1

4.4.1 Supporting Science on ICT

Considering (pure) science, we have to realise that fundamental developments are in computer science and related disciplines at technical universities, and lead by the United States (Stanford etc.) as well as some research laboratories of big IT multinationals (IBM etc.). The (American) military complex is a main driver as can be seen in the development of GPS or drones.

At best, agriculture and food could be an interesting case in some of those research programmes. For example because it is a challenge for robot developers to have them work outdoors in a much more dynamic environment, or with animals such as cows. Science policy (mostly executed in academies of science) could promote such cross-overs. This calls for multi- and interdisciplinary approaches.

4.4.2 Supporting R&D on ICT

In research and development, one of the objectives of government policy could be to stimulate the interaction between different sectors (in this case the ICT sector and agriculture and food) to overcome systemic network deficiencies that prevent sectors from working together on a routine basis. This calls for absorption capacity in universities and research institutes that deal with agriculture: they should have some staff that can act as a linking pin between ICT developments and the (challenges in the) agricultural sector.

A very interesting form of strengthening such cross overs are public-private partnerships such as in the EU FP7 Future Internet Public Private Partnership (FI-PPP), and in the coming years comparable expected Public Private Partnerships on, for example, Big Data, Internet of Things etc. A public-private partnership is an interesting form for several reasons. Firstly, many companies in, fpr example, the machinery and food industry have a commercial interest in innovating in these areas, making it attractive for the government to strengthen or adjust such processes instead of paying the full research bill (and running an extra risk of lack of take up by the commercial sector).

Secondly, it is attractive because such a PPP includes big ICT companies such as IBM, ATOS, SAP, Telefonica and others, and links their expertise and future business with the needs of agriculture and the food chain.

Thirdly, the FI-PPP has found an interesting form to link innovation in ICT with the (public) challenges of sectors and to support innovative start-up companies. This was done by running the PPP as a programme with several phases. In Phase 1 technology development in ICT was linked with (competitively funded) projects in different sectors (e.g. agriculture, energy, environment, public services) that had to identify potential applications of such technologies and come up with conceptual designs. In Phase 2 platforms for data-exchange were built and in Phase 3 accelerator projects run called for small projects (EUR 50.000) where SME and (start-up) web-entrepreneurs can build innovative apps to kick-start such platforms.

Fourthly, an approach with European platforms (such as those created in Phase 2 of the FI-PPP) helps to create European markets for smaller companies in specialised sectors. In many countries the market for, for example, farm management information software for potato farmers or bee keepers is rather small. Therefore ICT companies realise modest cash flows, which makes it hard to invest in new technologies (such as cloud computing) or new services. By providing them European platforms (and in the FI-PPP general enablers as building blocks for their software), they can enlarge their markets and upgrade their products.

The organisational constructions with several phases in the programme could be inspirational for Horizon 2020 projects and ERA-nets in several ways. The approach helps to organise multi-actor projects in which technology developers, (larger) agriculture and food industries and farmers are incentivised to work together. It helps to blend pure technology development with practical trials in innovation actions. It makes it possible for the European Commission or EU Member States to commission quite large projects (reducing transaction costs and freeing up capacity which is especially with the EC quite scarce) and nevertheless involve SME on small trials. For ERA-nets, that have to work with quite different financial commitments and national priorities from Member States, it could help to work on common platforms, standards and infrastructures but at the same time include small innovative projects and trials that could probably be funded in one country.

4.4.3 Multi-actor R&D projects

From a public perspective, the machinery industry has a big incentive to realise many of the technical developments (such as VRA or robot technology), and in general it seems that such companies are big enough to do their own R&D or form a cooperative alliance to do so. It would therefore be appealing from a public perspective to focus on multi-actor R&D projects with a public-private character with companies from sectors that normally do not work together, or have to invent together new solutions that are risky. An example could be the use of ICT in short supply chains and solving the "last mile issue" (How to link growers to consumers and restaurants?) on ICT platforms and then have the fresh products delivered in time at a reasonable price.

In addition there are a number of issues regarding ICT that firms will not invest in. The first group is linked to infrastructure. To maximise the usefulness of cars in the 1950 and 1960s, new roads such as motorways had to be built. In a similar way, the era of ICT needs infrastructure. Partly that is telecom infrastructure including broadband Internet (which is a bottleneck in some rural areas that can perhaps be solved with regional funds) but also more dedicated agri-food 'soft' infrastructure is needed. Examples are standards and data exchange facilities for interoperability.

To facilitate the exchange of data between actors standards for electronic data interchange (such as EDI, XBRL etc.) are needed. These have to be based on reference data models that provide a common understanding of data items. Standards can be created *de facto* by private companies (like the pdf standard for documents, created by Adobe) but often companies do not have a large interest in such an investment (or are afraid of the competition that is promoted by open standards). Sometimes branch organisations play a role or are created for that purpose (for example GS1, originally in retail for product codes). A European standards organisation for ICT in agriculture is lacking. Currently there are initiatives by the American standards organisation AgGateway (in which European multinationals such as BASF also participate) to set up an equivalent in Europe and on other continents.

Besides standards, also platforms are needed where data could be exchanged between actors: Agricultural Business Collaboration and Data Exchange Facilities (ABCDEFs). These are business-to-business software tools comparable to LinkedIn or Facebook – a social media service that connects companies (instead of persons) and companies' operations. Businesses can contact each other (or a government agency) and start a collaboration. They could, for instance, detail a contract and specify which data they would like to exchange, the standards the data will conform to (for example, EDIFAC or XBRL) and under which circumstances the exchange will occur. This could be data such as invoices or delivery notes, but also Internet of Things data that allow for real time tracing and tracking. Sharing such data should be as easy as uploading a photograph on the social media, but here the analogy with the social media in private life ends. Companies may be more willing to maintain control of their data, specifying access and use rights, and whether their data can be centrally stored with a third party. Essentially such ABCDEF-software makes it possible to give business partners (and governments) access to data of farms and helps farmers to combine data from different sources.

Like LinkedIn or Facebook, such platforms could grow out of a private start-up, but it is questionable if this will happen in the European context with low availability of angel and venture capital. In the meantime agro-food companies around the farm set up their own web portals where farmers are asked to enter their data. That is easier for them than creating a multi-sided platform. But the result is inefficient for farmers who have to supply the same information to many stakeholders. A clear example is the data that farmers have to provide to different certification auditors (for EuropGap, BRC, organic inspections etc., many farmers have to deal with more than one certificate). It also leads to a lock-in effect: farmers cannot take the data with them if they switch from one food processor to another.

Supporting farmers in this uneven power balance in the food chain and in this way reduce the administrative burden in agriculture could be seen as a public task. Related to the power balance is also the issue of ownership of data (IPR on data). It is not so clear who owns the collected data (and this might differ between EU Member States): are the data on the cows collected by the milk robot owned by the farmer or the robot manufacturer? Is the farmer free to provide his/her accountancy report to an advisory service, a risk management company or can it freely be shared in a software platform for benchmarking? Or is it co-owned by the accounting firm? These legal issues are complex, also as such ownership is based on privacy regulations (besides private contracts) that differs between EU Member States.

Another issue in which companies will not invest themselves at an optimal level is social innovation and the potentially negative externalities of ICT. Similar to the power balance mentioned above, issues such as privacy, data ownership, the effects of ICT on small farms and on remote regions etc. should be investigated and discussed. Research on social innovation could benefit from a foresight study on the potential effects of ICT and how it will change the agricultural, food and retail sector. Examples from other sectors such as music (iTunes, Spotify), books (Amazon.com), hotels (Airbnb) and transport (Uber) show that these effects can be more disruptive than expected. If such social innovation is lacking, there is a certain risk that the technical development is rejected by the society (c.f. GMO technology). It makes sense to specify in call texts that attention should be paid to such aspects.

From a public perspective, R&D projects on ICT could also focus on public issues in agriculture including environmental impact, food safety and animal welfare. In some of these issues ICT might be part of the solution. Better and cheaper tracing and tracking might help to improve food safety; environmental issues can be tackled with precision farming. Regulation of the environmental problems might induce investments in technology and development of ICT-based solutions, but sometimes it is attractive for the government to help develop the solution with research and development. That could be done in two ways, either by a call for research into the issue (for example, pesticide pollution), suggesting that an ICT-based solution could be one of the innovations, or by a call for an ICT project in which the issue (for example, pesticide pollution) is the domain of the project. From a societal point of view the first option is often most attractive as the most effective and efficient solution is not prescribed but has to be found in the project or programme. The second option is more attractive if some ICT technology has to be tested in several areas.

In all these cases a multi-actor approach is attractive in which the needs of farmers are taken on board. Projects should include a work package that looks to the exploitation of the research findings, by carrying out business modelling and value chain analysis.

4.4.4 Supporting innovation processes on ICT

Innovation is something different from R&D, and R&D is not the only instrument for the government to promote innovation. Operational groups could play a good role here. For instance on identifying ideas for good apps for agriculture, in operational groups with web-developers, researchers and partners in the food chain. They could also function as test-groups for software and provide test data. For advanced solutions on ICT such as the use of robots, drones, self-driving tractors etc. international operational groups could play a useful role to exchange experiences and help multinational companies to find European solutions.

One of the other instruments that governments could use to promote innovation is that of open data. The government has a lot of data in its computers, for example cadastre data on the land register, GIS data on parcels and crops grown, import and export data, weather data, data with registers of pesticides that are allowed on certain crops under certain conditions etc. Providing these data as open data to the public, including web and app developers, helps to create new services.

Also innovative procurement could be an attractive tool to promote ICT uptake. The government exchanges a lot of data with agriculture and the food business: CAP data, data on food safety, environmental legislation, organic certification data etc. The government has the possibility to exchange those data between farmers and government agencies using innovative ICT solutions. This would call for participation in ABCDEF's (as mentioned above) so that farmers could exchange the data with the CAP Paying Agency as easy and from the same farm management system and via the same ABCDEF as with their sugar company or the certificate auditor or their accountant.

Innovative procurement could go hand in hand with standard setting. The Netherlands has for example obliged companies (including farmers) to use an XBRL (eXtended Business Reporting Language) standard to report their profit and loss account and balance sheet data with their income tax statement to the tax authorities. This will in the future provide farmers with the opportunity to provide the same digital data to their bank or others who need them. It could also be a good basis for benchmarking and especially using more sophisticated statistical and graphical analysis of the farm performance with e-benchmarking.

Related to these two instruments of innovative procurement and open data is the issue that some regulations might hinder the uptake of ICT. An example is the use of pesticides. Not all pesticides are registered in a country for crops with small areas as they are in neighbouring countries with larger areas that are a bigger market for chemical companies. Some farmers feel that they do no harm in using those pesticides but know that they are doing something illegal. For this reason, they do not use ICT or record their use incorrectly. In such cases a process to change the regulation or harmonise with neighbouring countries could improve the ICT uptake.

4.5 ICT will change the research and innovation process

Multi-actor innovation might benefit from modern ICT support, comparable to how ICT (and in the last ten years especially the World Wide Web and social media, now enabled by smartphones) is changing working processes and collaboration in the rest of the daily life. There is a great potential for using existing social software tools and platforms for communication, interaction, knowledge sharing, preservation of information and as such stimulate multi-actor innovation (EU SCAR, 2013).

ICT will not only be supportive in innovation processes but also change research. E-science is becoming a reality. Modern science, research and development is changing rapidly into a data-driven and highly interactive process between all kinds of players, across the world. Unique knowledge in e-science, artificial intelligence and ontology engineering is more and more developed and applied in national and major international projects. Advanced ICT tools to share and analyse research data are being developed, such as Tiffany (an innovative Laboratory Information Management System) and Phenome One.

More and more software will be developed to gather data from the real world for research. An example in the area of food and health is the RICHFIELDS Platform (a Horizon 2020 project). Essentially this could be a platform where consumers maintain data on their food consumption, lifestyle (based on apps and wearable technology), medicine use and medical dossier. Consumers could then donate their data to research or trade these for, for example, specific advice.

In the same way, researchers and extension workers will in the future more often use data from farms instead of experimental farms as big data sets of farmers will become available. We could imagine a future in which they will use data from nearly all farms to give specific advise via ICT to individual farms instead of the current practice of researchers to use the data of a few (experimental) farms and provide generic advice. An example is the America Farm Business Network that between its launch in November 2014 and May 2015 has aggregated data from 7 million acres of farmland across 17 states, and is a benchmarking tool for farmers, able to assess the performance of 500 types of seeds and 16 different crops.

The next chapter looks in more detail to this use of ICT in transdisciplinary research and innovation, as an aspect of E-Science

4.6 Concluding remarks

The issue of ICT and agricultural research and innovation is complex. There are many ICT developments that will benefit agriculture and the food chain. Some will be disruptive and call for social innovation. Promoting such innovations is a challenging task for governments.

Firstly because innovation in ICT as such is mostly taking place outside agriculture, and even outside Europe. This calls for absorption capacity in agriculture. Secondly because ICT is an enabling technology, where the government could be more effective by defining the challenge (for example food safety) and not the solution (such as tracing and tracking with RFID). Thirdly, because many equipment companies and food processing companies are or could be involved, which calls for private-public partnerships in which the government focusses on the public issues at stake. These issues are not only in absorbing technical developments but also in interoperability with standardisation and data exchange facilities. Fourthly, research is not the only instrument the government has: open data, regulation, support of start-ups and innovative procurement are some of the others. Fifthly, the research and innovation process itself is changing due to the use of ICT and big data.

These challenges imply that funding and research initiatives should seek interaction with the beneficiaries (in the broadest sense) for successful research and innovation programmes. They[8] should stimulate interdisciplinary RTD comprising agronomics, engineering, computer science, economics and social sciences as well as public-private partnerships. The public and private actors who maintain the basic farm data and who are familiar with advice and support to farmers must be involved.

This should be done in a European context so as to ensure better utilisation of research results and a larger market for commercial products. Horizon 2020,

[8] Text from ERAnet ICT AGRI

Joint Programming Initiatives, European Innovation Partnerships and ERA-Nets (such as the ERA-net ICT-Agri) are well suited instruments for introducing such interdisciplinary research into national research programmes. Moreover, Entrepreneurship and Innovation Programmes and the Knowledge and Innovation Communities (KICs) funded by the European Institute of Innovation and Technology have the potential to bring together industry, education and research, in order to enhance the entrepreneurial culture and bring innovations to market.

But we should not look to Europe only. The issue is a global one, and many companies are working on a global level. Not only does the ICT developments for a large part come from the USA, many of the European companies in supplying machinery or inputs (such as seeds) export outside Europe. And some of the developing countries (such as in East Africa) are digital pioneers in mobile banking and extension, implying that this is an area where Agricultural Research and Agricultural Research for Development could reinforce each other.

The rapid development of technologies places high demands on the education and training of farmers. National and transnational agriculture knowledge and innovation systems should place a greater focus on the continuous training and qualification of farmers and farm consultants. ICT in the form of, for example, Massive Online Open Courses (MOOCs) might help. The 'next revolution' in agriculture and food is based on ICT. The quest for sustainable intensification of agriculture (more food for the world with a lower footprint) makes it necessary to fast track this type of research and innovation.

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5 THE ROLE OF E-SCIENCE IN AGRICULTURE: HOW E-SCIENCE TECHNOLOGY ASSISTS PARTICIPATION IN AGRICULTURAL RESEARCH

By Jan Top and Mari Wigham (Wageningen UR)

5.1 Introduction

The objective of this chapter is to analyse how e-science can increase the participation of practitioners and researchers in agricultural research, and hence increase the mutual impact of such research. In this chapter, we discuss the need for participation, and define four types of participation that are possible in agricultural research. We sketch the form that these types of participation can take in agricultural research, and the relevance of e-science for these participations. For each type of participation, we select relevant cases that already exist in agricultural domains, and discuss the e-science technology involved. The focus is on participation, and as such we will not include e-science tools that do not directly facilitate participation, such as high performance computing, algorithms for precision agriculture, lab management systems, visualisation, etc. Based on what we have discovered, we will identify a number of issues and opportunities relating to the use of e-science in agriculture. Finally, we will conclude with the steps that can be taken to more fully realise the potential of e-science for encouraging participation in agricultural research.

Most of the material in this study is based on an analysis of available information on the Web and from literature. We have also built on our experiences with e-science in projects such as the EU FP7 Valerie project[9] and the Dutch COMMIT/eFoodLab project[10].

5.2 Participation in agricultural research

In contrast to the stereotypical image held by many, innovation is a vital part of agriculture. Modern society is increasingly demanding efficient, effective and sustainable production in a global society. New competitors, new demands from consumers, and concerns about health, animal rights and environment, mean that today's farmer must keep abreast of a rapidly changing world in order to succeed. At the same time, agriculture must adapt to the large amounts of data being produced by new sensors, the increasingly global scale of production, widespread and remote locations and the diverging needs of different consumer markets.

To answer this need, innovations are springing up from academia, applied research institutions, and, not least, the agricultural industry itself. Scientific research is needed to understand the fundamental mechanisms occurring in soil, crops, atmosphere, transport, storage etc. This theoretical knowledge is to lead to practical innovations that improve agricultural performance and meet society's demands. Key to this process is a short, efficient pipeline of innovations from researchers to practitioners.

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[9] www.valerie.eu

[10] www.commit-nl.nl/projects/e-foodlab

The official EC for Horizon 2020 text recommends promoting closer involvement of citizens – which naturally includes practitioners – in science:

"With the aim of deepening the relationship between science and society and reinforcing public confidence in science, Horizon 2020 should favour an informed engagement of citizens and civil society on research and innovation matters by promoting science education, by making scientific knowledge more accessible, by developing responsible research and innovation agendas that meet citizens' and civil society's concerns and expectations and by facilitating their participation in Horizon 2020 activities"[1]. Interestingly, this recommendation does not imply an active role of citizens in research.

In their report 'Agricultural Knowledge and Innovation Systems in Transition – a reflection paper' [2], the SCAR Strategic Working Group AKIS distinguishes between *science-driven research* and *innovation-driven research*. Innovation-driven research requires an effective feedback loop to keep researchers informed of the challenges faced by the practitioners. This implies that researchers are actively involved in farming, and practitioners in science. This is far from simple, given that practitioners and researchers often come from very different backgrounds, use different terminology, and have different interests and priorities.

We have identified four types of participation in the research process by practitioners. Agricultural practitioners include – but are not limited to – farmers, extension workers, educators, food industry, government and even consumers.

- **Providing and collecting data for science.** Scientific research requires data about the real world as input for testing hypotheses. Existing data can be passed on to researchers by practitioners, which is a relatively passive participation.
- **Participating in experiments for science.** However, practitioners can also produce data in trials or pilot studies. This means that predefined experimental conditions are applied in a real life setting, i.e., outside the traditional research institutes. In this case, the practitioner plays a more active role in the scientific workflow. Extension workers can play an important role in setting up such experiments.
- **Contributing field knowledge *to* science.** One step further in the scientific process, practitioners can also contribute knowledge, as input for scientific models and theories. This includes knowledge about best practices, rules-of-thumb (heuristics) and terminology, but also identifying knowledge gaps and formulating research questions. Making knowledge available for scientific purposes requires practitioners to share their knowledge, and be available for collaboration with researchers.
- **Accessing expert knowledge *from* science.** Finally, the ideal outcome of agricultural research is a practical benefit for practitioners. For this to happen, the expert knowledge from science must be made accessible in one way or another.

These interactions are described as occurring between researchers and practitioners. They also occur between researchers and other researchers, and between practitioners. However, for the sake of clarity, we refer in this chapter to 'researchers' as those using data and field knowledge, and producing expert knowledge, while 'practitioners' participate in experiments, contribute field knowledge, and access expert knowledge.

5.3 E-Science

Information technology is changing the ways of science, research and development in a radical way. Modern science is changing rapidly into a data-driven and highly interactive process between all kinds of players, across the world. E-science [3, 4] is the commonly used term for a new type of research that is data driven and computationally intensive, replacing manual lab and field work and paper-based recording. It allows world-wide collaboration in flexible research teams using advanced, user-friendly and Web-based tools, services and databases. E-science is also sometimes referred to as e-research, data science, digital science or research informatics.

Strictly defined, e-science is computationally-intensive science that involves distributed networks or grid computing[11]. In practice, the term has come to mean any use of computers for scientific tasks. As a result, e-science is a broad discipline, covering such wildly differing aspects as high performance computing, simulation, 3D visualisation, workflows and provenance documentation. In this chapter, we will concentrate on the aspects of e-science that assist in increasing participation in research.

At this point it is useful to make a distinction between *data*, *information* and *knowledge*. *Data* are the qualitative or quantitative values obtained from measurements, either taken manually or from automated sensors.[12] *Information* is that which informs and which gives an answer to a question[13]. *Knowledge* is understanding[14] , and can be used to create new data and information. For example, the measurements of the amount of green colour in a satellite image are *data*. The extent of damage to vegetation caused by mice in the year 2014 derived from these images is *information*. Finally, a model that predicts the amount of damage given certain environmental factors is *knowledge*. Science can use existing knowledge to create new knowledge from information, i.e. meaningful data. This a creative and dynamic process, requiring the formulation of research questions, performing experiments, collecting data, building models and theories and sharing findings. It is also a collective process, involving scientists, engineers and practitioners. Hence, we can distinguish three aspects of e-science.

- **Generating (big) data**. Big data[15], i.e. large amounts of numerical and textual data, are being generated in automated and robotised processes, in industry, business and research. The Internet of Things[16], the ubiquitous presence of sensors in our daily environment, generates data outside the laboratory, which can also be made available as raw material for science and research. Electronic (laboratory) notes are being introduced in academic and

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[11] https://en.wikipedia.org/wiki/E-Science

[12] https://en.wikipedia.org/wiki/Data

[13] https://en.wikipedia.org/wiki/Information

[14] https://en.wikipedia.org/wiki/Knowledge

[15] https://en.wikipedia.org/wiki/Big_data

[16] https://en.wikipedia.org/wiki/Internet_of_Things

industrial research environments to record the research process. Nowadays most organisations, businesses, including farms, and even individuals are connected through the Web, which means that data and information can be handled in a distributed manner. Rather than being locked in separate silos, on the Web, in principle, anyone (with proper access rights) can access any data source. Similarly, anyone can become a data provider.

- **Turning data into knowledge**. As previously discussed, data in itself are meaningless. In the past decades, computer science has created text and data-mining techniques, robotics, machine learning, artificial intelligence, computer vision, speech processing etc. These assist the researcher in finding knowledge from their data. In addition to these techniques, where the computer must find the knowledge, it is also possible to build existing, explicit human knowledge into a computer application by modelling that knowledge, for example in a rule-based system. Whichever technique is used, it is possible to produce smart tools that translate simple data (e.g. an image of a fly) into knowledge (e.g. this is a particular type of fly, which can be eradicated using a certain pesticide). In this chapter, we will concentrate not on the techniques that form the basis of such tools, but on the tools themselves and how they increase access to knowledge.
- **Sharing data, information and knowledge**. New open access approaches and network infrastructures promote sharing and reuse of raw data, processed data and final results. This leads to new requirements for data handling. ESFRI, the European Strategy Forum on Research Infrastructures, states that data repositories should guarantee availability, permanency, quality, right of use and interoperability. According to the FAIRport conditions[17] data must be findable, accessible, interoperable and reusable. In addition, traditional 'closed' journals are being replaced by open access models. 'Altmetrics' provides new models for acknowledging the work of others and giving credits to peers, instead of just counting citations and impact factors [5], although it is the subject of some controversy.

These three elements of e-science clearly link to the four types of participation mentioned in the introduction. E-science technology related to big data helps practitioners to contribute data.

Participating in experiments and contributing knowledge helps scientists to turn data into knowledge – to be implemented in smart tools for decision making etc. These smart tools help practitioners to access expert knowledge. Infrastructure and support for sharing data and knowledge can help in all four types of participation.

The previously described four types of participation were present in science before e-science was introduced. However, e-science methods and tools can make such interactions easier to realise and more efficient, allow (global) upscaling, and enable the development of intelligent software that innovates both science and practical applications. In short, e-science can bring more people together with more data and more expertise, leading to more innovation.

E-science also suggests an alternative to the standard scientific method. The traditional scientific approach creates generalised and abstract models and theories from well-designed experiments, eliminating disturbing influences as

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[17] http://datafairport.org

much as possible. Application of these generic rules to specific, individual situations is not straightforward. Rather than setting up a single, well-defined experiment with specific conditions, the 'big data approach' uses many real-life observations with undefined conditions. This may provide more knowledge about individual situations than the traditional idealised experiment does, but may also be more difficult to analyse. An important new opportunity of digital approaches to science is that of *citizen science* or *crowd-sourced research*, which is defined as the conduct of science-related activities by individuals who have no formal training in a field specific to the topic of investigation [6, 7]. It is being put to work for a wide range of subjects, from classifying galaxies and city farming [8] to counting penguins[18]. The EU has set out a roadmap for citizen science in Europe [1]: *"We should promote the next phase of Citizen Science as 'Crowdcrafting' where citizens make projects with the help of scientists, not only for the benefits of professionals but for the benefits of society, a rather citizen-driven research".* Citizen science could be an important way to involve more practitioners in science-driven research. Involving people outside academia in scientific research will provide extensive new resources for research, increase the general understanding and acceptance of scientific research, and strengthen the interaction between science and society in terms of innovation.

5.4 E-Science in agriculture

While traditional craftsmanship and experience remain key, agriculture is increasingly becoming a data and knowledge intensive process, referred to as e-agriculture. This results in what we will call the 'quantified farmer' – a farmer who has access to hard figures about his/her business to guide his/her decision making. Chapter 4 of this report describes the impact of IT on general innovations in agriculture.

The 'quantified farmer' is a potential gold mine for science. This data could be used to take the 'big data' approach to agricultural research. We can imagine a future in which researchers in agriculture will use data from nearly all farms to give specific advice via ICT to individual farms, instead of the current practice of researchers to use the data of a few (experimental) farms and provide a generic advice.

The potential of 'big data' must not overshadow the importance of the other three types of participation. Participation is far more than data alone. Fortunately, practitioners have increasing access to research networks. Hence, e-science can be used to bring them even closer to the researchers. In 2013 the Agricultural Relations Council (U.S.) conducted a survey[19] of farmers. On a scale of 1 to 7, 74.4 per cent of the farmers ranked themselves as 5 or higher for expertise with smartphones, and 62.2 per cent ranked themselves as 5 or higher for Facebook. Email, smartphone and website were also listed as the three most valuable communication tools.

We will now discuss in detail, referring to cases, how e-science can assist in realising the four different types of participation for agricultural research.

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[18] http://www.penguinwatch.org

[19] http://hwcdn.libsyn.com/p/8/9/0/890c451ec43f212a/131030_TMN_ag_digital_media_farmer-with-openend.pdf?c_id=7486587&expiration=1440751962&hwt=4d19c2f9396747aa568a447eb5e12409

5.4.1 Providing and collecting data for science

The rise of precision agriculture [9] is associated with a fast growing diversity and abundance of sensors in farms, on fields and on livestock. Technologies such as GPS, radar, moisture sensors, infrared cameras, feed sensors, soil sensors, remote imaging, mobile resource kits etc. are turning practitioners into producers of data on a massive scale. Practitioners are using these data to make better decisions about how to manage their land, crops and livestock. Equipment manufacturers (e.g. John Deere) and seed providers (e.g. Monsanto) collect data from farms[20]. Several manufacturers offer systems to analyse the raw data (e.g. FarmSight[21], FieldScripts[22], 640Labs[23], Field360[24], Ez-Farm[25]), to produce overviews and even to forecast production or diseases, e.g. VitalFields[26]. Standards such as AgroConnect[27] (NL) or AgGateway[28] (US) and data platforms such as EdiCircle[29] (NL) enable data exchange between different stakeholders. The vision for the future is that such data will enable practitioners to respond much more rapidly and effectively to problems such as extreme weather, pests or climate change, leading to a more reliable food supply for all[30,31].

Today, most data collection on farms is intended to support informed decision making at the same farms. However, if the 'big data' collected from many farms becomes available for analysis, they can be used to create improved advice for individual practitioners. The data could be shared within a limited, 'closed' circle, or be made publicly available as 'open data'. Open data are, quite simply, data that have been made accessible to all to search and reuse, usually on the Internet. There are a large number of open data sources available, including such diverse topics as nutritional data about food, statistics on production, data on market demand and data on climate or weather. However, these data mainly come from research institutes or public organisations. The synergy of these data

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[20] http://fortune.com/2014/05/30/cropping-up-on-every-farm-big-data-technology/

[21] https://www.deere.com/en_INT/products/equipment/farmsight/farmsight.page

[22] http://www.fieldscripts.com/

[23] http://www.640labs.com/

[24] https://www.pioneer.com/home/site/us/programs-services/pioneer-field360/

[25] http://mgafrica.com/article/2015-07-01-telephone-farmers-listen-up

[26] https://www.vitalfields.com/

[27] http://www.agroconnect.nl/

[28] http://www.aggateway.org/

[29] http://www.edi-circle.nl/

[30] http://www.theguardian.com/global-development-professionals-network/2013/nov/25/open-data-food-security-agriculture

[31] http://www.worldbank.org/en/news/feature/2013/04/26/open-data-can-transform-farmers-response-to-crisis

with farming data could be very powerful, leading to new insights for both practitioners and researchers.

Two examples from the Netherlands illustrate how practitioners can provide data:

- *Cloudfarm* is an initiative of a farmer in the south-east of the Netherlands. The farmer produces his crop (e.g. potatoes) on over 300 ha of sandy soil divided into more than 100 individual fields. He is one of the pioneer farmers in precision farming[32] in the Netherlands, and sees the opportunities of using real-time spatial crop, climate and soil data in combination with other data, information and decision support in optimising yields, inputs and costs. By setting up Cloudfarm, he has a database on the Internet in which he stores all his sensor data. He has also added software for data analysis and decision making. He can now generate new knowledge with the data, for example he can identify spots in his field that have reduced growth and may need additional fertiliser, pest control or irrigation. Other parties can also have access to the data and analysis tools. He allows others to use his data in R&D activities in which he is a stakeholder. In return, he gets access to state of the art information on innovations or products and services he needs on his farm, for a better price. Data are used as in kind payment for products and services, creating a new business model.
- *Akkerweb* is an initiative from Agrifirm, one of the largest farmers' cooperatives in the Netherlands, and Wageningen UR, a scientific partner in several precision agriculture projects. Akkerweb is a platform for data management and decision support for precision farming[33]. It gives practitioners a tool to view and analyse their own spatial crop and field data, and has several links to internal apps and external databases and Web coverage services, allowing them to do site-specific management with as much real-time data as possible. They can use the data to make management plans at farm and field level, and task maps at individual field level. Akkerweb also has a data sharing option. Practitioners can share the data with parties they trust, e.g. farm advisors, researchers, supply companies and processing chain companies. A condition is that the data are not used without the consent of the practitioner, and publications do not contain a direct reference to individual practitioners. These conditions will be further developed in the near future in discussion with the practitioners.

These cases demonstrate the feasibility and value of collecting and sharing such data. They also indicate issues involving these data, such as trust, payment, privacy and consent. These are important issues to be considered when planning to use such data in research. No standard solutions are available as yet for these non-technical aspects of data sharing.

5.4.2 Participating in experiments

So far, we have discussed data that have already being gathered for other reasons, to improve production, or to provide benchmarking statistics. This is a passive form of data collection. For research, this sort of data is not always enough. Often researchers need to be able to interact with the practitioners, for

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[32] http://www.vandenborneaardappelen.com

[33] http://www.akkerweb.nl

example to try out different sets of growing conditions on new seed varieties, or to test if a new pesticide offers improved results. In these cases it is necessary for researchers and practitioners to work closely together. The advent of modern technology and sensors makes it much easier to involve practitioners in such experiments, as they already have the data-gathering capacity. This makes it possible to have a much larger pool of 'citizen scientists' who can contribute to scientific research [8]. Citizen science differs from passive contribution of existing data (the 'quantified farmer'), in that the specific data, and the way they are gathered, are carefully selected to fit with the purposes of the experiment, and the citizen scientist may alter conditions to fit the experiment. Agricultural researchers are starting to use this concept to increase participation in their research.

Citizen science in itself does not necessarily use e-science. However, just as with other forms of science, citizen science can benefit from using ICT technology, such as the Internet of Things.

In the UK, the Farming Futures consortium[34] has been set up *"to raise awareness of climate change in the agriculture sector …. However, it has been the very recent widespread use of smartphones that has taken citizen science to a new dimension. Smartphone technology has enabled the design of data collecting and communication applications that allow users to record, for example, species occurrences, submit records of unknown species to experts, or update databases practically 'on the go'…. But citizen science can be more than just data collection, with participatory research methods involving farmers also in research design, valuing farmers expertise and knowledge exchange."* [35]

Another example is the Farming Concrete case study [8], which attempted to determine the amount of food produced in New York City's community gardens by involving gardeners throughout the process. Farming Concrete aims *"to define community gardens in the context of the New York City food system and to educate local communities about developing and conducting meaningful research. The project employs citizen science methods in which the gardeners and researchers alike are involved in the design and implementation processes… By employing citizen science techniques, Farming Concrete works directly with people who have a stake in research outcomes, as well as in how the data is used. Increasing gardener agency in both the design and the implementation of the study may improve the rates and quality of garden participation, and may contribute to a rise in similar action research projects in New York City and elsewhere. Future research could explore possible connections between citizen science, civic participation and action, community garden land tenure, food security, and urban ecology"*. The software developed by the Farming Concrete case study, for measuring the impact of community and urban farms, has been made available as an open source toolkit, which can be used by others[36].

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[34] http://www.farmingfutures.org.uk

[35] http://www.farmingfutures.org.uk/blog/could-citizen-science-advance-agricultural-research?page=4

[36] http://farmingconcrete.org/toolkit/

Bioversity International[37] is working with several partners on "Seeds4Needs, a series of projects that are trying to give farmers more access to crop varieties and landraces to help them adapt to climate change.… But a new twist has been added to the trials. In 2012, we started an innovative approach to test the varieties: Crowdsourcing crop improvement. The idea behind this approach is to involve farmers massively in evaluating varieties as citizen scientists. Each farmer grows a combination of three varieties drawn from a broader set of ten. The farmer then ranks them according to different characteristics …. The idea is to make things as easy as possible for the farmers, and then we, the researchers, use some nifty statistics methods to combine the rankings and share the results with the farmers. With this information, farmers can then identify the best varieties for their conditions and preferences. Farmers become citizen crop scientists, actively contributing to science with their time, effort and expertise. In India, 800 farmers are now testing wheat varieties as citizen scientists." The Seeds4Needs project also identified some concerns about such use of citizen science: "An important aspect of the work is that we work with national and local organizations. The real litmus test is to see if the approach will be picked up by our partners after their first experience with it. In Vaishali, our partner organizations liked the approach a lot. They found it practical to do and clearly saw its value for getting varieties to farmers. They were however, a bit worried about how scientific all of this was".

These cases show that participation in agricultural research, using e-science technology, is already happening. It makes it possible to gain data from new sources, and to increase the effectiveness of research by involving the stakeholders. However, the challenge is how to arrange participation while still safeguarding the scientific quality of the research.

5.4.3 Contributing field knowledge to science

As stated in the introduction, the potential contribution from agricultural practice to science goes further than providing sensor data or participating in experimental studies. Agricultural workers already possess a wealth of knowledge, built up over years of experience. This includes best practices, heuristics and experience.

An example initiative in this area is the Farmers Business network[38]. This network supports farmers in sharing their data but also in learning from each other's experience. One of the attractive features for farmers is the fact that the data and knowledge are not shared with people outside this community.

WeFarm[39] is a similar system for sharing knowledge between practitioners. *"Members can ask questions and share farming tips and advice by sending a simple, local SMS message. WeFarm uses the internet, and our unique peer translation system, to share this knowledge by SMS with other WeFarm members around the world."* An interesting aspect of this system is its reliance on very simple technology, which enlarges the group which can access the information.

[37] https://ccafs.cgiar.org/blog/testing-wheat-crops-climate-change-adaptation#.VdWkLPmqpBc

[38] http://www.farmersbusinessnetwork.com

[39] http://wefarm.info/what-is-wefarm/

A frequent problem experienced when sharing knowledge is that people talk in terms of different concepts and terminologies, and even languages. This can make it hard to find the right data and information, and to link different systems together. AgroKnow, one of the members of agINFRA[40], has developed an Agricultural Learning Repository tool (AgLR)[41], which is an online tool for the organisation, preservation, enrichment and sharing of learning resources in agriculture. To deal with the problem of linking together different languages and types of metadata, AgLR uses semantic technology and machine translation to translate automatically information about the resources. We will discuss the potential benefits of semantic technology further in Section 5.5.1.1.

From these cases, we see that e-science technology is already being picked up by practitioners to share their knowledge. This knowledge is aggregated over individual farms and can be used as a rich source of knowledge for scientific research. However, at present, it is rarely shared with the scientists. The question is how this valuable source of practical knowledge can be shared with scientists and translated into useful scientific material, while keeping the trust of the practitioners.

5.4.4 Accessing expert knowledge from science

Previous sections have discussed how practitioners can help science, through contribution of data, experimental capacity and field knowledge. If there were no stream of knowledge in the other direction, it would eliminate the practical value of agricultural research. This section is therefore about the highly important issue of how good science can become good practice. This can be through advice given by extension workers, development of products or services for practitioners, educational systems (e-learning, life-long learning), smart tools such as Web-based question-and-answer systems, and dedicated decision support systems. These activities are part of the Agricultural Knowledge and Innovation Systems [2]. Just as e-science technology can assist in making the age-old process of data gathering and experimentation easier, so too can it assist in making dissemination easier and more suited to the modern global agricultural sector.

At the same time, accessing expert knowledge is also an essential part of a researcher's work. Discovering what others have done avoids costly duplication and can inspire researchers to new discoveries. Building on each other's work is an important keystone of good science.

5.4.4.1 Disseminating research results

The classic way of disseminating research is in journals. These have traditionally been closed access, allowing only those who have paid a subscription to view the research. This seriously limits the reach of this information and, especially as such research is often funded from public money, there is a growing sense of discontent with this model. More and more results are becoming available through open access. Sometimes this is via a specific journal that chooses to make its content available as open access. However, there are also approaches which aim to be more general. Two examples of important initiatives are discussed here.

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40 http://www.agroknow.gr/agroknow/

41 http://wiki.agroknow.gr/agroknow/index.php/AgLR

The European research project VOA3R[42] has produced the Virtual Open Access Agriculture & Aquaculture Repository, currently available in a beta version. The aim of this repository is to share scientific and scholarly research related to agriculture, food and environment. It includes theses, reports, datasets, multimedia and more. The VOA3R consortium consists of 14 partners from 10 different countries and 52 affiliated partners, including universities, archives and research institutes (both agricultural and technical). They cite the cooperation between content providers and technical partners as being key to success. The target users include practitioners as well as researchers and students. The platform uses the Agrovoc[43] vocabulary to suggest suitable search terms, to make it easier to find the right information. Specific vocabularies are also used to tailor the platform to the different needs of different target users. Experts can annotate documents with vocabulary terms to make them more findable, tag certain documents as being useful to practitioners, and share them further via social media. Unfortunately the platform does not currently seem to be working. This highlights the issue of how research projects can be made sustainable, which will be further discussed in a later section. In addition to the platform itself, the VOA3R consortium has produced recommendations for improving access to scientific information via repositories and online communities.[44] They regard it as essential to integrate social networking tools into the repository.

AgTrials[45] focuses specifically on the datasets produced by agronomic and plant breeding trials. Data are a particular issue as, while papers tend to be published, even if it is in closed-access journals, datasets resulting from research are often left hidden away on hard drives, or even lost altogether. This results in new research being limited due to incomplete knowledge, or wasting time duplicating work done elsewhere. The AgTrials Global Agricultural Trial repository compiles data from crop trials from all over the world. It is hosted by CCAFS, a CGIAR research programme on Climate Change, Agriculture and Food Security, which includes centres all over the world. The repository contains more than 800 trials carried out in the last three decades, in more than twenty countries. Access to the data itself may be open or restricted, but the metadata are available to all. It is interesting to note that, in addition to compiling the database, the AgTrials team is working on data analysis methods, crop modelling, building a community of data analysts and collaborating with existing communities. This links the data to implementations.

Another initiative is Plantwise[46]. In this global extension programme, led by CABI, farmers can send plant disease information by smartphone to the expert in order to get feedback.

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[42] http://voa3r.eu

[43] http://aims.fao.org/vest-registry/vocabularies/agrovoc-multilingual-agricultural-thesaurus)

[44] http://voa3r.eu/images/Downloads/20130530_VOA3R_D_6_4_Final_Recommendations_v10_final.pdf

[45] http://www.agtrials.org/

[46] https://www.plantwise.org/

Such initiatives have the potential to improve dissemination both to researchers and practitioners. Basic e-science technology, in the form of Web applications and networks, makes the reach of the dissemination much greater. More advanced e-science technology, such as semantics in the VOA3R case, can greatly improve the findability of data. At the same time, the issue of sustainability is clearly important. Both cases emphasise the needs for communities and social interaction, a point which we will discuss further in Section 5.4.4.3.

5.4.4.2 Tools

Research papers are not always very understandable for lay readers, and are often too far removed from the daily practice to be directly useful. Even practical knowledge is often difficult to translate from documentation into an answer to a practical question. Tools using e-science technology can help to present this information in such a way that it quickly and easily supplies the answer. This kind of interaction between science and practice is already embedded in many intelligent applications for practitioners. New developments in information technology and in particular artificial intelligence facilitate continuous involvement of expert knowledge in applications. Researchers also benefit from smart tools for conducting their own research.

The GroenMonitor (GreenMonitor)[47] tool developed by Wageningen UR is an example of how expert knowledge is used to turn raw data into knowledge which practitioners can easily apply. Alterra processes data from satellites to produce a vegetation map of the Netherlands. This map shows, in simple terms, how 'green' the land is, in sections of 25 by 25 m. The data are made freely available via the GroenMonitor website. This apparently simple characteristic enables practitioners to derive a wide range of information about the land, from measuring the extent of damage due to mice[48], to comparing the growth of different types of crops, or even identifying the crop type. Uses cover the whole scale, from a practitioner measuring the rate of growth of his crops, to a seed manufacturer comparing batches of different seeds to develop better strains (cultivars), up to agreeing a national approach to tackling pest problems. The website Natuurbericht.nl used the data to compare the growing season of different plants in nature areas over the years, while the Faunafonds developed an app to assess the damage done by geese to wheat and grass fields in the Netherlands, a task that used to rely on the expert opinion of an insurance assessor, but which can now be measured objectively.

The EU FP7 Valerie project [49] is an example of how the gap between finalised scientific research and practitioners can be closed by developing smart tools for knowledge transfer. The aim of the project is to disclose findings from past European projects and turn them into innovations in agriculture and forestry. One of the main outcomes is a smart tool called 'ask-Valerie'. Ask-Valerie goes beyond the standard 'Google approach' in which the user searches for relevant documents on the entire Internet via a set of search terms. Ask-Valerie [10] instead involves scientific experts, who select new documents from reliable

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[47] http://www.groenmonitor.nl/

[48] http://www.groenmonitor.nl/news/muizenschade-friesland

[49] http://www.valerie.eu

sources, and use their own expert knowledge to indicate the useful elements for practitioners. A practitioner can then enter a question into the system and receive answers extracted from the documents. This ensures a higher quality result than the usual search applications do. Both the inclusion of expert knowledge and the personalisation of the question-and-answer process are partly automated to make the tool as user-friendly as possible. In this way the 'blind' dissemination of research results is transformed to a targeted transmission of knowledge specifically applied to the practical problem which a practitioner faces. Ask-Valerie is currently being submitted to internal review, a first public version is expected at the end of 2016.

In Spain, the SigAGROasesor[50] project, co-funded under the Life+ programme, is developing online services for decision support for farmers, helping them to make decisions more systematically and thus achieve the most efficient and competitive crop yields, while at the same time keeping in line with social and environmental sustainability. Using the latest GIS technologies, these decision support tools provide precision advice for individual plots on many issues, including fertilisation, irrigation and risk of diseases. For example, they can recommend the optimal dose and moment of fertilisation, or estimate the risk of a particular disease appearing in that plot. The tools combine information from different organisations, allowing the user to take full advantage of the available knowledge. The data are displayed in the form of layers on a map, using both existing data and remotely sensed data. Sustainability indicators are also included, allowing farmers to assess the environmental, economic and social impacts of the suggestions made by the tool, such as the carbon footprint. The platform incorporates knowledge of soil, meteorology and crops. Groups of farmers in pilot schemes throughout Spain have been involved both to calibrate the tools and to validate their performance.

A similar project is also being conducted in France. The API-AGRO project[51] is developing a platform for providing access to agricultural data and services. The API-AGRO consortium consists of 12 partners, including technical institutes such as INRA and agricultural institutes such as ARVALIS and ACTA. The project will produce a catalogue of the available data and services at the partner institutes, and produce a pilot platform offering a minimum of 5-10 services. This platform provides interfaces to the different data sources, with information on soil, crop varieties and pests. An example application is to provide tailored advice to farmers via smartphones, based on a combination of agronomic models from ARVALIS with weather prediction from Meteo France and information from the farmer's own information system. ACTA also has a diagnostic tool[52] which helps practitioners to assess their degree of engagement with agro-ecology – the combination of economic, health, environmental and social performance.

These are examples of existing tools or tools under development which are expected to be available shortly. Many more tools are still in the research prototype stage, such as a classifier for automatically identifying types of fruit

[50] http://agroasesor.es/en/

[51] http://www.api-agro.fr/

[52] http://www.diagagroeco.org/

flies[53]. However, it is essential that such tools make the jump from research prototypes to actual products in order to have an effect in practice.

The available tools show how applying expert knowledge to raw data can produce information and knowledge that can be used by others. Other tools can also be built on top of this information to answer specific questions, as the FaunaFonds app did with the GroenMonitor data. These smart tools represent an important translation step between the world of research and agricultural practice. It is interesting to note the importance of the close involvement of practitioners in the development of these tools in the cases discussed. The similarity of the French and Spanish projects raises the question of whether such initiatives could benefit from working together.

5.4.4.3 Communities

So far, we have discussed one-way access to expert knowledge. The knowledge is placed online and the practitioners use it. This represents a successful pipeline of innovations from researchers through to practitioners. However, a key element is missing. In order to ensure that researchers can continue to develop relevant, appropriate and effective innovations, it is essential that there is a feedback loop from the practitioners back to the researchers. Best of all is if this feedback loop is not a formal, artificial occurrence, but part of a natural interaction between researchers and practitioners. In some research projects, this interaction is a fundamental part of the project.

The Village e-Science for Life project (VESEL)[54] aims to enable rural communities in sub-Saharan Africa to increase agricultural output and employ best practices by using appropriate digital technologies. This project is funded by the Engineering and Physical Science Research Council (EPRSC), led by the London Knowledge Lab. VESEL investigates the use of mobile resource kits that contain a special sensor device, which gathers data on air temperature, humidity, air pressure, light, soil moisture and temperature, so key agricultural decisions about planting, fertilisation, irrigation, pest and disease control and harvesting can be made with the best information available. However, the technology is only part of the project. A key part is to help the communities to use these tools effectively and to transfer lessons learned between communities. That is why UK experts in telecommunications, renewable energy sources, sensor technology, education and design are working with local experts at the University of Nairobi, organisations such as Aptivate, agricultural information providers and teacher training organisations in Kenya. VESEL is not a citizen science project, although the mobile resource kits have the potential to be used in the future to contribute data to research. Instead, VESEL is ensuring that the ICT technology produced by research is put to effective practical use by working closely together with the practitioners.

It is, however, far from possible for all research projects to work so closely with their target audience. Sometimes, the target audience is at a distance, is too numerous, or may not even be known at the moment at which the research takes place. Online communities can be an effective means of interaction. In the

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53 https://recodbr.wordpress.com/2014/08/18/e-science-paper-on-agricultural-application-published-at-jicr/

54 http://www.lkl.ac.uk/projects/vesel/index.php?q=about

interests of space, we will focus on communities which involve practitioners, and will not discuss purely research communities such as ResearchGate[55].

There are many communities on the Web sharing agricultural knowledge. These range from social networks, for example FarmTime[56], to knowledge cooperatives sharing knowledge of a given topic, such as Pig Academy[57], up to sector-wide communities of food buyers, producers, distributors and industry suppliers together, such as FoodHub[58]. Communities differ from more traditional websites that offer tips and show messages from users, in that they involve more parties, stimulate more interaction and often strive for a particular aim. They work if farmers can see the impact on their daily business. These are exactly the aspects we would like to see in a community of researchers and practitioners. For a more in-depth discussion of social media and agriculture, see [11].

There is already a limited number of online communities involving researchers and practitioners. For example, the Online Farm Trials project[59] aims to provide crop growers with the information they need to improve productivity and sustainability through improved access to trial research knowledge. The Federation University Australia leads the project, with a team of senior scientists, researchers, programmers and specialist agricultural experts. The project has a strong collaborative approach, working with a range of crop research groups, industry experts and grain industry organisations to ensure that the trials lead to relevant, practical and beneficial results for the growers. Tools have been developed for submitting trial data (which remain the property of the organisation which submits it) and anyone conducting trial research may submit their data. The data are available to the general public for browsing and download, but only the data owner may modify them. Along with the library of trial data, the community site also offers decision support tools and encourages collaboration to address crop issues. This emphasis on collaboration and interaction between scientists and practitioners is the key difference between Online Farm Trials and AgTrials, which we discussed earlier.

The conclusion is that (online) communities exist that can disseminate expert knowledge to other researchers and practitioners. This has the potential to lead to more collaboration between researchers and practitioners.

The examples we have found for dissemination, tools and communities demonstrate that e-science technology can lead to novel ways of accessing expert knowledge from science. It is important to make sure that such initiatives are sustainable. What is notable in the examples found is that they tend to concentrate on research that has been completed. This increases the time delay before knowledge reaches the practitioners and limits the extent to which the practitioner can influence the research. It would be desirable to make research

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[55] http://www.researchgate.net/

[56] http://www.farmtime.com/

[57] https://ec.europa.eu/eip/agriculture/en/news/inspirational-ideas-pig-farms-flanders-improve-their-performance-sharing-data-and-results

[58] http://food-hub.org/home

[59] http://www.farmtrials.com.au/cb_pages/about.php

information accessible while the research is ongoing, both to the direct participants of the project (both researchers and practitioners) and to a broader audience.

5.5 Issues and opportunities

In the previous section we listed a number of developments in the combination of agriculture and e-science that are already happening or are expected in the near future. There remains, however, a vast potential in e-science that has not yet been fully tapped for agriculture. For example, knowledge that is freely shared with colleague practitioners is not shared with researchers, and citizen science possibilities are regarded warily due to the concern that they may not be 'good science'. In this section we will identify the issues that need addressing and the opportunities which can be taken to get the best out of e-science for agriculture.

5.5.1 How to collect and share data

The discussion in Section 5.3.1 revealed the tip of the enormous iceberg of data that are available for agriculture. However, at present, a large part of this information is simply not useable. Many public and proprietary datasets are hard to decipher, as their structure is unclear and metadata and context information are often missing – for example, parameter names are ambiguous or even non-existent, units of measurement are left out, documentation is missing. Data are often scattered across diverse data sources, using different formats. The reason is that the data are usually collected for a specific purpose and no attention is paid to preparing the data for use by others in the future. To make data useable, they must be properly structured and annotated. In that way, others than the original authors can find, understand, analyse and integrate existing data to derive new facts.

In the FAIR Data approach[60], which is being internationally promoted for good data stewardship, data should be:

1. Findable – Easy to find by both humans and computer systems and based on mandatory description of the metadata that allow the discovery of interesting datasets;
2. Accessible – Stored for long term such that they can be easily accessed and/or downloaded with well-defined license and access conditions (Open Access when possible), whether at the level of metadata, or at the level of the actual data content;
3. Interoperable – Ready to be combined with other datasets by humans as well as computer systems;
4. Reusable – Ready to be used for future research and to be processed further using computational methods.

Of course, several standards for data interchange already exist in agriculture, for example agroXML[61]. These standards support only part of the domain and are

[60] http://www.dtls.nl/fair-data/

[61] http://www.agroxml.de/

often specialised to certain processes. This leads to an interoperability problem, with data needing to be translated from one technology to another [12].

Findability is a particular issue for practitioners, both for data and knowledge. Practitioners benefit greatly from search tools which are more tailored to their needs, to help them find their way in the enormous sea of information available on the Internet. These tools need to filter out 'noise' – poor quality or irrelevant data.

We will discuss how semantic technology can assist with both findability and interoperability in Section 5.5.1.1. In Section 5.5.1.2, we will discuss existing infrastructure which is available for sharing both data and computing resources. Finally, in Section 5.5.1.3, we will touch on the issue of the vast amount of legacy data.

5.5.1.1 Semantic technology

Semantic technology, such as that used by AgroKnow, VOA3R and Valerie, can assist in handling findability and interoperability problems by 'annotating' data or texts (adding descriptive terms) to make them understandable, both by humans and by machines. Experts in a given domain can build vocabularies (also called ontologies) which consist of the key concepts that exist in a domain, for example 'cereal', and 'maize', and also the relations between those concepts e.g. 'maize is a cereal'. A concept may have multiple labels for multiple languages or different terminologies. In this way, an American dataset about 'corn' can be annotated with a concept which has labels 'corn', 'maïs', 'maize' etc., making it easier to find the data and combine them with other datasets. Semantic search is used in a few platforms, but not yet widely.

The relationships between concepts in the vocabulary act just like hyperlinks on the Internet, with the important exception that computers can follow the links, as well as people, to find related data – for example, information about corn can link to information about pests that can attack corn. This is the basis of linked open data. Linked open data are starting to appear in agriculture, as is described in [13]. Recently, the EFITA conference devoted a separate workshop to 'Semantics for Precision Livestock Farming'[62]. The workshop focused on semantic-based information management and linked data in the precision dairy farming. However, there is a long way to go before the full potential of linked open data for agriculture is realised.

The starting point for semantic technology is a good quality vocabulary for the given domain. Creating vocabularies can be expensive and time consuming, as traditionally it requires an ontology expert to interview a large number of experts in the given domain. This has contributed to there being only a limited number of agricultural vocabularies available. The ROC+ approach [10], successfully applied in the Valerie project, offers a means to accelerate this process and to place the control back in the hands of the domain experts.

The data must then be annotated with terms from the vocabulary. People are highly unlikely to spend time laboriously hand-annotating data. Manual annotation would, in any case, severely limit the amount of semantic data available. The ideal is to build this into the tools which capture the data so that it

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[62] http://efita2015.org/files/UserFiles/workshop2.pdf

is done automatically. Where this is not possible, semi-automatic support should be provided to make the job of annotating the data as easy as possible. Such support is being developed but is still at the research stage [14].

As well as defining agricultural concepts, vocabularies can be used to define more generic scientific concepts, such as QUDT and OM, which both define units of measurement. Traditional software will not detect the error when a user tries to combine data in metres with data in inches, but semantic software using such ontologies could not only detect it, but also perform the necessary conversion. Semantic models for data structures, such as RDF DataCube[63] and RDF RecordTable [14], will make it possible in the future to support easier integration of datasets.

All these features together make data much more findable, interoperable and reusable.

5.5.1.2 Infrastructure

At some point in the future, semantic information will make it possible for software agents to locate available data easily. In the meantime, directories are a valuable way of providing overviews of the available data. For example, the CIARD Routemap to Information Nodes and Gateways (RING)[64] acts as a global registry of Web-based information services and datasets for agricultural research for development. CIARD allows data providers to register and categorise their services. All datasets must be accompanied by metadata about which standards are used (such as vocabularies, dimensions and protocols). This promotes data reuse and discovery, and allows for greater automation. CIARD currently lists 1000 information services, of which approximately a third are agrifood datasets. The RING is used by many global initiatives in agrifood research, including AGRIS and agrINFRA. [15]

As the available amount of data grows, where and how to store and analyse the data becomes more of an issue. Moreover, high-speed connections are needed to transfer these large datasets, including multimedia formats. Fortunately, disciplines such as geophysics and genomics have already led the way in this, and access to cloud computing, grid computing and supercomputers is being actively developed at international (e.g. EGI – European Grid Initiative[65]) and national (e.g. SurfSARA[66] in the Netherlands) levels. The EU ESFRI[67] (European Strategic Forum on Research Infrastructures) initiative will not only carry out an in-depth analysis of current research infrastructures but also fund projects for new or upgraded infrastructure. Agriculture has so far not been much involved in this type of computing infrastructure; however, with the growth of precision farming, this is starting to change. India is building a nationwide grid of

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[63] https://www.w3.org/TR/vocab-data-cube/

[64] http://ring.ciard.info/

[65] http://www.egi.eu/

[66] https://www.surf.nl/en/about-surf/subsidiaries/surfsara/

[67] https://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri

supercomputers for agri-science[68]. IBM's Deep Thunder analytics technology for agriculture weather modelling uses a supercomputer for data processing[69].

Virtual Research Environments (VREs), often built on top of such shared infrastructure, enable researchers and practitioners to share more than infrastructure alone, and to actively exchange documents, data, models and tools. This has the potential for involving practitioners (and other researchers) in research at an earlier stage, and for making the feedback loop much shorter. VERCE[70] is an example of a Virtual Research Environment which allows researchers working on seismology to achieve better results by working together. A similar environment for food researchers is currently being developed in the EuroDish project[71]. The National Bio-Computing Portal for agricultural bioinformatics in India[72] is an example of such an environment for a specific area in agricultural research. We have found no indication that a more general agricultural VRE is in development. B2SHARE[73], from EUDAT, is a generic service for all research domains, for storing and sharing data.

On a simpler level, there are plenty of Web applications which make it possible for scientists to document and share their data. These can also be made accessible to practitioners. Examples are Figshare[74], the Dutch Dataverse[75] and Tiffany[76]. E-science tools such as supercomputers can also be accessed via existing providers, without the need for a dedicated infrastructure or research environment.

5.5.1.3 Legacy data

There is also the question of legacy data. Not all data are available electronically, and not all data are in a form which makes them ready to be made publicly available. At the same time, these data may still be widely in use. In particular for scientific research, data from the past may be invaluable for making predictions about the future. The costs and benefits of cleaning up these data (possibly including a semantic annotation step) must be weighed up to see if the investment is worthwhile. The more this task can be automated, the more

[68] http://www.hpcwire.com/2013/12/17/supercomputing-bolsters-agricultural-science-india/

[69] http://www.livescience.com/37400-smart-farming.html

[70] http://www.verce.eu/

[71] http://www.eurodish.eu/

[72] http://cabgrid.res.in/cabin/

[73] https://b2share.eudat.eu/

[74] http://figshare.com/

[75] https://dataverse.nl/dvn/

[76] http://www.wageningenur.nl/nl/show/Tiffany.htm

legacy data can be made available. In the digital humanities, crowdsourcing has been used successfully to make historical data available online[77].

5.5.2 How to collect knowledge

As previously discussed, there is a wealth of knowledge available from practitioners. This knowledge is valuable input for scientific research, and is distinct from data as it includes valuable understanding. We suggest that this source of inspiration has not been explored sufficiently. We have discussed how human knowledge can be modelled and used to build smart tools. This knowledge can be made explicit and modelled by the art of knowledge engineering [16]. This means that through structured and unstructured interviews, vocabulary construction (as for example in the Valerie project, see [10]) and logical formulation of heuristics, *if-then* rules and causal patterns, this knowledge is made ready to be processed by computers. It is then available for scientific verification and for use in smart tools.

One complication in the process of translating practitioners' knowledge into input for scientific research is the fact that part of this knowledge is 'tacit', meaning that he or she is not even aware of this knowledge and when it is used. This kind of knowledge is notably hard to model. It requires, for example, so-called think-aloud sessions and observational studies.

Relying on only the 'quantified farmer' may lead to a situation in which valuable knowledge is disregarded. This not only does an injustice to professionals in agriculture, but also overlooks opportunities for new science in this field.

5.5.3 Accuracy and reliability of data

Assuming that the proper structure and metadata are present, the next questions are 'How do I know the data is valid? How accurate are the data? How do I handle erroneous data?' These issues are far from simple. The answers to these questions are even more important if the data are used for scientific purposes. In this case, there is a chance that the scientific rigor in setting up the experimental conditions and in performing measurements is less than in the academic laboratory or on a research plot. At the level of participation experiments, not only raw data but also methods must be described properly. This relates to the reproducibility of experiments [17, 18]. Recent news publications have shown that this is a major issue in medical and psychological research. The reported effects from many studies cannot be replicated in later studies due to disturbing effects and complexity of the matter. This is also a risk for agricultural science, and even more so in experiments involving laypersons unfamiliar with the scientific method.

Ideally, the full provenance of the data should be embedded in it so that it is possible to see who measured it, when, where, with which equipment and which calibration protocol, how it has been processed etc. In reality, this may not always be technically feasible or may conflict with privacy rights. Still, there is a strong argument for – at the very least – being able to indicate the source of the data. In this case, if there is a problem then it can be communicated and hopefully corrected, and data users can also have an indication of the reliability of the data source. For data generated by scientists themselves, and also the conclusions drawn from the data, it is reasonable to expect full provenance

[77] http://news.stanford.edu/news/2013/may/humanities-crowd-sourcing-052113.html

documentation. Here, the steps taken in measuring, analysing and publishing the data are an essential means for ensuring reproducibility. Standards such as PROV[78] exist for describing the provenance of data and systems such as Tiffany provide a user-friendly means for scientists to document provenance. Data can also be published together with valuable extra information or even software in the form of a ResearchObject[79]. These mechanisms all assist in determining the reliability of data.

Citizen scientists, on the other hand, cannot be expected to provide such detailed documentation. Several studies are available on data quality and validation for citizen science. The University of Illinois presents a host of evaluations of the accuracy and reliability of citizen science in 'Citizen Science: Evaluating Citizen Science' [80]. Most of the research activities discussed in these evaluations are related to monitoring biological populations and environmental research. However, some of their conclusions may extend to agricultural citizen (e-)science as well. For example, one study on the drivers for the quantity and quality of online citizen science participation concludes that *"Contribution quality, ... , is positively affected only by collective motives and reputation."* This could mean that agricultural e-science may work better when relatively closed groups of practitioners collectively participate.

The authors of 'Modeling Experts and Novices in Citizen Science Data for Species Distribution Modeling' claim that modelling the expertise of bird-watchers can improve the accuracy of predicting observations [19]. The study 'How do "Citizen Scientists" stack up against the experts?'[81] also suggests that expertise on the considered subject increases the quality of the obtained data. If this is so, then as long as we can track from whom the data has come, we can model their expertise and use this to estimate the accuracy of their observations. An interesting difference between citizen science involving just 'any type of citizen' and 'farmers only' citizen science is that the level of expertise with respect to the research object is relatively high in the latter. The hypothesis is then that the quality of the data would also be better.

In addition to correcting or discarding erroneous data, the occurrence of such data in the first place can be reduced by a good design of a participative project. Both [20] and Wiggins[82] give suggestions for designing successful projects, such as choosing the right group of participants, selecting an appropriate task given the expertise of the participants, training them well, and repeating samples or tasks. Citizen science, like any other tool or technique, needs to be understood and applied correctly in order to work well.

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78 http://www.w3.org/TR/prov-o/

79 http://www.researchobject.org/overview/

80 http://uiuc.libguides.com/citizen-science/evaluation

81 http://io9.com/how-do-citizen-scientists-stack-up-against-the-expert-1085597896

82 http://andreawiggins.com/tag/citizen-science/

5.5.4 Data ownership

Data that have been made available must be protected. Certain data will only be available to certain data users and so access restrictions are necessary. Even data that are available to everyone needs protecting, as it should be possible for authorised users to make revisions and corrections, while other users should be prevented from altering it, whether out of malice or by accident. An important issue in determining access and protection is the ownership of the data.

A major obstacle in involving agricultural practitioners in scientific activities is the question 'Who owns the data?' Practitioners are traditionally not equipped to manage the data they generate. What happens is that companies that deliver hardware solutions such as farm control systems, smart tractors, feed systems etc. typically also deliver software solutions that collect, store and process the data. They use the data to create decision support for the individual practitioner, but also to analyse the data aggregated from multiple farms. The latter allows benchmarking, but also creates new insight. With that, these technology providers also claim ownership of the raw data.

This has its consequences. Firstly, the primary producers of the data have no direct financial benefit from the data they generate. Secondly, they have no control over the use of the data, including many details about their individual performance. This creates mistrust among practitioners, not knowing what happens with their data. This touches on the very core of their success – their superior knowledge of their business, which has been built up through years of experience and hard work. If this is leaked or sold to rivals, then they could lose out[83, 84]. In addition to this, practitioners often prefer to be able to select the precise tools or technology they work with, and not be locked into doing business with a single provider because their data are being held by that provider.

The lack of trust of manufacturers, or simply the wish to retain control over the data, has led to several initiatives being set up by cooperatives of practitioners. An example is the America Farm Business Network, which between its launch in November 2014 and May 2015 has aggregated data from 7 million acres of farm land across 17 states, and is a benchmarking tool for farmers, able to assess the performance of 500 types of seeds and 16 different crops. There are many others, such as the Farmers Business network[85] and the OpenAg data alliance[86], which has been formed to help farmers access and control their data. Apparently these farmers are prepared to give up some short-term competitive lead for long term advantage.

Organising such agricultural e-science collectives can be a way to guarantee ownership and at the same time organise controlled access to the data. Farmers' collectives have the power and resources to arrange the legal aspects and

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[83] http://www.economist.com/news/business/21602757-managers-most-traditional-industries-distrust-promising-new-technology-digital

[84] http://www.techrepublic.com/article/open-sourcing-agriculture-one-seed-at-a-time/

[85] https://www.farmersbusinessnetwork.com/

[86] http://openag.io/

financial structures for access to and use of the data. Moreover, they can aggregate the data to a level where it cannot be traced to the performance of individual farmers. For e-science, this model could be extended to executing collective experiments and sharing experience, heuristics and best practices. This knowledge is then transferred to science for further examination – after explicit consent. This transfer process can occur within virtual research environments or via simpler infrastructure, as discussed in Section 5.5.1.2.

The same question of ownership also holds at the other levels of e-science in agriculture, i.e. participatory research and transferring knowledge. In the sense of privacy this kind of information is probably less harmful than data obtained from every inch of a field or all individual live-stock, since it is more abstract or 'artificial'. However, in terms of financial value and reputation, the value of active participation in scientific experiments and of long-time experience is probably higher than that of raw data. For this reason, researchers are often very wary of sharing their results, even with other researchers, in particular while the research is still ongoing.

Ownership of data is linked to the funding of making the data. It is a different situation if the funding is entirely public (e.g. 100 per cent funding by EIP-Agri operational groups), or if public and private funding is combined. The ownership issue is more complex in public-private partnerships.

One question is whether science should pay for the data and other information, either in cash or in kind. This is an ongoing debate, and the outcome will probably be different for each situation. However, the farmers' collectives can at least become recognised participants in e-science activities. Other means of recognising contributions and providing incentives are discussed in Section 5.7.

5.5.5 Bridging the divide

The connection between the local practitioner and the researcher that is needed to generate new scientific knowledge is not simple to set up. There are a number of gaps between the two communities that need to be bridged.

Firstly, they judge success in different ways. Practitioners need to achieve good yields and financial health. Researchers, on the other hand, are expected to push back the boundaries of science, publish good publications and ensure a stream of future research projects. While research is increasingly becoming focussed towards ensuring good application of the results, as in the Horizon 2020 projects, the time lag before research achieves practical benefits is still typically long, and frequently longer than the span of a single project. This means that practitioners must accept the fact that participating in a research project may not yield immediate benefits. It is very important to manage expectations from both sides.

A second gap between agricultural practice and science arises from the different styles of communication. Scientists typically use abstract language that requires a certain level of scholarship. Scientific papers are written in a very specific style, which scientific researchers learn to quickly comprehend, but which is generally quite obscure to lay readers. Some papers are accompanied by a lay summary, a short account which is targeted at a general audience, but this is far from common practice. However, once practitioners start to participate in scientific experiments, it is to be hoped that mutual understanding will grow. New information technology can help to alleviate this problem as well. For example, in the Valerie project, agronomy experts and practitioners define a vocabulary that covers both scientific and lay terminology. Relationships between these terms allow automatic translation, enabling both communities to understand the other's perspective. In this way, the path from practice to theory is smoother.

A third obstruction is the presence of borders between countries in terms of legislation, culture and language. This problem arises already within Europe, but even more so in collaboration with other countries, for example the US. What is the liability of a French farmer when participating in a research project in Denmark? Here the formation of farmers' collectives at the national level, as described before, can be a way to make the step towards international collaborations. Such collaboration already exists with African farmers. In terms of language differences, here multi-lingual vocabularies and automatic translation can help to bridge the gap. For example, the 32,000+ terms in Agrovoc have been translated into 23 languages.

Finally, it is important that researchers are aware of the realities for practitioners regarding which innovations they use. A paper published by researchers at Stanford [21], discussed the need to understand the social and economic networks that practitioners depend on, citing in particular the example of practitioners only accepting a new technology once credit union officials approved the investment.

5.5.6 Awareness, training and education

E-science is, for the most part, new and unknown, not only for practitioners, but also for researchers. The tools and technology sometimes include familiar items such as smartphones, but often not. More than the tools, the principles of e-science, in particular collaborative e-science (e.g. sharing resources and results, ensuring reproducibility and reusability, collaborating with researchers from other disciplines and practitioners) are new and unfamiliar to both researchers and practitioners. It is therefore unreasonable to expect all participants to jump straight into e-science participation.

The first step is to raise awareness in the agricultural (research) community. Internet and social media have their own roles to play in raising awareness. For example, the TedTalks website[87] hosts videos in which people explain 'ideas worth spreading'. This sort of medium can be used both for spreading the general idea of participation in agricultural science, and for raising awareness of specific research projects. It is important that communications about e-science and participation in agricultural science make the benefits clear, in order to translate awareness into interest, and hopefully into enthusiasm.

Assuming that the first step results is a pool of would-be participative researchers, the next step is training and education. We distinguish training – the use of tools and environments – from education – knowledge of the theory underlying e-science. Training will have a broader audience than education.

Education can be offered as part of the existing formal education for researchers or as separate initiatives. Education in e-science is usually fragmented into different topics of interest within e-science, for example the Software Sustainability Institute in the UK[88] concentrates on skills for producing good

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[87] https://www.ted.com

[88] http://www.software.ac.uk/

research software. Some unified initiatives are starting to appear. In Sweden, the SeSE[89] has been set up for training and education of e-science researchers, the only such graduate school in Europe.

Training potentially presents more difficulties. Training is specific to particular tools, and the community of researchers using particular tools does not necessarily match with any grouping according to educational institutions or courses followed by researchers. Often, even researchers in the same group use different tools. For this reason, it is often useful when training is offered by centres of technological expertise or data providers, tailored to the specific application area. For example, AgPARC, a centre for public access to agricultural resources[90], trains end users in how they can use the geospatial datasets and imagery available at AgPARC. At the same time, they perform research into new applications for this imagery in agriculture.

The issue of scattered geographical location is even more present when we look at practitioners. Practitioners may be in an isolated location and typically are not linked to an educational institution. This issue is where e-science can borrow solutions from existing practice. The concept of the Massive Open Online Course – MOOC[91] – is already widely in use for training on agricultural topics. MOOCs are offered free of charge on the Internet by educational institutions all over the world, from India[92] to the Netherlands[93], to France[94] and Australia.[95] Such courses can attract a large number of participants (in the thousands) from all over the world. The reactions of the participants are enthusiastic. Online material is complemented by contact with the teachers at the institutions. Sometimes courses are sponsored by agricultural suppliers.

Training can also be offered in a much less formal way. A simple 'HowTo' video on the Internet can be sufficient to help people to get going with a tool. Such training can be informally shared by practitioners and researchers alike.

5.5.7 Incentives, support and sustainability

For both researchers and practitioners, exchanging knowledge takes time and sometimes money. They have to invest in tools for recording data, in time to record and contribute the data, time to prepare datasets for publishing and time for explaining them to others. What is more, there is the investment in time and effort required to adapt to a collaborative way of working and to understanding each other's worlds. This investment will not be made unless there is a reasonable incentive and a clear understanding of the benefits. Currently, most

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[89] http://sese.nu/

[90] http://www.umac.org/agriculture/index.html

[91] https://en.wikipedia.org/wiki/Massive_open_online_course

[92] http://agmoocs.in/AgMOOCs

[93] http://www.wageningenur.nl/en/Education-Programmes/Online-education/MOOC.htm

[94] https://www.france-universite-numerique-mooc.fr/courses/Agreenium/66001/session01/about

[95] http://yara.com/media/news_archive/yara_sponsored_online_course_is_a_hit_with_farmers.aspx

researchers are judged on their publications, and practitioners are judged on profits. While there are always enthusiastic individuals willing to dedicate their own free time to helping each other, if there are no incentives then the pool of available contributors will remain limited to these enthusiasts. This is noticeable in the difficulties in persuading researchers to share and document their work.

Including funding for knowledge exchange in the budgets for research projects can help to at least ensure that the efforts do not cost the participants too much. However, while compensation may help to remove barriers, incentives are not necessarily limited to the financial. Seeing that contributions are valued can also be key. Simply acknowledging contributions is a basic requirement – contributions that appear to be going into a 'black hole' will not last very long. Recognition for good contributions or expertise can be a reward in itself, for example, by using digital badges[96]. Keeping contributors up to date with the results of their success can also be a valuable incentive and create a sense of shared pride and community. Getting them involved in rating the success of research projects can have a twofold advantage, increasing their engagement while also giving valuable feedback to researchers. Altmetrics[97] is one possible way of tracking the value of papers; a similar measure could be developed for the usefulness of the research in practice. Successful crowdsourcing sites, such as Galaxy Zoo[98], can offer more examples as to how to stimulate, reward and retain contributors. The EU Green Paper on Citizen Science [1] and this paper on 'Crowd science' [22] also discuss drivers and barriers for citizen science.

Even assuming a good initial training in using tools, users will always run into difficulties. Support is then vital to help them to solve the problem and to keep them engaged. Setting aside adequate funding and effort for support should be done while planning the original research. However, all research projects eventually come to an end, meaning that the support also ends. This brings us on to the issue of sustainability.

Most research is carried out in the form of projects, which have a fixed budget. Once the project is completed, tools or initiatives developed during the project may be maintained within a new project, may be supported ad hoc as a hobby of a given researcher, or may simply be left to their own devices. This is highly undesirable. Tools need to be developed actively or they will rapidly become obsolete. Also, without active involvement, many initiatives tend to die a quick death. Despite the increasing number of sustainability plans included as part of research proposals, sustainability remains a significant problem. This was evident during the research for this study, as many systems, while still present on the Web, were inaccessible or unusable. For example, the Voa3r portal was not accessible, even though they had a sustainability plan. Where work has been continued in another project, it is often impossible to discover that from the original project. This can be easily seen by browsing the websites of EU projects, for example, the FutureFarms[99] project made many recommendations as to the

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[96] http://openbadges.org/

[97] http://www.altmetric.com

[98] http://www.galaxyzoo.org

[99] http://www.futurefarm.eu/

use of technology by practitioners, but it was impossible to discover what had been done with these recommendations.

The issue of sustainability is a complex one, which is certainly not limited to e-science, so we can learn from other areas. For technical solutions, groups such as the Software Sustainability Institute can offer expertise on possible solutions. There are also plenty of places on the Internet where tools and data can be stored for access, see Figshare[100], GitHub[101], myExperiment[102] etc. It should be noted though that making tools available, even in a safe location, is in itself no guarantee of sustainability. A recent study showed that of a sample of 1443 workflows on myExperiment, only 29.2 per cent could be used [23]. Active support is needed to keep tools 'alive'. One possible solution is to transfer the tool to a company to develop into a product. To do this, there must be a viable business case, which is not the case for many tools, particularly if the idea is to offer the tool for free. Development as a product can also mean that research results are locked into proprietary solutions of one company, and can no longer be freely developed. The correct choice of a licencing model is important in such a case. Another possible solution is to involve communities of practitioners and industry groups, as these remain after research projects are over. They may be able, with some training, to maintain the tool themselves. They can also offer each other support. Even where the technical sustainability of a tool is secured, an enthusiastic user community can mean the difference between success and failure. It is an interesting hypothesis that involving practitioners earlier, via e-science, may lead to better sustainability due to their raised interest and understanding of the potential benefits.

5.5.8 Learning from existing initiatives

While compiling this study, it was clear that many other research domains are far more developed in their use of e-science than agricultural research is. This includes 'big data' domains such as seismology (VERCE), climate [24] and environmental research [25], and bioinformatics (where the BBRSC has recently put out a GBP 6 million call for infrastructure for bioinformatics[103]). However, it also includes domains such as the humanities, which were the subject of a workshop at the 2014 IEEE conference on e-science[104], despite being historically not so closely linked to computing. There are several possible reasons why e-science is less developed for agricultural research than for these domains.

Firstly, a large amount of the available data is economically valuable and so may be less likely to be shared (as was discussed in Section 5.4.4). This is different to disciplines such as seismology, where scientific institutes supply most of the data.

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[100] http://figshare.com/

[101] https://github.com/

[102] http://www.myexperiment.org/

[103] http://www.bbsrc.ac.uk/funding/opportunities/2015/2015-bioinformatics-biological-resources-fund/

[104] http://dhandes2014.ime.usp.br/

Secondly, agricultural research does not tend to use hugely expensive equipment such as the radio telescopes used in astronomy. For this equipment, the costs of duplication of data are so high, that data are more likely to be shared. This financial driver is missing in agricultural research. Thirdly, agricultural data are sensitive to a large number of factors, such as weather, soil type, farming practices, geographic location etc. This heterogeneity makes it difficult to combine the data together and examine the effects of specific factors, which is necessary for research. It also means that upscaling of experiments is not necessarily desirable. An experiment conducted on a thousand fields will not necessarily provide better results than an experiment conducted on a hundred fields, as the amount of noise can also increase due to all the differences in conditions between the fields.

Finally, agricultural research is often strongly tied to particular countries or even regions, depending on the local products and practices.

Agricultural e-science can learn from the experiences of other domains, in particular domains such as climate science and bioinformatics, which have close ties to agriculture. It is, however, not reasonable to expect that agricultural research can simply pick up e-science tools that have been developed for these other domains. The simple fact that research infrastructures and virtual research environments are developed for specific domains demonstrates the need to tailor the basic technology to the needs of the users. Successful initiatives, such as VERCE, have involved both experts in e-science technology and the domain scientists working closely together, and this is cited by the creators of both VERCE and VOA3R as being a key success factor. E-science technological expertise is widely available. Individual technological aspects are covered by research centres around the world, for example by institutes for high performance computing. General expertise over the whole area of e-science is also available via a network of national e-science centres, for example NLeSC[105] in the Netherlands, which offers both funding for projects and a platform for e-science resources[106]. These centres can offer expertise and work together with domain scientists to develop solutions tailored to the needs of the domain.

When learning from other domains, it is important to note the different challenges faced by agricultural research in order to reach an effective solution.

5.6 Conclusion

E-science in agriculture is already a reality. Practitioners are generating data, participating in experiments and contributing their expert knowledge to build practical tools. Online communities are sharing data and knowledge. The number of available sources of 'real-life' data is growing rapidly, including data obtained via citizen science approaches. E-science creates important new opportunities for farmers and other practitioners. There are effective techniques for turning data into knowledge, and applying this knowledge to support practitioners in their work. Moreover, the infrastructure and technology are available to bring researchers and practitioners together so they can share and extend their knowledge. All four types of participation identified – providing data, participating in experiments, contributing field knowledge and accessing

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[105] https://www.esciencecenter.nl/

[106] https://www.esciencecenter.nl/project/estep

expert knowledge – can be made easier by using e-science technology. This has been demonstrated by several cases discussed in this chapter.

However, there remains a vast potential for e-science in agriculture to explore further. Far from all of the potential data are available to researchers and practitioners, and the links between science and practice remain few. In order to make progress in this direction, the following issues need to be addressed:

- Scientists and practitioners need to understand the potential of working together with the support of e-science.
- Barriers to data sharing, such as mistrust and concerns about data ownership, must be resolved.
- The data must be made available for use, and be of sufficient quality for research.
- Search and analysis tools are necessary to find the right information and to reduce noise.
- Knowledge must also be collected.
- Shared e-science tools and infrastructure need to be made available for agriculture.

Possible activities to address these issues are the following:

- Disseminate information about e-science in agricultural circles.
- Form (online) communities between scientists and practitioners to discuss issues related to data sharing and quality, and to set up a feedback loop between science and practice.
- Follow the FAIR[107] principles for open data and use semantic technology to help with findability, provenance and interoperability.
- Actively involve practitioners in research projects; this can be as data and knowledge providers, active participants (possibly as citizen scientists) or data and knowledge users.
- Create semantic standards for more effective communication between people and for the automation of specific tasks.
- Use both research and practical knowledge to build smart tools.
- Learn the lessons from the experiences of related domains with e-science and citizen science, such as climate research and bioinformatics.
- Identify the needs of agricultural researchers and practitioners relating to tools and infrastructures. They should work in partnership with technological experts to find or develop these.

It is important in developing e-science for (participative) agricultural research, to keep the needs and limitations of the research central, and find the e-science tools which support those needs and can work within those limitations. The e-science should be a means, not an end in itself. It is of little use to invest heavily in a citizen science application where a traditional trial on an experimental farm is more appropriate. At the same time, in order to assess the potential of

[107] https://www.force11.org/group/fairgroup/fairprinciples

collective science, it is necessary to encourage both researchers and practitioners to give e-science methods due consideration. The human factors of awareness, education, perceived cost and reward must always be taken into account. A one-size-fits-all solution for e-science does not exist.

To conclude, e-science is already having an effect on the way agricultural research is conducted, and has a great potential for helping scientists and practitioners to get the best out of each other.

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6 Foresight – towards the AKIS of the future

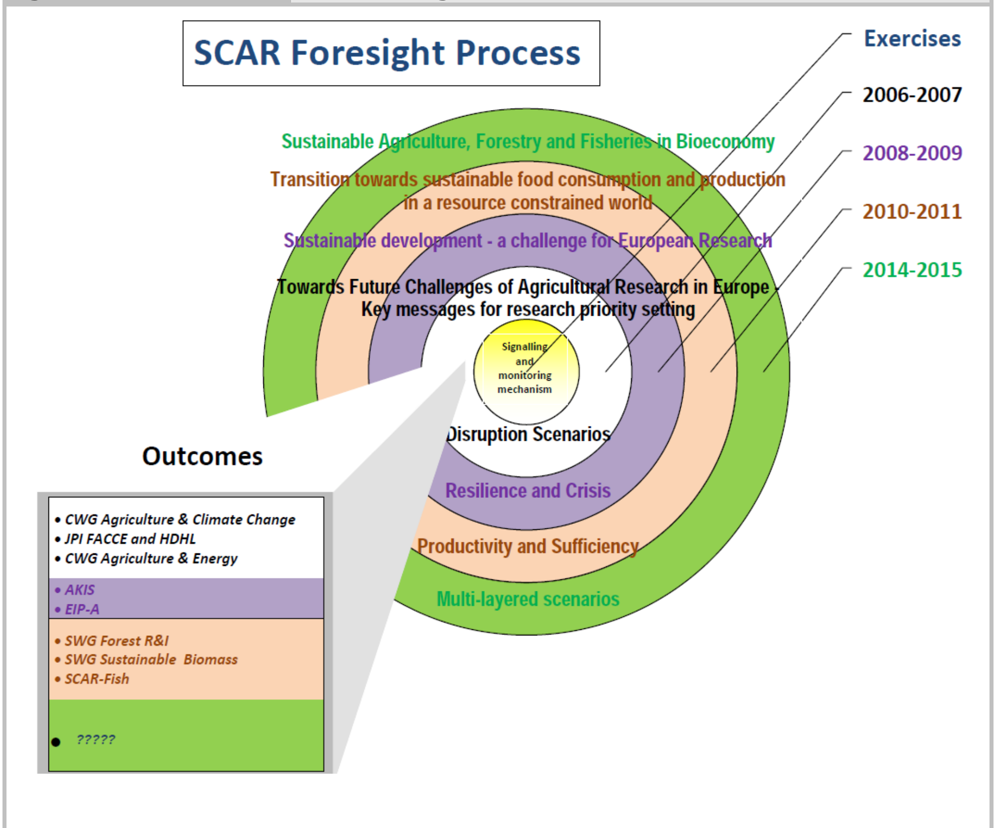
By Floor Geerling-Eiff, Trond Selnes and Krijn Poppe, in interaction with the SWG AKIS

6.1 SCAR Foresight on the bioeconomy

To cope with the wide range of complex and interlinked challenges facing agriculture and the wider bioeconomy, the SCAR regularly carries out a foresight exercise. Through its long term focus, foresight is an excellent instrument for public research planning and public policy building. In particular, the SCAR foresight exercises:

- Explore new challenges, take up cross-cutting issues, feed the strategic planning process of research policy making and give advice to political decision makers (SCAR members, COM, MS);
- Highlight weak signals as well as future opportunities (e.g. mid- to long-term priority setting for research) to provide input for a more integrated research system for agriculture in Europe;
- Result in a high number of joint activities between EU Member States, such as the implementation of working groups (CWGs, ERA-Nets and Joint Programming Initiatives with a wide scope (e.g. climate change, food security).

Figure 5.1 **SCAR Foresight activities**



Source: SCAR

Strongly encouraged by the EU Council, SCAR has launched four separate foresight exercises since 2005 which have identified possible futures scenarios for European agriculture as the basis for prioritising research and other activities in the medium to long term (Figure 5.1).

The fourth and latest SCAR foresight addresses a critical issue with very broad economic, social and environmental implications and is entitled: "Sustainable Agriculture, Forestry and Fisheries in the Bioeconomy – a Challenge for Europe" (EC DG RTD, 2015). The aim of the foresight is not to predict the future but by gathering existing information, analysing trends and comparing expectations of a broad range of sectorial experts, uncertainties and their implications can be identified, possible conflicts exposed, and future opportunities highlighted. This is felt as an urgent need in the area of the bioeconomy for the many expectations and uncertainties it raises among EU Member States and industry, as well as the primary production sectors.

The development of the exercise has been based on a wide consultation. A survey was launched to identify dilemmas, while three workshops were organised with the participation of a large number of experts. In addition interactions of the Foresight Expert Group (which is appointed by the European Commission) with the SCAR Strategic and Collaborative Working Groups (including the SWG AKIS) and sectorial analytical documents have also provided invaluable inputs.

The Fourth Foresight Exercise[108] identifies and compares different scenarios in a long-term perspective (2050) based on varying levels of biomass supply and demand, examines the reasons that might lead to such situations, describes opportunities and risks for the different sectors, social groups and regions, and explores possible research areas and policies that might maximise benefits and minimise undesirable outcomes. The experts conclude that in order for the bioeconomy to achieve its multiple goals of food security, environmental care, energy independence, climate change mitigation and adaptation and employment creation, it needs to be implemented according to a set of principles: food first, sustainable yields, cascading approach, circularity and diversity. The following research themes are proposed:

- New paradigms for primary production based on ecological intensification;
- Emerging enabling technologies, especially the digital revolution;
- Resilience for a sustainable bioeconomy;
- The new energy landscape;
- Business and policy models for the bioeconomy;
- Socio-cultural dimensions of the bioeconomy;
- Governance and the political economy of the bioeconomy;
- Foresight for the biosphere.

Concerning the knowledge and innovation system (KIS) that has to take up these research priorities, the Fourth Foresight supports the transition towards a

[108] The text in the remainder of this section is directly taken from the executive summary of the Fourth Foresight report (EC DG RTD, 2015)

system in which knowledge is co-produced by all actors that engage with each other in processes of learning and even co-evolution that has the following characteristics:

- Challenge-oriented - Rather than only being driven by scientific curiosity, the KIS should also be challenged-oriented. The KIS should find a right balance between basic and applied research. Orientation is currently provided by the Europe 2020 strategy and more specifically the Grand Challenges for the bioeconomy.
- Transdisciplinary - The KIS should be transdisciplinary, that is, multiple theoretical perspectives and practical methodologies should be used to tackle challenges. Transdisciplinarity goes beyond interdisciplinarity as it transcends pre-existing disciplines.
- Socially distributed - Knowledge should be diverse and socially distributed in the KIS. Communication barriers have been largely lifted, such that knowledge is created in diverse forms, in diverse places and by diverse actors. However, several barriers still exist, such as intellectual property rights and unknown cost structures, hindering the inclusive and public-good character of knowledge. We recommend that open access and open innovation should guide knowledge production as much as possible. Particular attention should be devoted to social innovation and the inclusion of socially disadvantaged actors and regions.
- Reflexive - Rather than an 'objective' investigation of the natural and social world, research has become a process of dialogue among all actors. The KIS should devote sufficient attention to these reflexive processes, both within the boundaries of a research project and at the meta-level of organising and programming research. Current efforts of multi-actor participation and stakeholder engagement in projects and in programming are steps in the right direction.
- New rewarding and assessment systems - Quality control transcends the classical peer review as transdisciplinarity makes old taxonomies irrelevant. In addition, the integration of different actors also broadens the concept of quality into multiple definitions of qualities. As a result, assessment/rewarding systems relating to researchers, research projects and programmes, research institutes/bodies, other actors, education and even the organisation of regional/national/international KIS need to change. This makes the research and innovation process more uncertain from a traditional perspective on research.
- Competencies and capacities - Researchers, other actors as well as other stakeholders in the KIS need to acquire a new set of skills and competencies. Institutions of higher education in particular can play a key role by integrating these skills and competencies into their curricula. The capacity to engage in KIS not only depends on the aforementioned competencies, but also on resources that need to be invested by actors and stakeholders.

These recommendations are very much in line with the previous reports of the SCAR-AKIS working group. To support the Fourth Foresight, as requested by SCAR, and to look into more detail to the future of the AKIS, the SCAR-AKIS group has carried out a specific foresight analysis. Besides the research themes of the bioeconomy, as identified above, and the suggested, ideal characteristics of the AKIS (or even broader: covering the bioeconomy knowledge and innovation system) there are other factors that might influence to a great extent the AKIS in Europe. Besides political developments outside agriculture, it is expected that also the digital revolution could have a large effect on organising research, innovation and extension itself. In the next sections we present the results of this specific foresight exercise.

6.2 Foresight for AKIS

To prepare for the future, governments need not only foresights on the agricultural markets and food supply in relation to the bioeconomy, but as well as on how innovation processes could and should be organised. Owing to changes in, among others, technologies (such as ICT that makes communication easier), scarcities and politics (that favour central or decentralised, market or governmental solutions), the organisation and governance of science and research is not static. Policy ideas and instruments in this area develop. The rest of this chapter reflects on the future organisation of innovation. The insights from previous chapters as well as those of the foresight on the bioeconomy reported above have been taken into account in this foresight.

The methodology of this foresight is based on a basic version of Scenario Planning as used in business (Van der Heijden, 2005). Annex 1 contains the details of the method, its application in the Strategic Working Group AKIS (including an internet questionnaire that involved 120 persons who scored 59 drivers of change). The foresight concentrated on the challenges of the European AKIS towards 2030, with potential trends in agriculture up to 2050 (for which research has to be carried out much earlier).

In a workshop of the SWG AKIS, the outcomes of the Internet survey were processed into scenarios following a number of steps (see Annex 1 for the basic results in table form that have been used to write the scenarios below). In the end three scenarios resulted:

- *High Tech*: represents a world dominated by large multinationals and advanced technology (ICT, robotics, genetics). It is characterised by globalisation, widespread use of unmanned vehicles, contract farming and outsourcing, with a large urban population. European institutions are strong, national governments are weak. In general it is a wealthy society, but inequality creates concern. Sustainability problems are largely solved through technical solutions such as precision farming and genetic modification (GMO);
- *Self-organisation*: a world of regions where new ICT technologies with disruptive business models lead to self-organisation, bottom-up democracy, short supply chains and multi-forms of agriculture. European institutions are weak, regions and cities rule and follow quite different pathways for agriculture. Products are traded between regions. There is inequality between regions, depending on endowments;
- *Collapse*: a world where climate change, mass-migration and political turbulence leads to a collapse of institutions and European integration. Regional and local communities look for self-sufficiency. Bio-scarcity and labour-intensive agriculture, including permaculture and urban farming arise out of necessity. Technology development becomes dependent on science in China, India and Brazil.

The next sections discuss these scenarios in more detail and look to the effects on AKIS. The scenarios have been influenced but not been fine-tuned with the bioeconomy scenarios discussed in section 5.1. The Bio-boom scenario correlates with the HighTech scenario, where the BioScarcity scenario can be linked with the Collapse scenario. Bio-modesty can be paired with Self-organisation.

6.3 Scenario HighTech

6.3.1 Society and agriculture

Owing to the removal of barriers for globalisation through far-reaching international agreements, the trend to big data in ICT and patents on agricultural organisms in genetics, large private multinational companies with huge resources and influence are dominating the food chain and agricultural production. Multinational retail companies are dominant too. Private technology is now one of the most important drivers of innovation in society. Much attention and means go to chain management, the use of drones and robots, run by multinationals. European family farms have increased in scale and have become specialised SMEs that are contracted by the multinational companies in the food chain. Non-governmental pressure groups use the reputation mechanism of multinational companies and brands to exercise a corrective influence for public issues.

New technological innovations (especially in ICT by companies that mass-produce sensors but also by companies such as IBM and Google with big data expertise, and with GMOs) have solved the sustainability problems and are the basis for a booming bioeconomy industry that provides food for the many and inputs for the chemical industry. After a number of crises, the European Union has evolved into a political unity named the United States of Europe (USE). As such, it is a serious counterweight with its competition policy to the huge multinationals. At the same time the federal character of the EU has limited the powers and the reach of the national states. However the institutions of the USE also have a limited influence – they are more following and correcting than steering the powerful business community. Social inequality is causing concern in this society which is on average rich, but with a wide distribution.

Extreme public budget cuts, trade liberalisation and deregulation fuelled this process. Through global private summits (in Davos or elsewhere) private – public action programmes are made for many sectors of society. A combination of technological solutions and Green Deals under the pressure of NGOs solve sustainability problems. Precision farming and genetics have delivered their promise and added significantly to the solutions of pollution, climate change and animal welfare. Pollution can for instance now easily be traced, measured, taxed or regulated through systems of best practices and certifications. As a result, there is less need for national policy and law enforcement, which is cost reducing for companies. Government officials are now mainly steering at a distance, which allows them to observe or participate, but usually only on invitation. They are seldom involved in steering committees and suchlike. Business sectors negotiate directly with the World Trade Organization and the Convention of Biological Diversity. Consumer concerns and their claims for sustainability, as expressed by powerful non-governmental organisations (such as Greenpeace) are leading for business, not governments. Companies are often concerned about paying higher taxes in the EU than in certain parts of, say, Africa or Asia.

The technological development has resulted in much higher production levels in a sustainable way. Owing to solar energy, energy prices are very low and therefore water shortage is also not a problem. There is a booming bioeconomy. The production covers both food and non-food products including plastics out of biomass and algae in food and chemicals. Transport is electric and self-driving. Privately-run stock and commodity exchanges regulate prices in cases where production is not contracted.

The process of internationalisation has forced farmers and cooperatives of farmers to either grow big or be integrated with multinationals, turning to large scale and highly technological production. Large cooperatives have listed themselves on the stock market to attract capital for this internationalisation process. Information is centralised on a few websites with a dominant position (such as Alibaba and Facebook) and sales take place on far away markets. There is much attention to optimised logistics and exchange of best practices. The notion of "strange food', as in artificial meat or insects, has been accepted. Algae and insects are now common. This high-tech driven society provides the masses with sufficient and cheap food. As there is quite some inequality in society, the CAP has adopted a food-stamp programme.

The dominant business models are legitimised by certified and protected labels. Food service companies such as McDonalds have contracts with highly specialised farms and factories spread over different regions all over the world. Their contract partners are usually cooperatives of farms or factory companies, but also governments are bound to long-term contracts. Vegetables are grown in plant laboratories (vertical farms). Companies produce in many countries and profit from global marketing, branding and property rights. Food supply is very high, and so is also the general food safety. Much of the bulk production is now placed in Ukraine, Russia and Africa, where farming is about large quantities and commodities, also for the poor in Europe. Precision farming and cheap transport, as well as local 3D-printing (e.g. of spare parts for machinery), helped to solve the problems of the heterogeneous soils in Africa.

Politics: array of private arenas and institutions

Much of the decisive influence comes from an array of international and even global arenas and institutions. National parliaments still exist but their influence is reduced and governments struggle with public budget cuts. Large-scale effects on the use of land, sea and air are often successfully kept outside politics and yet resolved, and for instance the North Sea is largely privatised and industrialised for the production of energy, aquaculture and algae. But at times land use and access to land and resources are still a source of dispute. Struggles emerge from disputed legal consequences of for instance the ownership of genetically modified crops or animals. Outbursts of conflicts and crises cause a blame game between business and governments, but these are usually solved through social media platforms offering a range of interactive tools for dialogue. Prevailing struggle is often resolved through privately-organised dispute settlement mechanisms (as Round Tables), with reference to long-term contracts or far-reaching international agreements on, for instance, intellectual property rights. NGOs play an important role in this process.

The private food industry, input companies and retailers are active in law enforcement and carry out their own monitoring and control of farmers through private law (contracts with liability claims). The claims from some farmers that only the government can do this are rarely met with success, as governments are not very competent and also not overly united on these matters. Farms are large and very specialised: the typical broccoli farmer operates holdings in three countries. They are seen as just another SME and their number is low with reduced political clout. Owing to collaboration between the USE, national governments and the (food) industry, many problems of the past are now resolved through integrated solutions, instead of the old fragmentation.

Technology: advanced and complex

High-tech has in this scenario become more than popular, it is one of the main drivers of society and the foundation for success. The large multinationals own complex, large-scale research entities that create totally new business models based on ICT and a range of advanced research on genomics and synthetic biology for food security and safety. Their ability to create global game changers is huge. A privately-run European Safety Control Agency is working on a contract basis for the USE. Private industry also develops and produces drones (unmanned vehicles) on a large scale. Knowledge is about technological-based developments. Not only environmental problems are largely solved by such high tech solutions, technologies and market innovations are also the essence of food production. 3D and 4D printers for food are commonplace and "the fridge tells you what to do". Robots run the kitchen, and quite some health conditions are now leading to computer-steered treatments and computer supervision: obesity and other lifestyle conditions might lead to a controlled access to the refrigerator, and biological sensors in the body and brains of these patients regulate behaviour. Personalised nutrition is standard. Data on food consumption and lifestyle are shared by consumers with their insurance company for risk-based (lower) premiums.

As the food demand is high, much technology is oriented towards the quantity and the nutritive value of food. The type of food is changing, with high-tech factory production of synthetic burgers which are now fashionable and common. Insects were for a while eaten by a few, but expanded to the mainstream due to smart marketing, heavily driven by large companies using celebrities in billion euro campaigns. The poor find it attractive for their low price or are more or less forced to buy it with their food stamps. There is food waste but it is limited by international chain management.

Social: much richer, more free time but also important inequalities

Much of the social fabric of society is caught between an advanced elite and the socially deprived. The elite pursues a lifestyle where many issues, such as health, fashion and shopping, are technologically steered by advanced business models. Many jobs are taken over by robots. Robots are for instance performing most of the tasks within online sales, media commercials and model work. Computer modelled designs prevail, controlled by business experts behind the scenes. There are only specialised roles for real people in the rare occasions when a robot is not sufficient. The leisure industry is an important employer, given the reduced working time of most people. Health matters are also often solved through online services and even surgery is being done through remote online devices and robots. A happy life is seen as the foundation for health, but many are also highly medicalised, supported by online health advice and counselling from Internet platforms. Advances in neuro-science and ICT have helped and have led to a complete understanding how food influences the body and brains, and how the brains influence food choice. A deregulated online world of buying and selling of medicine and other health products ensures a large flow of capital for investments in this sector.

Many poor and deprived social 'misfits' are unable to catch up with the high-tech society. There are widespread concerns about the wealth inequality and an elite in their gated communities that is not very respondent to social problems. But the argument that we should and must solve the hunger problem by technology, not politics, is supported by many. Critics argue that a small elite of an extremely rich upper class usually sets the agenda, whereas the 25% living in deprived and disorganised poverty are unable to catch up, despite repeated promises of a better life. The poor are politically weak as well, and unable to organise themselves and stand up for their views.

There are now fewer farmers and people are living largely in urban settings. There has been a rural exodus, with many agricultural functions centralised in attractive cities. The city administration is usually important for the social dynamics of urban life. Rural areas are depopulated and administered through private contracts. There are many nature reserves where local (often poor) people are denied access, both physical access of living and working in nature areas as well as the right to make use of natural resources. Large parts of the Amazons are owned by a global consortium of food, mining and pharmaceutical industry in search of genetic and mineral resources. But these parties are in that way also able to protect much nature. Much of the day-to-day social life is determined by high-quality advice on how to create a happy life, supported by advanced neuro-science. It is a social life with little politics and much techno-driven individualised fun and risk management.

6.3.2 Impact on AKIS

Economic and political

AKIS are in this HighTech scenario very centralised and also largely privatised. Owing to public budget cuts, national governments are unable to be involved in many issues, and the big companies have taken control of the knowledge exchange in the agri-related business. The organisation of the food chain now mimics that of the car industry at the beginning of the millennium: large global automotive companies such as Volkswagen and Toyota organise a large part of the chain from design (in co-innovation with suppliers) to sales by dealers and knowledge development with some universities. As farmers are often contract farmers of a large company, and their political influence is much weaker than in the past, politicians see less need to maintain state extension services and governmental applied research institutes. Levy organisations such as commodity boards have disappeared and do not finance applied research anymore. The main interest of the government is to have first-class university education for the needs of the multinational food companies and large farms. Agricultural universities have been merged into general universities where students take majors on system biology and ICT with a minor in agriculture, sometimes labelled as applied biology. Such universities have become third-generation universities: besides teaching and research, innovation is their third objective. They support start-up companies that develop basic research findings into new products ('spin-outs') on their campus in a science park, in collaboration with alumni that act as business angels and with incubators and venture capitalists. Multinationals support this as a kind of open innovation. Once start-ups are successful and need more capital and access to global markets they buy them.

There is a strong orientation towards competition, internationalisation and the subjects in education tend to be very specialised. There is however some resistance against the domination of multinationals. This is a type of resistance, with a few so-called independent and 'non-corporate AKIS', established and run by many different types of people and organisations, including engaged individuals, NGOs, small universities, with some participation of governmental agencies. Such a resistance is organised from outside the establishment. Dominant multinationals usually frame this resistance as 'radical' and 'idealistic', accepting its presence, as long as it does not disturb the agenda of private industry.

Through AKIS, companies try to reach and engage consumers in dialogue and discussions on the often used Open Minded Society, which is mainly online platforms for discussions on consumer issues as health, nutrition and lifestyle. Among the topics discussed are regulation and labelling. An increasing interest in insects as daily food in the EU has caught the attention of AKIS as well. Gourmet insects produced on a large scale is one of the business models that has become a billion-euro business. Trust, and the role of transparency of the system with big data, is an important matter that is monitored closely by large companies. The role of certifications and global institutions for regulating the rules of play are important. Partly owing to these issues, collaboration has become pivotal to AKIS. But a reduction of knowledge exchange outside the large companies is a concern. In general, AKIS also goes for non-food issues, as food in many respects is 'already taken care of' and is fully integrated in the bioeconomy. The links between food and for instance lifestyle have become more pressing for the agenda. The language of AKIS is now English.

Technology and innovation

International competition is the main driver for innovation. Competition involves competing for the attention of consumers. As AKIS serves the interests of multinational companies, AKIS also focuses on producing or stimulating the development of skills. Such a process has become known as "up-skilling"; i.e. the development of specialised knowledge and expertise, including skills in international networks and consulting, and 'international networked research' is one of the essential topics. There is a tendency to focus on technology and the technical context. Farming is more for technologists rather than for instance for land managers. AKIS tools for innovation are often technology-driven with a global scope. Developing benchmarks for economic efficiency is of great interest. But innovation is also about labelling and consumer science; thematic cross-overs such as health, ICT, lifestyle, design with agricultural production are of great importance. Much attention is also paid to the functioning of global food chains and flows, in relation to the rest of the bioeconomy. Themes of interest are food security, ICT and robotics for production and control, the ability of day-to-day advice and reporting. Innovation also occurs as a result of AKIS integrating into other global knowledge areas. Agricultural production and services are coupled to infrastructure development, urban-rural relations and transportation systems. Often this concerns technical and technological research but it is also often related to system analysis and the effects on consumers and the consumers' sense of well-being. The danger of exclusion of groups and claims of closeness is a source of inequality and can be a threat to innovation when there is not enough diversity in the system.

Knowledge organisations and other actors

The dominance of a few large companies ensures that innovation is about the needs of these companies. Multinationals teams up with the most important and largest globally-oriented universities and these partnerships run much of the R&D on the food system. There is an 'Ivy League' of seven global universities with a strong bio-based and agricultural faculty who collaborate but also compete for the best students and train them for top science and management functions for the multinationals in the bioeconomy and food chain. 'Connecting the globe' is an often used motto for their need to innovate at an international level, because the focus of AKIS is on the global food chains and flows.

There are hardly any independent, publicly-funded AKIS, other than education, and governments only play a minor role now. R&D is organised at the European level in the form of public-private partnerships: to improve its competitive position and to deal with some of the public issues that NGOs put on the table. The United States of Europe sets up such PPPs with, for example, the remaining five largest dairy multinationals. Joint Programming Initiatives are used for collaboration with other continents, ERAnets have disappeared due to small budgets in EU Member States and centralised decision making with multinational companies. However, PPPs and JPIs do not compensate for the declining public R&D. The result is less focus on public-oriented issues. These are mainly addressed by regulation (that leads to innovation within companies) and much less by research. The concept of interactive innovation, in which much use is made of 'innovation in the wild' based on local knowledge, has disappeared. However the method of co-creation of products with wealthy consumers that have time to spend has gained much more ground: retailers and food manufacturers run highly popular five-day courses on 'discovering new recipes and innovating products' with big chefs in theme parks, where also new technologies like 3D food printers are tested.

Not only public applied research institutes (that were merged into universities) but also public extension have disappeared in this scenario. Advice to farmers is now given by the input industry and food industry, as part of their contracts. They offer a few days a year training to their farmers on their own "university", but in reality the JohnDeere University and the Danone University are high level training centres, sometimes run together with a real university. Some multinationals use specialised consultancies such as Ernst & Young to provide advice to large farms and have taken over the role of the traditional advisory services that were not able to meet the demand for advice and training on topics such as strategy, contract design and human relation management in large SME-type farms.

6.4 Scenario Self organisation

6.4.1 General and agricultural characteristics

Concealed in a multitude of institutions and actors lies a Europe that is facing common challenges but approaching them with much (and increasing) space for self-organisation. Some speak of a 'Europe of the Regions'. On the one hand, this provides fuel for a mosaic of cultures to thrive on their own. On the other hand, at times, and for some much more than others, it is a struggle against economic hardship. While some regions face poverty due to a lack of resources and skills, others are prospering in growth and new investments. However the financial crisis at the start of the century is still fresh in the memory. Some regions are now independent as their countries have broken up. Several of them are de facto city states, where the main metropolis runs the region. The choice for these regions of using the euro or their old national currency has become a non-issue as consumers are using ICT based bitcoins. For most regions the major debate is related to social inequality and nutrition. Owing to global warming, desertification has become an issue for some and it has even led to a shift in food production from southern Europe to other regions in Europe and the rest of the world. However in most cases trade solves such problems.

Economy and ecology: the importance of the regional scale

The ability to solve the problems around social inequality and nutrition through a common, central approach is currently limited as the solutions are often chosen and restricted at regional level. In this scenario the regional approach has been strengthened, as ICT provided plenty of opportunities for new ways of organising the society. ICT has proven to be very disruptive, with Airbnb and Uber as early examples, and very much used to shape new collaborative business models in the sharing economy. Crowdfunding and the block-chain technology have weakened the position of the old banks considerably. This disruptive character of the technology has strongly undermined the position of large companies in retail and the food business.

Agriculture in this scenario is characterised through high food supplies and differentiated food streams: organic, conventional, mainstream, cheap, luxury and many hybrid forms. Branding and brands have also increased in importance, partly as a result of increasing consumer demand for experience and a (regional) authentic character. The consumer wants to know if food is technologically processed or based on traditional 'granny' recipes like homemade food. As a result, the demand for different types of food and production methods is high, not only in terms of quantity but also in terms of quality. Regional food is popular. Labelling and certification have partly given way to full transparency as the buyer can trace the history of an individual product with ICT. Consumer demands differ by region. Farmers are not only food producers. There is economic demand for bio-based energy including biogas from manure. Tractors and other electric machinery is used for energy storage at night and in wintertime as they are connected to the grid.

The importance of self-organisation is also reflected in the evolution of agricultural cooperatives; the EU started to accept cooperatives as beneficiaries in the CAP, enabling them to operate as contract partners. This made regional management contracts with lower transaction costs possible. Such cooperatives are regionally organised and are used as tools for the marketing of products. Much of the trade takes place on the international market via Internet market places where consumers and producers are often directly linked.

Care for nature is a regional responsibility. The protection of natural areas is mostly managed by regional government bodies, but in close collaboration with citizens, environmental groups and farmers' groups in the region. After years of conflicts between advocates of agriculture and advocates of nature, nature and farming have started to evolve a serious relationship. It did not really take off until a sufficient set of economic incentive schemes were properly put to work. The Ecosystem Services Approach now forms the umbrella label for a rich variety of linking products combining agro-economy and ecology including ecological farming, agro-forestry, high nature value farming and other activities.

There are quite some societal debates on the scale of farms. In practice there is a whole range of farms, from very large industrialised high-tech factory farms to very small family farms. The variety is huge, with many cooperatives and many SMEs. In some cooperatives larger farms 'take care' of smaller-sized enterprises (with a risk of elite capturing). Regions and cities make up their own rules when it comes to spatial planning and the type and size of farms suited and accepted in the region. The CAP has been fully regionalised: regions can make a choice from the CAP menu and mainly have to prove that their measures are not trade distorting. Choices depend on conditions like demographic and historic background, economic competitiveness in and between regions and the presence of human capital. In some regions the population is shrinking while others experience great pressure for urbanisation and growth. In some there is a rural renaissance with population growth as ICT permits some to work in areas of interesting scenery and a nice climate.

Politics: community based self-steering mechanisms

The political framework of the EU is characterised by different geopolitical settings. The EU sometimes takes the lead in certain cross-regional political matters, but the implementation usually lies in the hands of regional governments and cities. The practical plans are often worked out in public-private covenants, with a substantial role for private parties and citizens. The powers of the EU are often (viewed to be) dispersed or at least decentralised. A part of the decentralisation is caused by and is a tribute to Europe as a mosaic of local cultures. It led to a maze of regional governments and collaborative settings of which the latter are quite influential in certain policy matters. Many regions make use of referenda by Internet comparable to the longstanding tradition in the Swiss system. The notion of Europe of the Regions fits a picture of a Europe where the role of regions has been increased substantially, providing space for self-organisation and regional sovereignty. Public institutions have budgets for a range of (public) tasks. In general EU and national institutions and subsidies are gradually disappearing, giving way to regional governance. The role of the EU is mainly concentrated on foreign policy, defence (a European army), internal market and basic public and private law. This causes public debates on the possible effects, as for instance on the fragmented character of the politics.

Risk management in agriculture is shared between different regions, based on agreements between cooperatives and through chain management. Food waste is an overall problem as food supply is higher than food demand. Food safety on the other hand, is well organised, mainly driven by consumer organisations but also managed through full transparency in the food chain with ICT. Public agencies (mostly regional) ensure publicly-controlled law enforcement. However critical incidents such as animal diseases are a recurring societal problem. Responsibility for the environment is in the hands of regional governments and agencies but there are many public-private covenants. Chain management, cooperatives, certification and public-private covenants form different instruments to handle risk. Public authorities provide the assurance that community problems will be solved.

Technology: focus on the social context

Technology is important for society, but the main driver is knowledge, especially on consumer demands in an aging society, not so much technology. In fact, technology is rather well regulated and public-private platforms among stakeholders as citizens, NGOs, businesses and governments are central to this work. In most regions cities dominate and there is quite some resistance to new technologies in genetics, nanotechnology and ICT, especially as it does not have a social component. The regional level is important because there are plenty of opportunities for self-steering of the development. Many look upon this as a democratic control of ICT/technology. Active participation in Wikipedia-like media is one of the tools for participation. Many regional newspapers are now mainly based on volunteer journalism.

In terms of agriculture and food technology, high-tech lives side by side with traditional crafts, often being intertwined by the freedom/space and support for creative innovations. There is a variable usage of drones and other kinds of unmanned vehicles, depending on the regional and local context. But there is also resistance as it raises many new questions. Some ICT developments are however met with scepticism, like big data concentrations with the government or multinationals if persons cannot control and delete their data. Especially liability matters and privacy issues are at stake. It tends to be seen as a potential risk to people's freedom. Using drones to monitor food production seems unproblematic but using it to monitor your competitors is another matter. The emerging 3-D printing of food however came much more quietly, at least in a legal sense. Its specialist usage in health situations and in the case of food shortage is undisputed, but its expensive technology is continuously up for debate. Technology has delivered totally new business models, often based on ICT and sharing of (over-)capacity. There is great diversity and space for entrepreneurs and opportunity seekers. A range of new regional food websites and digital platforms are following this development. There is an intensive coverage on the social media. But the unequal spread of opportunities is a concern, as some technology is quite expensive. Introduction of new foods such as algae or insects has been unprofitable due to the expensive tests that are required for novel foods and which do not guarantee that consumers take the product for safe: market introductions are very sensitive for negative social media campaigns. When it comes to artificial meat, there is resistance to the application of it, in some regions and within certain groups. If there is some acceptance, it is usually related to sustainability issues or low prices. In social media, that have a large influence in this scenario, it is often hard to distinguish between expert statements, lobby input and amateur opinions, now that everybody is involved in participatory processes and co-creation.

The new business models that come from the technological development are diverse due to the creativity that has been tapped. It is about plastics out of biomass, algae in feed, fuels and chemicals. There is a modest growth in demand for biomass. It is the non-competitiveness of bio-based solutions and the fast breakthroughs of prominent alternative solutions, particularly solar energy, that keep the use of biomass down. Owing to the sharing economy, the demand for energy has seen a modest development. Products based on insects that have been able to pass the strict food legislation thrive, particularly among groups advocating alternative or avant-garde lifestyles, of which there are many in this pluriform society.

Social: strong community orientation

Social life is now very much oriented towards community life and being part of one or more communities. It is a value-guided choice in many ways, but at the same time it is part of a daily practice that reflects an economic reality. The value orientation is based upon the notion that many problems can be solved within and by the community in question. This is partly the case with environmental problems (where regulation and public incentives often comes from) and stems from, the region or community itself. Often cooperative and regional solutions are preferred to national or European law.

Communication has become a process that is both virtual and face-to-face based. For many, happiness in life is built upon trust in the community and its ability to solve problems. In terms of demography, a rural renaissance has often taken people out of the city. Many start-ups in rural areas reflects this trend and gradually the share of people living in rural areas is increasing. There are in general fewer specialised farmers as mixed farming (often organic) is preferred. In many regions multi-functionality is important. In cities urban farming and short supply chains have become mainstream and are integrated in food delivery services. Many people study life-long. It has become common to combine work outside agriculture with food production and at same time being a student. The regional variations on this matter are nevertheless huge.

Lifestyle is often oriented towards the community. In health and lifestyle at large, self-diagnosis based on smartphone apps information is common, as is remote treatment of illness and disease. Consumers track their food intake, lifestyle and medicine use nearly automatically by smartphone and post their data anonymously on an Internet platform, where doctors and big-data analysing firms provide advice. As for the type of food, there is a strong emphasis on regional products, but regions differ in terms of dominant diets.

6.4.2 Impact on AKIS

AKIS are strongly regionally organised (decentralised) and diverse. They have a more specific character, meaning there is no particular focus on specific cross-regional topics. AKIS are often locally governed and agendas are set by communities. AKIS have different governance and financial systems. In some regions farmers pay for advice, while others have publicly-financed extension services. Some regions have their AKIS dominantly publicly managed and financed, others are more privatised. There are many public-private partnerships to stimulate knowledge and innovation; The civil society and NGO's participate in such partnerships. Knowledge services dominantly focus on the 'grass root' regions and projects are either conducted on national or regional scales or conducted cross-regionally through multi-linguistic actors combining multi-regional knowledge, experience and insights. Farmers and agri-business are integrated in the AKIS which leads to trust among consumers that the food they eat is safe. Food safety is everyone's concern and problems and incidents are traced through profound chain research (in this system arguments count, not positions of parties of actors).

Technology, knowledge and innovation

The main driver for innovation is competition. There is both competition between regions and collaboration between regions to be competitive on an international scale. Because of the diversity in food and agricultural skills innovation is often small scale. Especially owing to a large number of SMEs, public-private partnerships for innovation are more likely to focus on optimising methods and reduction of time for production. Emphasis on the regional level is more on R&D and innovation than on basic science. Long-term focused knowledge development is mostly derived from scientific fundamental research conducted by some universities and research institutes. Often industry is not involved in this type of curiosity-driven research hence there are several debates on knowledge valorisation and the gap between science and practical impact. Radical breakthrough innovations are quite scarce. Industry, knowledge institutes and governments are involved in the AKIS debate on the efficiency and effects of knowledge and innovation and on how to optimise the knowledge chain and its services (research, education, advice and extension work) for both economic and societal impact.

There are multiple skills and professions in the agricultural sector. Farmers are both land managers technologists, care takers and facility managers (e.g. nature, care and hotel farming). In this scenario the type of skills and demand for human resources also differ by region. AKIS become diversified and increase in number in order to be able to properly address all these different and new professions. AKIS are oriented on adaptations in regional settings yet connect regions because of the stimulation of peer-to-peer learning networks. Several innovation and demonstration centres (IDCs) arise, focusing on either sectors or specific topics (such as ecologically-friendly farming and short supply chain marketing). Their aim is to connect knowledge development closely with the immediate demonstration of the results. Knowledge workers work closely with frontrunner farmers who share their best practices with other farmers and chain partners. In exchange they receive a subsidy for further innovation. These IDCs are built on regional partnerships from the start but quickly extend their network on an international scale. They are financed through regional funds but they disseminate their results on a global level and receive interested spectators from all over the world. The interactive innovation model with transdisciplinary research and co-creation between farmers and consumers are important phenomena in this system. These IDCs are exemplary to the complex subsidy instruments for knowledge and innovation that Europe of the Regions knows. Regional funds are not seldom a combination of both local public investments, national subsidy programmes and EU instruments that focus on the development of different regions within its continent, next to investments of the private sector. All different instruments have various regional or national juridical backgrounds and different criteria leading to complex financial audits and bureaucracy. Because of relative high overhead costs and risks of fines if not properly administered, especially industrial partners are not very keen on entering calls for proposals. This means that subsidy instruments for knowledge and innovation are mostly left to scientific and research infrastructures.

Knowledge organisations and actors

In general farmers are becoming more and better educated. Farmers have various and ever more diversified roles, depending on the local context and personal aspirations. Some are mainly farm entrepreneurs focussing on production and quality. Others focus on nature and landscape maintenance. The trend is the farmer with different skills rather than the specialised farmer. Both specialised in high-tech as in traditional agriculture.

There are many regional universities that are specialised in specific skills and types of professions needed for the region. For instance precision agriculture in Denmark, multi-functional agriculture in Baden Württemberg and organics in Austria. Different universities closely interact with each other. AKIS organise interregional exchange programmes so that students can follow different minor courses for which they receive formal certificates in addition to their degree/diploma. Universities are both academic schools and perform scientific research which makes them second generation types. This trend jumps over to higher education which incorporates the function of applied research, intertwined with experimental farms and advisory services. The idea behind this is that central hubs of life-long learning and applied research are close to the clients in different districts of a region. Peer-to-peer learning processes (such as operational groups) are quite popular in several regions. The challenge for AKIS is to organise multi-knowledge networks that integrate initial and post-initial education and training.

6.5 Scenario Collapse

6.5.1 General and agricultural characteristics

Rising temperatures due to climate change cause drought in several regions in Africa and the Middle East, leading to massive floods of refugees to Europe. But also the northern Mediterranean is affected by heat waves and lower agricultural yields. Meanwhile an EU-unfriendly government in West Africa has military control of the phosphate mines and sells its resources exclusively to China and India. These geopolitical developments lead to a lack of energy and phosphate resources and rising prices of raw materials. European soil exhausts due to intensive agriculture and overpopulation – leading to rising poverty. Several European countries are in conflict either internally or leaving the European Union (the Grexit and Brexit have become reality).

The combination of several of these events amounts to a tipping point for a European Union collapse. It marks the end of the euro which is divided into the mark (a.k.a. 'neuro' for northern Europe) and the franlire (a.k.a. 'seuro' for southern Europe). The institutions are in despair and Europe is in desperate need of reconstruction. The situation is often compared to Europe directly after the Second World War. Food and (clean) fresh water are the basic needs and have first priority, but also infrastructure for transport often needs repair. A directive agricultural policy is back on the agenda, mainly run by national governments and a light coordination in Brussels. Politicians are breaking their heads over building a new governance model. Socio-economic situations are fragile and concentrated in various and different regions. This scenario can be best described with the motto: "freedom is just another word for nothing left to lose" (Janis Joplin).

Economic and ecological

The Collapse scenario is characterised by various communities in different regions. Each community has its own agenda for reconstructing their small, local economy. People work closely together with their direct family relatives and neighbours. Unemployment is high and many persons have returned from cities to their old family country house to grow their own food (subsistence farming). Money is not seldom informally replaced by new forms of barter and division of resources between communities. Europe depends on investments from Asia (such as China and India) or Africa (for example Nigeria) to get its economic system back on track. Resources are scarce and people depend on what nature has to offer. People now tend to return to nature for their basic necessities (food, water, shelter and medicines), but nature is also an enemy due to severe weather conditions, natural catastrophes, diseases and environmental problems. Knowledge has become essential to gain power, and it is limited to few. Local knowledge sources are scarce but an emerging information transfer takes place through storytelling and mouth-to-mouth.

Farming is a dominant economic sector. Farmers both preserve food and focus on the production of edible new types of food (such as insects and plant bulbs). Agriculture can be characterised as urban permaculture, where agriculture is conducted in close interaction and respect for nature. Some cities resemble Detroit in 2010. People now develop their own ecological farming systems, in combination with technological advances offered by city administrations, individuals or small groups and companies. Urban agriculture is hot, with for instance the use of roofs. Farm business types are small and the focus is on 'local for local'. There are hardly any large and intensive farms. Often farms are involved in both horticulture (vegetable gardens) and cattle (various animals) to have manure. Cooperatives are formed as a way to survive and combine resources in the most efficient way. The need for human capital and resources is traditional and basic (crafts). Food supply is scarce, natural, mostly organic and there are few new technologies developed for food production. Older technologies are still in use, with the exception of some that demand too much expensive energy or have been replaced by cheap labour from immigrants. The demand for food is modest and based on necessities. Sources of risks such as poisoning or other critical incidents are tracked and traced within the farming system. Trust in the producer is built directly between farmer and consumer, based on close relationships. The threat of poverty due to bankruptcy or loss of reputation through diseases in the community makes sure that the production processes are carefully handled. Risk management is important in this scenario and addresses uncertainties with unknown probabilities. The dominant focus on farming creates strategic space for new innovative ideas within the community and between communities through knowledge circulation. Innovation is oriented on reinventions in new formulas, adapted to the new environment.

Political

National and European governance is restricted to a few politicians and policy makers. The institutions have become fragmented. Focus is on facilitating the local communities (as well as possible). Umbrella governance is oriented on control and setting rules to prevent communities from clashing. Political leaders depend on their own wisdom or they are experienced managers using their local network often guided by knowledgeable advisors (professors). China's economy is leading and therefor a very powerful nation. European public budgets are restricted which does not lead to robust institutions.

Agriculture policy is renationalised as a sector linked to local food distribution systems. Farmers set their own rules for their small production and distribution business but are restricted by some rules and legal frameworks within the economic and political context (in order to prevent chaos). The main political topic is bio-scarcity and division of resources, and avoiding further widening of the gap between supply and demand. Food security comes first, food safety next.

Technological

There is a downfall of technological development. Because resources are scarce (except labour), technology is expensive. The focus is more on repairing old technologies instead of fabricating and inventing new ones. Those who have access to technology and the Internet profit most and are able to further educate and develop themselves. The communities depend on those who chose to stay and rebuild the economy, others chose to go to China, which is the land of opportunities, to live 'the Chinese dream'. Remittances are for some regions an important source of money.

Social

Partly owing to the streams of refugees, the population in Europe grows, leading to most people living in cities. Social relationships are focused on families and neighbours (they are your best friends). Communication mainly takes place face-to-face, although there are local internets where social platforms support social interaction. The global Internet has broken down into different versions. People's happiness is based on living in (relative) peace and freedom. Their lifestyle is oriented on the survival of their families and self-provision of basic necessities. Medicines are scarce and herbs have become popular. This leads to the search for finding and inventing new types of medicines and food, such as insects that are considered to be a nutritious diet for proteins. Agriculture supports social work such as the operationalisation of care farms for thieves, not for punishment but to work on the land to avoid further downfall ('agriculture as a hobby to work').

6.5.2 Impact on AKIS

AKIS work with a 'must reach all' interaction, as agriculture now is essential for everyone. The focus is on small group-learning processes. Farmers are the pivot in the food chain and enjoy a high social status. AKIS are very important but fragmented and locally organised. As nearly everyone works in agriculture or connected sectors (including herbs for medicines), AKIS have a large target group. This group is divided in three types of jobs: land managers, technologists and knowledge workers. The focus in the AKIS lies on the primary production process, resources such as soil and water and food safety issues due to, for example, animal diseases. AKIS are characterised as problem oriented. Much (previous) knowledge on agriculture was lost due to less access to Internet and digital sources. There is need for 'knowledge caretaking' a.k.a. restructuring AKIS to avoid (further) knowledge losses. Good absorption capacity is viewed as important for survival. The first priority is on regaining basic skills with help of information from elders (the grandparents). One learns though trial and error. There is strong community thinking. The agricultural sector and actors exist in local networks that differ within the EU because of nationalisation on the one hand and the work in small communities on the other. AKIS are struggling to address the variety in society within the different communities. It is a challenge to make use of the potential of new ways of farming. An important working method is stimulating community thinking and access to variable ways and branches of agriculture. English is no longer the dominant language; knowledge is communicated in different community languages and dialects.

Technology, knowledge and innovation

Innovation is characterised by urban and ecological farming. Europe depends on China which controls genetics, ICT and big data. Innovation agendas are set by individual communities. Projects are often supported through charity and philanthropic organisations. Donors can be very decisive in allocation of AKIS resources. Projects are conducted through small groups and individuals in communities working on new entries and ideas for farming. Agriculture has cross-overs with other industries to further develop urban farming, farming and city development. Integration with health science and research becomes more important, such as new plants and food as medicines. Knowledge development happens on a small scale and mostly concerns private R&D. Research and innovation topics include technological development for farming, food security, optimisation and food safety in relation to food composition (nutrition) and usage. AKIS facilitate combining research results and the dissemination of results to a wider public, connecting people through applied solutions. Public-private research is facilitated through foreign (e.g. Chinese) research programmes ("Orient-ation 2060"). It concentrates on negotiating global deals with, for example, China and the USA on acquiring basic knowledge. Education and (vocational) training focus on hands-on information, agricultural basic skills and craft work. The best students are recruited for the student exchange programme quotas for China and India.

Knowledge organisations and actors

Universities suffer from reduced public funding as they struggle to exist and to avoid loss of relevance. Focus in science is on societal challenges regarding food security and climate change, especially adaptation scenarios. There are hardly any financial means left for scientific research, thus universities distinguish themselves in the quality of teaching, turning back to first-generation university types. There is more demand for applied research. Fundamental scientific research and know-how is obtained from China and India and through "knowledge archaeologists" that search for and dig up saved and left-over knowledge sources. Experimental farms cater for the needs of local farmers while advisors and agricultural coaches return to traditional extension workers to instruct farmers how to apply knowledge and innovate. There is a push to think about applied solutions led by many interests and individual competition. This leads to connecting actors in agriculture in networks. Innovative farmers are the head group of the peloton and distribute their skills and experience in local operational groups to facilitate colleagues. Donors (non-governmental organisations) and educated locals such as school teachers help to organise communities. The driver is to form a school (of 'fish') that together leads to a stronger local agricultural business, than individual farmer themselves. The demand for initial and post-initial education can be divided into three levels: 1) vocational for skills and craft work, 2) higher education for advice and extension work and 3) the academic level for scientific development, teaching and (applied) research.

6.6 AKIS in three scenarios: quo vadis?

The reader of these scenarios might be tempted to choose one of them as the most attractive. In the case of three scenarios like those described above, there could be a tendency to agree on a scenario that in some important aspects is in the centre, with the others being more extreme. However that is not the purpose of a scenario analysis. Scenarios represent external circumstances that are not under the influence of the decision maker, in this case the SCAR community. One could argue that the European Union could influence some of the developments that are important in the three scenarios, but reality in matters such as climate change, immigration, the future of the euro or the position of the UK or Greece in the EU, are not fully under control of the European Commission, the Council or the European Parliament.

Scenarios are not created to choose from, but to prepare for the situation that they might come true. Of course the scenarios will never become history in exactly the way they have been described here. But important elements of them (also in other combinations) might become reality faster than some of us would wish or dare to think. Scenarios should be evaluated on the question if they contribute to a strategic conversation: what do we to do now, to make AKIS more robust for these futures, how can we make them future-proof? To support this discussion, Table 6.1 summarises the way AKIS is organised and governed in the three scenarios.

Table 6.1: Organisation of AKIS in the three scenarios

Characterisations	HighTech	Self-organisation	Collapse
Economic			
Geographical economic scale	Stronger internationalisation and more specialised orientation.	Stronger regionalism and more general orientation. Community oriented.	Stronger individualism and holistic orientation. Clan oriented.
Financial	Large scale private R&D. Private industry does not compensate reduced public R&D. IPR (intellectual property rights) provides funding.	Mix public-private. Farmers pay for advice and new actors in AKIS. Linked to regional governance. Stress by rapid change "everybody is challenged".	Small scale private R&D, some local awareness building. Increasing urban farming. Individual but increasing community thinking. Often tribal (family/area).
Role of consumer (feedback)	Consumer: indifferent in product choice; "it is all far away anyway" but issue management via NGOs.	Consumer: co-creation and incident oriented "problem-by-problem".	Consumer: food first, no big quality issues. Essentials first (like animal disease research).
Language used	English	Multi-linguistic actors and projects as connectors	Local
Political			
Governance	AKIS centralised and privatised. No independent public funding.	AKIS decentralised and diverse (public-private collaboration).	AKIS fragmented and local (farm/food driven). Very specific and localised AKIS.
Government role and policy	Minor role of government, private multi-national business models dominate. Guerrilla type of resistance	Government active on community level, mixed public-private orientation and regional public finance. Grass-root	More local groups and individuals: fragmentation and "many internets". Rising status and importance of the

	('non-corporate AKIS').	research and innovation.	agricultural sector in policy making.
Agenda setting	Agenda set by business.	Agenda set by communities.	Agenda set by individuals and donors.
Organisation of food safety	Trust: monitored by large companies. Certifications and global institutions important.	Trust in civil society is high via transparency: "arguments count, not positions".	Trust: about rebuilding institutions. Short distances Government fragments are important and influential.
Technology, knowledge and innovation			
Driver for innovation	International competition.	Regions in both competition and collaboration.	Individuals and small groups searching for new entries and ideas to farming.
Risks in innovation	Risk: Danger of exclusion (closeness) and controlled access. "Access for the few".	Risk: much "muddling through" and sense of "nothing is gonna change". Reduced capacity AKIS.	Risk: outside control of ICT (China). "Local survival of the strongest".
AKIS skills / type of competences	"Up-skilling" through the need for specialised knowledge and skills in international networks and consulting: "network research".	"Multi-skills", efficiency, territorial and value competition. Community representation, "peer consultation".	"Basic-skills", problem oriented towards the basics as food, soil and water.
Basic educational orientation / profession of farmer	Technologists, not land managers.	Land managers, not technologists.	Technology and land management.
Domain of AKIS	AKIS go for non-food (bio-boom).	AKIS go diverse – increasing in numbers.	AKIS go for more community thinking: access to variety. Food only: bio-scarcity.
Internationalisation	Connecting the globe: centralised research; dominance by a few large companies.	Connecting regions, decentralised research.	Connecting people through applied solutions.
Focus of AKIS	Global food chains and flows. Strongly	Adaptations in the regional setting	Food composition (nutrition) and

	product oriented.	(cooperatives). Strongly farm system oriented.	usage.
Tools in AKIS	Global tools and benchmarks, economic efficiency and labelling; thematic cross-overs. IPR is important.	Demonstrations and regional network tools, institutional efficiency (best practices).	"Must reach all" interaction; small group learning processes; trial and error.
European research programmes	Large PPP between EC and multinationals dominate (such as in Future Internet PPP and Bio-based PPP). JPI and KIC survive, ERAnets disappear (no national funding).	Very differentiated landscape of AKIS across Europe. Need to link them, but difficult to find good instruments. Role of EU becomes less important. Probably most influential in basic science and in research infrastructures.	Not relevant, as EU is hardly relevant. Concentration on negotiating global deals on acquiring basic knowledge. Recruitment of the best students for the student exchange programme quota for China.
Cross-overs with other industries	Important (see ICT and Bio-based PPP). More beta science than social science. Strong specialisation in disciplines. Technology becomes more important than (traditional) agricultural research.	Multidisciplinary. Need for (traditional) agricultural research in combination with other disciplines. Technology / beta science is important, in combination with social science.	Urban farming, attention for farming and city development. Health science / research becomes important (new plants / food as medicines).
Knowledge organisations and actors			
University	Direct contact on research and education programmes with companies. Silicon Valley model. Innovation is part of the mission and business model (patents etc.): third-generation university (teaching, research and innovation). Students from all over the world through MOOCs and TEDx's. Only a few, big Life Science universities in Europe. Campus with research stations.	Many regional universities that collaborate and specialise second-generation universities (both teaching and research).	Struggle to exist and stay relevant due to reduced public funding. Focus on the societal challenges of food security and climate change. Less money for research, focus on teaching. Back to first-generation university (teaching).

Applied research	Moves into (applied) *universities*. Companies find it more attractive to deal with universities. Public support declines.	Moves into applied (higher) *education*. Life-long learning hubs. More intertwined with experimental farms and advisory service.	Relatively important over fundamental research. Gets part of its basic know-how from fundamental research in China and India.
Farm research stations	Public funding ends. Collective funding via levy / commodity boards ends; some are saved by big farms.	Networked in a research infrastructure and on campus with education. Farmer field schools and on farm research.	Cater for the needs of local farmers.
Advisory service	Advice stays but becomes a service provided by multi-national food companies and input industry, and their computer-generated advice. Public extension disappears. Some consultancies with certified independent consultants and coaches (facilitators).	Mix of public extension service and commercial advisory organisations. Linked with applied research and higher education.	Para-professionals act as the traditional extension-worker that gives instruction on low-risk practices. Could be part-time farmers or local problem-solvers like teachers. Extreme big role of donors.
Operational groups / interactive innovation	Less relevant as innovation is more top down driven.	The challenge is to organise multi-knowledge networks that integrate education and training.	Innovative farmers contribute to local innovation.
Education	More scientific. Gap between lower education and academic level. Higher education under threat. Emphasis on in-company training on the John Deere University.	International exchange programs and minor programs are important. Both initial and post-initial training. Focus on lifelong learning.	Higher education for advisors. Focus is on skills and crafts.

To make the AKIS more robust for the three scenarios[109], the SCAR strategic working group AKIS identified the following actions that could contribute to more resilience of AKIS at European, national and regional levels:

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[109] The scenarios might also be used to programme research or promote innovations on certain topics that are very relevant for one or more scenarios (such as permaculture in the Collapse scenario or

Research on ICT, and especially its governance. The role of ICT and how information systems are used and governed is an important aspect in the three scenarios. The differences between the scenarios High-Tech and Self-organisation is even mainly based on the way ICT is used and data are owned and shared in society. This underscores the message from chapter 4 in this report, that there is a need to investigate the governance of data exchange and where needed to create neutral platforms on which farmers, SMEs, consumers and others share data.

Cross-overs between agriculture and themes such as ICT but also other sectors in the bioeconomy (including chemistry, energy, logistics and waste management) are a direct consequence of the importance of ICT as well as the bioeconomy (see section 5.1 on the bioeconomy foresight). Design studies (for an era where totally new products are possible with genetics, ICT, nanotechnology, and richer consumers have new desires) with the creative sector are an interesting sector too.

Such work on cross-overs will influence AKIS themselves in the sense that AKIS need collaborative and absorption competences to run cross-over research and innovation programmes. Collaborative competences refer to capacities in AKIS to find partners in other sectors and to cooperate successfully with them. Absorption competences refer to being able to apply research and innovation results from other sectors in agriculture. Such competences should not only be available in the universities, institutes and research stations that carry out R&D or are active in innovation, but certainly also at the level of programming and financing. This is not new. In the 7th framework programme and Horizon 2020 DG RTD and DG Connect have experience in running generic ICT-programmes that include projects for application in specific sectors including agriculture and food. Some EU Member States have specific programmes that target cross-over innovation.

Big Data is a development that not only will influence agriculture but also science, research and development and innovation processes in AKIS. This goes much deeper than open access and linked open data sets in science. Especially methods and incentive mechanisms for farmers and consumers to share their data real time with researchers deserve attention (see also chapter 5 on E-science). Where the past is characterised by doing research on data from one experimental farm or only a sample of farms (such as in the FADN) that results in one advice for everybody, the future is characterised by doing research on data of all farms, real time, that results in individually customised advice for individual farms. That also further blurs borders in AKIS between research and advice.

In designing such methods and incentive mechanisms for sharing data it should be realised that the governance mechanism of data platforms and the attitude of farmers and consumers on sharing data with research is very different in a HighTech scenario than in a Self-organisation scenario. Early positive successes in this area could also influence the developments that lead to the different scenarios.

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the functioning of cooperatives and the role of trust in the Self-Organisation scenario). As research programming is not the objective of this report, this is not pursued here with the exception of a few issues such as ICT, social science and cross-overs that also heavily influence how AKIS are organised.

Social sciences, including economics, are an important discipline, not to be neglected in programming research. The bioeconomy foresight calls for more attention to business and policy models, the socio-cultural dimensions and the governance and the political economy of the bioeconomy. ICT as well as the challenges of the transition towards one of the different scenarios (or a mix of them) underpins this need too. This should partly have a reflexive character that helps actors in the transition by monitoring and evaluation (in the sense of a learning process).

This implies that not only challenge-based, agricultural research and innovation should have work packages for social sciences (and be multi-disciplinary), but that there should also be some basic programmes on social sciences where agriculture and food is a case to study new ways of governance, public administration, political economy etc.

Interactive, transdisciplinary innovation as well as transdisciplinary research and development processes should be strengthened in the AKIS. Using 'innovation in the wild' that reflects local needs and circumstances and the competences of an educated, creative population in a diverse European society is essential in the scenarios Self-organisation and Collapse. But also in the scenario HighTech it is useful that people can adapt to centrally-developed innovations. The developments in ICT with easier data exchange and communication channels between farmers and research make interactive innovation easier and more likely. New rewarding and assessment systems in research and innovation are needed to foster this type of innovation, and would contribute to some of the other actions in this list too.

Public-private partnerships in research and innovation for agriculture should be tried out. In scenarios like HighTech and Self-organisation these will be more used than in today's world. In agricultural policy (for example on sustainability) and in innovation processes around specific agricultural products, farmers do not want different incentives from food companies and government that are hard to integrate into one management decision. They want synergies so that for instance part of the cost of sustainability measures (such as ecological focus areas) can be paid for by a certified niche product of their chain partner, and the rest by a CAP premium. In a similar way they benefit if innovation on such topics is coordinated. Via levy boards (commodity boards) many countries have a long tradition of public-private partnerships and the same is true for DG RTD in the ICT areas. Some sectors are taking initiatives to coordinate research and innovation (such as the Animal Task Force). This could be a fertile soil to experiment with public-private partnerships at a European level. In designing such programmes it is important not only to connect with, for example, the seven largest sugar beet or dairy companies (which fits in the HighTech scenario), but also make space for SME to collaborate in such programmes. This not only would fit in the Self-organisation scenario, but in many industries part of the innovation is done by SMEs (be it start-ups, spin-outs from universities or small support companies from, for example, ICT or design) that are in a later successful stage bought by multinationals to realise global growth. This means that also multinationals have an incentive to include SMEs in such innovation programmes, with respect for their limited possibilities to contribute to financing them. In addition, also NGOs (such as the WWF or Greenpeace) should be invited to take part in such partnerships as they often act as change agents in public issues such as sustainability.

Involvement of regional authorities and cities in research and innovation in agriculture and the food system should also be tried out. These authorities should not only be participants (beneficiaries) in the programme but also contribute to its funding, not unlike in joint programming initiatives. Experience in this type of collaboration is relevant for the futures that are described in the Self-organisation and Collapse scenarios. Topics such as healthy food for children, food and aging, malnutrition, short supply chains in relation to the current retail infrastructure and mobility issues, peri-urban farming (multifunctional services around the city), urban farming, vertical farming etc. are just some of those that might interest cities that, like London, Amsterdam, Barcelona and Göteborg, have a food-related policy agenda.

Excellent Research Infrastructures are relevant in all three scenarios. In several scientific areas Europe has created common research infrastructures (RI) under the guidance of the European Strategic Forum for Research Infrastructures (ESFRI). Originally these were centrally-located hard infrastructures that were too expensive for a Member State (such as the collider of CERN in Geneva), but RI's are now also soft (for example databases and standards or protocols), distributed and virtual and include for instance blood banks and DNA data for health research. Until now the concept has not been taken up in agriculture and food (with the exception of a recent proposal to start a DISH-RI on food choice and food intake by consumers, linked to body status and health). The scenario analysis on AKIS suggests however that the idea might make sense. In the HighTech scenario it is probably the multinational industry that links and coordinates innovation programmes in farm research stations and applied research in the different regions to develop and test new seeds, analyse big data, investigate cropping rotations or no-tillage etc. In the Self-organisation scenario the regional specialisation and relatively low regional budgets make European research infrastructures as a coordination mechanism interesting. It could be easier to exploit together a research infrastructure as a platform in which regional AKIS partners could collaborate and compete, than to organise joint programming where regions have to contribute financially and then a central committee decides what happens. It is the difference between subscribing to a service and paying a levy. In a Collapse scenario the fast climate change implies that it could be beneficial to have some mechanisms where know-how on innovation in farming moves from one region to another, as cultivars and pests migrate.

International collaboration with partners from other continents is attractive in several scenarios, however for very different reasons. In the HighTech scenario companies in the input industries and food processing and retail dominate on a global scale. That makes it useful to collaborate with other global powers on standards (IPR, food safety, data exchange), basic science and regulating the industry. Top universities that work with these companies in innovation as well as being a place for recruiting the managers of the companies will also adopt a global perspective. It makes sense to support some European universities to develop themselves in a global leadership position. This also makes Europe a more attractive place for headquarters and research laboratories of those multinational companies. In the Collapse scenario the drivers of international collaboration are quite different. Collaboration with Africa and the Middle-East moves from altruistic motives to targeted actions to combat effects of climate change and reduce migration. With China and India, who in that scenario invest heavily in basic research and are investors in European agriculture and the food industry, the motive is collaboration in and access to basic research. Whatever the future looks like, these potential developments make it attractive to invest in more joint programming of research at the global level. The USA, Africa, China and India are attractive partners, although that should not rule out others, like Brazil.

A real **European Research Area** is a prerequisite for many of the actions suggested above. With the European Innovation Partnership (EIP) for agricultural productivity and sustainability in Horizon 2020 and the CAP, this research area is becoming a bit more advanced. The EIP includes processes in which farmers become aware of (applied) research done elsewhere in the EU. Multinational farmers' cooperatives (nearly 50 cooperatives have members in more than one EU Member State, and others are also active cross borders) and input industries working in many countries also contribute to integration. The Erasmus programme helps too, now also farm advisors are active in exchange programmes. Farmers that are more mobile, and for example use the Internet or visit international agricultural fairs such as the DLG fairs in Hannover or the SIMA in Paris, also become more aware of what research and innovations are carried out elsewhere in Europe.

Nevertheless the ERA is still a patchwork that leaves much to be desired. A small (but on the European level not unneglectable) part of it functions as a market with tenders for research in which players have very different 'business models' with which they compete and collaborate. Some research institutes for example function as a not-for-profit company that have a full cost pricing model, while others are hardly motivated by money or receive considerable 'state aid'. A large part of the ERA also functions nationally or regionally as part of the administration (often in an agency at arm's length of the central government) under political governance without much incentives, other than curiosity, to collaborate and specialise. Or it is a local market in which a small number of universities compete. Especially this national or regional part is in many regions confronted with large budget cuts. This not only reduces the amount of research but also hampers the hiring of new, young staff, often one of the mechanisms how applied research takes up new ideas from basic science. Or, like in extension, public functions lose from private organisations. It is hard to see how this optimally contributes to the challenges of the bioeconomy and developments in ICT (other than that it makes the HighTech scenario more likely). It also reinforces the need for common research infrastructures as a platform in which a European market could function.

A starting point for this action would be to have a much more informed discussion in Europe on the need for a real European Research Area and how it should look like and function. In this respect it does not help that the current system is not well understood. Fortunately in recent years the AKIS has been much better studied, not only by this strategic working group but also in European projects such as Solinsa, FarmPath, Pro-AKIS and Impresa. The role of education in the ERA is still unclear, and probably undervalued seeing the trend towards life-long learning. One of the next steps might be to try to understand the European Research Area, and its potential futures, better by modelling the area. Research projects that try to understand the functioning and resilience of food chains could probably include or be inspirational for new projects on trying to understand in more detail the functioning of the ERA. New techniques such as agent based modelling and interactive serious games might help. This would also help to carry out an impact assessment of the action points we propose as an insight from our foresight resulting in the three scenarios HighTech, Self-organisation and Collapse.

6.7 REFERENCES

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7 INTERACTION WITH AND GOVERNANCE OF INCREASINGLY PLURALISTIC AKIS: A CHANGING ROLE FOR ADVISORY SERVICES

By Ulrike Knuth and Andrea Knierim

7.1 Introduction

Privatisation and commercialisation in agricultural advisory systems have been ongoing processes for over 30 years now. One could question whether the public sector should still play a key role in such systems. The expected benefits of privatisation are greater efficiency of service provision in terms of costs and resource allocation, increased provider accountability, a demand-driven elaboration of contents, and an emphasis on benefits and results. Competition is assumed to ensure constant improvement in the quality and diversification of goods (Klerkx *et al*., 2006).

Nevertheless, the implications of privatising or commercialising advisory services are described as (1) the tendency toward a reduction of linkages both among organisations and among farmers in the exchange of agricultural and other relevant information; (2) the tendency to enhance advice for large-scale farms and to emphasise less on small-scale or less commercial farming; (3) the advancement of knowledge as a saleable commodity which makes it prone to interest biases of the advisor[110] (Rivera and Cary, 1997) and (4) the diminishing emphasis on public-good information regarding for example environmental issues, mostly dealt with in a rather short-term perspective (Labarthe, 2009; Klerkx *et al*., 2006). Still recently it was confirmed that knowledge gaps exist for example with regard to the effectiveness of advisory services for agri-ecological practices (OECD, 2015). And there are also a number of farmer groups that are not reached by these advisory services. For example, regarding small-scale or less commercial farmers, Labarthe and Laurent (2013) point out that "the dismantling of coordinating authorities has made these farms less visible as a target client and that less direct interaction with advisors makes it more difficult to co-produce knowledge that is relevant to small farms' needs. Back-office activities have been restructured in a way which does not serve small farms' needs".

In practice, diversity in the provision of advice is a fact; different providers are required for different clienteles, with public providers and funding focusing more on smaller-scale and less commercial farmers. Supporting farmers to find their way around the multiplicity of sources and information is crucial (Garforth *et al*., 2003; Feder *et al*., 2011). Therefore, researchers that have analysed the change processes in advisory systems clearly state that the government should continue to fund some provision of advice and information and play a key role in governing and coordinating AKIS and integrated advisory services, because there are significant market failures in the supply of and demand for advice and information (Garforth *et al*., 2003; Rivera and Cary, 1997).

The EU FP7-funded research project PRO-AKIS (www.proakis.eu) aimed at providing such a situational analysis of agricultural advisory services on EU-level and to answer the following question: How and from what sources can farmers

[110] We refer to 'private advisory services' as independent entrepreneurial organisations or individuals while advice provided as a co-service of a commercial transaction (e.g. provided by input industries etc.) is not considered here.

get reliable and relevant knowledge, orientation and support to continuously evolve, to successfully solve problems and to respond to external expectations and development opportunities? The PRO-AKIS focus was to investigate the agricultural advisory services across Europe within the context of AKIS. Besides an inventory of the current AKIS institutions and interactions in the EU Member States, PRO-AKIS used a case study approach to investigate the challenges of today's pluralistic AKIS: i) small-scale farmers' access to relevant and reliable knowledge, ii) bridging scientific research topics and farmers' demands and iii) offering appropriate support for diverse rural actors that form networks around innovations in agriculture and rural areas.

The PRO AKIS inventory revealed that the European AKIS are increasingly gaining an institutional diversity and that, notably, advisory services are provided by manifold different organisations. This organisational heterogeneity (public or private sector, farmer-based or civil society organisations) results in a diminishing importance of classical, well-established interaction and ways of communication. Moreover, there is a growing necessity to develop new horizontal and vertical linkages and frequently to coordinate knowledge flows beside purposeful steering and government activities.

Against this background, the findings of PRO-AKIS, in particular the case studies and related synthesis reports, are being systematically analysed, enriched with material from stakeholder involvement through synthesis seminars, workshops and the final conference with the goal to identify challenges and emerging tasks that derive from this increasing diversity for public administration. In the following text, policy recommendations on the role of the government and support to multi-actor innovation networks are proposed. An early version of these recommendations was presented in the SWG AKIS workshop in Antwerpen, Belgium (March 2015) and thoroughly discussed there in breakout groups. Additionally they were discussed and further developed within the PRO-AKIS project work repeatedly. The discussion results from both working processes were used by the authors to develop the recommendations presented in the following, which regard the role and responsibilities of public administration (section 7.2) and further focus on how to design, maintain and implement innovation networks (section 7.3). The recommendations are, where suitable, illustrated by PRO-AKIS examples, and further literature is reviewed and discussed. The chapter ends with some short conclusions (7.4).

7.2 Roles of public administration in governing increasingly pluralistic AKIS

Rivera and Cary (1997) speak of a "key role of the public sector and […] its responsibility as a coordinating agent". But what are the respective tasks of such a key role? The following questions of Rivera and Cary (1997, p. 10) help to define these tasks: Whether and to what extent should the public sector:

"(i) Attend targeted audiences unserved by the private sector? (ii) Coordinate multiple extension providers? (iii) Serve as the final reference or arbitrator of conflicting information? (iv) Assure accountability of both public and private extension services to the public? and (v) Facilitate the operation of the complex [of extension services] through regulation and information provision?".

Answers are manifold and have to be derived from individual country's situational analyses and institutionally adapted solutions, instead of formula like "one fits all" because, as Garforth *et al*. (2003, p. 332) reason, "[…] sustainable rural communities and economies are more likely to emerge from creative processes of identifying problems and opportunities, and developing strategies for dealing with them, than from the implementation of a package of measures developed by others".

The following sections describe the necessity for AKIS diagnoses and possibilities for its implementation (section 7.2.1), discuss as well as give examples on how much and what kind of public advisory infrastructure is needed (7.2.2), show the added value of monitoring and evaluation activities (7.2.3) and point out opportunities for promoting professionalism and quality management of agricultural advisory services (7.2.4).

7.2.1 Conducting AKIS diagnoses

Public authorities and coordinating bodies concerned with agricultural advisory systems may use and promote the AKIS concept as a diagnostic tool for public actors at national and regional level; suitable competencies and methodologies should be acquired.

The PRO-AKIS inventory revealed that the AKIS concept is appropriate to guide systematically the characterisation of infrastructures and coordinating mechanisms, supporting the analysis of system integration and fragmentation (Knierim *et al*., 2015). PRO-AKIS case studies exposed gaps between public advisors and public research or experimental stations (Bayern/Germany, Bulgaria), public advisors and private consultants (Bayern/Germany), public research and private consultants (Brandenburg/Germany) or demonstration farms and public advisors (Poland). Case studies often concluded that increasing interaction between AKIS actors could substantially improve knowledge exchange and innovation capacities of a region – and showed in this way the usefulness of an AKIS diagnosis.

A (regular) AKIS diagnosis, especially if done in a participatory way, has the potential to increase interaction in a region between knowledge producers, providers and users and therefore enhance participation in and capacities for innovation projects, such as aimed at within the EIP framework. Additionally, such diagnoses have the potential to ground targeted governmental interventions to support cooperation between farmers, advisors, scientists and other actors of AKIS in solving problems. Addressing more specifically the level of Rural Development Programme (RDP) decision making, policy makers will find an AKIS diagnosis appropriate to identify and describe the relevant actors (education, research, advisory services, public and private knowledge providers and users etc.) for a certain agricultural topic/sector, to recognise strengths and weaknesses of the AKIS and to search for gaps and missing interactions among actors and understand influence and power relationships. Special attention should be paid to the divergent knowledge needs of farm-level actors according to, for example, farm size, gender, education level or professional orientation.

A possible start and participatory approach to an AKIS diagnosis could be a regional 'AKIS conference' inviting concerned and interested AKIS actors to exchange information about their own organisations' activities as well as to discuss and collect views on the functioning of the regional AKIS with regard to the innovation capacities of farm managers. Relevant actors should include the private and the public sector as well as actors from non-governmental and farmer-based organisations either from the agricultural sector in general or from single branches (horticulture, pig production etc.) or orientations (e.g. organic, conventional integrated farming etc.). A well-established methodological approach for a participatory AKIS diagnosis is the 'Rapid Appraisal of Agricultural Knowledge Systems' (RAAKS), which was developed in 1990s by the

Wageningen University and tested in many different agricultural extension contexts (FAO, 2015). RAAKS consists of the following three phases: 1) problem identification, 2) constraints and opportunities and 3) action planning; and it aims at “improving the problem solving capacity of stakeholders through improved communication and joint learning” (Salomon and Engel, 1997). The framework of Birner *et al*. (2009), recently adapted by OECD (2015) for evaluating ‘green growth initiatives in agriculture’, provides an analytical concept for an AKIS, ‘entangling’ advisory services into governance structures, capacities, management and advisory services. It further points out related contextual factors that are relevant for the design and development of national or regional AKIS, such as the policy environment or the market access of farm households.

7.2.2 How much and what kind of public advisory service infrastructure?

Public authorities need to provide advisory services’ infrastructure or public support of private independent advisory services particularly regarding public goods topics and less favoured groups of farmers.

Forms of organisation and financing of an agricultural advisory system within a region are manifold and diverse. The scheme of Rivera (1996) distinguishing between ‘who delivers and who funds’ is helpful to have a quick overview of aspects of institutional design for advisory services. The PRO-AKIS case studies revealed the on-going commercialisation trend and the growing diversity of actors in this field. When distinguishing between private and public as well as farmer-based organisations (FBO) and NGO service providers (according to Birner *et al*., 2009), diverging goals for the provision of advisory services within these organisations can be expected. This often leads into a lack of adequate services for specific groups of farmers, e.g. small-scale or resource-poor farmers as important actors in rural development. Furthermore, services that sensitise farmers for environmental topics such as water and nutrient management or biodiversity are often not profitable for private providers, for example because the number of potential clients is too small (Rivera and Cary, 1997; Labarthe, 2009; Klerkx *et al*., 2006).

The case studies conducted in PRO-AKIS show different levels of responsibility taken up by public authorities for such advisory tasks. For example, in Scotland a mix of public, private commercial and non-governmental actors is involved in the provision of advice, with strong governmental intervention (Prager and Thomson, 2014). The ‘monitor farms programme’ appears to be a successful farmer-led and government-supported programme to enhance farm development which integrates a broad range of rural actors from all sectors private, public, NGO, FBO) (Creaney *et al*., 2014). On the other hand, in Brandenburg, Germany, only private advisory companies exist without any public advisory infrastructure or public regional support, for example for building up such networks as monitor farms. Existing innovation networks, which are funded by federal public research funds, fulfil gaps only for a short time, missing a long-term perspective for ongoing interaction within this regional AKIS (Boenning and Knierim, 2014) and sustainability issues in agriculture are not addressed by private advisors (Knuth and Knierim, 2013).

A variety of options exists for publically funding advisory services, ranging from traditional advisory service provision by public bodies, policy-induced rural networks (c.f. section 7.2), maintenance of experimental stations and monitor farms, to providing financial support for farmers to use private advisory services (voucher systems, incentivised extension programmes). What is appropriate in a regional context can be very different and research and evaluation of the manifold mechanisms for intervention are limited. A case study from Ireland reports on the one hand that rewarding farmers' participation in extension programmes encourages participation, especially with cohorts of farmers that previously eschewed such programmes (Läpple and Hennessy, 2014). On the other hand, an additional study showed that farmers who joined the discussion group of the extension programme before the financial incentive significantly improved their farm performance, as measured in gross margins and yields, while farmers who joined after the financial incentive was introduced did not significantly improve their farm performance after the extension programme. This led the authors of the study to question the financial usefulness of rewarding farmers for participating in extension programmes (Läpple and Hennessy, 2015). The evaluation of a complex government-funded support service for 'Nutrient Management' in the Netherlands questioned some of the conceptual and practical assumptions of such interventions and proposed that it may be more effective and efficient for governments to build more permanent institutions to facilitate the development of the agricultural knowledge market than to invest into voucher systems (Klerkx *et al*., 2006).

Such more permanent institutions can be public organisations or publicly funded networks, which act as platforms of knowledge exchange, coordinating multiple suppliers of advisory services, research and education institutions and other AKIS actors. Feder *et al*., (2011, p. 31) speak of a need for "some regulatory oversight of private-sector extension activities, particularly when public funding is involved". A rather simple example for such 'oversight' is the provision and updating of a list of (certified) advisors in a region that also provides information on the scope of the service providers' work. Another option is a web-based platform on farming policy and subsidy-related information for farmers and advisors. More participatory, interactive approaches are related to events that support the AKIS diagnosis mentioned earlier. To integrate private advisors in such events merits specific attention as this needs a certain level of trust and a cooperative relationship between public authorities and advisors in order to motivate for a form of participation that has no direct influence on the advisors' income.

Public funding is also required to ensure knowledge flows between research and farmers (especially small-scale and resource-poor farmers). If "Business as usual" research activities such as state-financed field trials are endangered by reducing the budget, one base for qualified region-specific agricultural advice disappears. Publicly investing in regionally-applied agricultural research is crucial, but without access for all (public and private) advisors to publically funded research results, knowledge flows and innovation processes in a region are hindered. A good way to support interaction between research, advisors and other actors of a pluralistic AKIS is to publicly support co-location of different public and private organisations. One example for such an infrastructural support are the topic-related competence centres in Lower Saxony, Germany (here on grasslands and on organic farming), which allow for the exchange and establishment of linkages in an informal way. Furthermore, such centres could also be a way to better connect education and advice providers in a given region.

7.2.3 Monitoring and evaluation of advisory systems

Systematic evaluation and monitoring of advisory services need to be encouraged by public authorities in order to make comparisons of different advisory systems possible.

The PRO-AKIS inventory revealed a great diversity of AKIS in Europe, where a comparative view and aggregation was not easily possible, and concluded that there are insufficient data available to assess the impact of advisory services (for example, who has access to what services, outcomes of advisory service provision). Similar evidence is observed for the OECD countries: "Available evaluation studies are largely qualitative, mainly focused on 'snapshot' evidence and often based on small numbers of participants, interviews and surveys (OECD 2015, p.7). This is particularly problematic in a context of rapid and fundamental structural changes in AKIS. Hence, the here recommended AKIS perspective should not only aim to evaluate and assess knowledge infrastructures but also include monitoring activities on information exchange and 'knowledge flows' in order to observe and acknowledge the performance of interaction processes.

As an AKIS diagnosis is a single analytical step at a certain moment, monitoring and evaluation is meant as a public responsibility to be fulfilled repeatedly. It becomes increasingly important as advisory services and innovation activities receive more and more attention within Rural Development Programmes (RDP). Monitoring of advisory services may include the observation of both the demand and the supply side of the advisory market, particularly if more private than public actors determine the system. Information collected by public authorities could include which actors are out there on the market, which topics are covered, where are gaps or topics which are covered or not by the existing services, and the effectiveness of advisory service related policy instruments and coordination initiatives. It could further include observations regarding in how far the various groups of farmers can access services, as e.g. by Läpple and Hennessy (2014) for Ireland. It is also important to check within the regular evaluations of RDP how far these programmes have changed existing AKIS infrastructures and, vice versa, how far AKIS infrastructures provide the necessary conditions for certain RDP measures.

Structural funding for regular monitoring activities or result-oriented support for single evaluation activities provided by public administration at European or national level could enhance monitoring and evaluation activities in respective regions and improve the availability of sufficient data. These data could then be also used for targeted comparative assessments of AKIS components between and within most European countries, enabling regions / Member States to learn from each other, without pushing a "one size fits all" approach.

7.2.4 Towards transparency and quality management in the agricultural advisory 'market'

Transparency about quality of advisory services needs to be enhanced and support for training, education and acknowledgement procedures of advisors is recommended.

The diversity of public and private advisory service providers as well as the funding opportunities for advisory services in the rural development measures have led to the development of selection procedures and/or accreditation schemes for advisors. Certification schemes – mostly for single advisors and their organisation - are developed by public authorities, defining minimum standards (e.g. infrastructure, educational level, professional experience) in order to approve for participation in public extension programmes. There are many different ways to certify or choose advisors for public-funded services, but comparative exploration and evaluation of existing certification schemes is yet missing. For public authorities it could be helpful to invest in monitoring and evaluation and comparative research on selection procedures and accreditation schemes for advisors in order to obtain transparency about the degree of competition in the advisory market. A common instrument of professional organisations to assure a certain quality of services is the certification. Advantages of such a tool would be that a comparable standard of service provision can be assumed and by this a certain transparency within the market is created so that farmers get a better overview. Also, advisors disposing of such a certificate could expect a comparatively higher pay for their services.

However, with regard to agricultural advice there is yet no widely accepted, overarching certification scheme in the EU. Along with the increasing pluralism in advisory systems, a number of professional associations have emerged in recent decades which concentrate their activities on the enhancement of advisors' competences, networking and knowledge exchange. Among them, one of the oldest associations is the German speaking "International academy of rural advisors" (IALB), founded in 1961 (www.ialb.org). Annual organisational meetings mainly focus on the exchange of trainers, of experience, the atonement of educational issues, benchmarking and accordingly on the cooperation in education and counselling. Another one is the European Federation of Agricultural Consultancy (EFAC), an independent association of professional agricultural consultancy organisations in Europe, focussing on tax, financial, legal and economic advice (www.efac.net). The most recent organisation at the European level is the European forum for agricultural and rural advisory services (EUFRAS) (www.eufras.eu).

Regarding competence enhancement and certification of advisors, IALB developed the competence development standard CECRA (Certificate for European Consultants in Rural Areas) (www.cecra.net) which would – if widely adopted – serve as a quality certification. As it stems from a professional organisation across German-speaking countries, mostly Swiss, Austrian and German organisations are involved as providers of training. However, since just recently, EUFRAS started to take a coordinating role in rural advisor qualification and certification in Europe by joining CECRA, a broader dissemination and adoption of the scheme has become more likely. Also, the new CAP fosters the discussion and awareness creation in this regard as it allows for the funding of advisory services on the basis of competitive procedures. In Germany, some authorities take (selected) CECRA standards as benchmarks for approving advisors for public funded extension within the new CAP. Summarising, public authorities should not hesitate to seek transparency or make acknowledgement procedures and standards of advisors a topic of discussion.

7.3 Public support for rural multi-actor innovation networks

Network structures have gained increasing attention for enhancing innovation capacities in a region or in a certain sector (Weyer, 2008; World Bank, 2012). Interactive innovation projects, namely operational groups, are the core element for funding under the policy scheme of the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP) and its related measures in the EAFRD and the Horizon 2020 research programme of the EU. Operational Groups are a particular format, since they focus on concrete objectives of end-users, on the engagement of various actors as co-creators of solutions, and intend to generate co-ownership and outcomes that are ready for practice application.

When looking at existing innovation networks, engaging various stakeholders, it becomes obvious how diverse they can be. There are policy-induced networks that focus on research and development of something new. Other funded networks rather focus on knowledge exchange and learning without having in mind to develop an innovation but rather stimulate innovative capacities of farmers or demonstrate the implementation of a new approach, e.g. in networks of demonstration or monitor farms. Then, there are also networks that are an association focussing on institutionalised cooperation and interaction with regard to a certain topic or interest, often not funded by public money, but through membership fees. Furthermore, the term 'network' is being used synonymously for many different forms of groups working together, such as group consulting, transdisciplinary research project groups or political interest groups and more.

PRO-AKIS has studied in depth five quite diverse networks regarding funding, actor composition and content in order to find out about which features of the networks enhance farmers' ability to co-innovate in cooperation with other actors. These case studies highlight a diverse range of multi-actor learning and innovation networks in agriculture and rural areas respecting their structure, content and dynamics (Boenning and Knierim 2014; Caggiano, 2014; Creaney *et al*., 2014; Madureira *et al*., 2014).

Synthesising the PRO-AKIS case studies, it can be concluded that rural multi-actor innovation networks are a successful tool for advisory services, as they "are actually able to deliver advisory services within innovative formats that overcome some of the limitations of the conventional advisory systems. They enable multi-topical advice, enhance the farmers' role as creators, co-creators and converters of knowledge, and reduce the distances (geographical and cognitive) between farmers and other actors, such as researchers and experts" (Madureira *et al*., 2015, p.13).

Therefore, rural multi-actor networks should be understood as complementary to classical advisory services, as they are capable of increasing interactions within a regional AKIS, especially in 'weak' AKIS with low levels of interaction or public AKIS infrastructures. When policy makers decide to invest in 'networking' in a rural region by designing policies to initiate new networks, special attention needs to be paid to several different aspects. In the following sections, selected insights from the PRO-AKIS case studies are used to highlight appropriate public authorities' activities regarding the initiation phase and the actor composition of innovation networks, the potential role of advisory services and the communication within and the funding of such networks.

7.3.1 Building up rural multi-actor innovation networks

Publicly induced multi-actor innovation networks in rural areas should be open to the diversity of knowledge providers and stakeholders in a region. Topics should be drawn from problems, challenges and opportunities as perceived by farmers.

Ideally, networks are initiated bottom-up and find their own ways of funding. In case of policy-induced innovation networks tailored around projects, which produce new solutions to certain problems or aim to enhance the capacities of farmers to change practices, PRO-AKIS observed that it is crucial to draw the networks' topics and issues from the problems of the farmers. Topics addressed by such networks, which are relevant to the farmers, have to be seen as a key feature for participation (Madureira *et al*., 2015). The farmers are therefore better to be integrated early into the process of designing such networks. For a successful cooperation between diverse actors, in particular scientists and farmers, questions need to be formulated together in the beginning. This requires an 'open attitude' for ideas expressed on both sides, in particular to overcome personal interests; being willing to consider different ideas an innovation potential is challenging but essential to the success of such programmes (Creaney *et al*., 2014). Another way to ensure a common understanding is to search for participants as in the way of one innovation network studied by PRO-AKIS: "For complementing the list of practical partners, the university professor looked for farmers in the relevant regions who had finished agricultural studies at his university", thus assuming a common language and an easy understanding with new cooperation partners (Boenning and Knierim, 2014, p.15).

'Diversity of knowledge providers' as used above means that all actors (no matter if they are a public, private or charitable organisation) have a chance to participate, if they have relevant knowledge and competences for the topic of the network. 'Multi actor' should therefore not be limited to the agricultural background or only farming or research, but all actors in a rural landscape or concerned by the issue should be involved. Not all actor groups (research, education, farmers, NGOs) need to participate in every network; the composition depends on the topic. This is a principle already in use in the EIP framework and the PRO-AKIS case studies have found similar well working constellations. For example, the Scottish monitor farms programme shows how the interaction of the farmers (as the core actors) is enhanced by integrating further actors into the group meetings such as private advisors and scientists as well as industry partners.

When designing rural multi-actor innovation networks, special attention needs to be paid to the composition of the network and the risk of large established players 'taking over' and pushing their interest to the disadvantage of less powerful actors. The government could act as a transparency-creating and levelling force and filter out risk in the beginning by creating conditions so that everybody has an equal chance to participate. Characteristics such as (farm-level) resources, especially economic power, but also gender roles and the belonging to certain socio-demographic groups may be taken into account in order to avoid power asymmetries in a network. Besides the mentioned conditions in the beginning, along the working process a good internal and external communication strategy is needed.

7.3.2 *Collective learning processes, facilitation and trust within the network*

Collective learning processes are crucial for enhancing innovation capacities of actors in a network. Successful networks leave time and space for social concerns as trust-building activity, and ensure the fulfilment of different roles and functions, most importantly the facilitation role.

A mixture of different methods during meetings including demonstrations, invited talks, field trials and intensive, facilitated discussions are essential to achieve collective learning processes. Meetings on a regular basis provide repeated opportunities to experience changes in farm practice and learn about farm improvement as a result of changes. Both characteristics could be observed in the monitor farm networks and have resulted in high participation rates:

"A key motivation […] is the social aspect to the monitor farm network, which contributes to boosting participation rates, overcoming farmer isolation, as well as building new, and reinforcing existing, connections between farmers in a local area, both on a personal and business level. [The participants] benefit from the opportunity to share struggles, questions, ideas and solutions, while also benefitting from a type of informal *benchmarking through participation*" (Creaney *et al*., 2014).

Fulfilment of the facilitation role is quite important and the facilitator of an innovation network or project needs to have specific competences to steer the processes of levelling different interests and managing the innovation process. A so-called innovation broker can help during the preparation phase to connect relevant actors to initiate an innovation project. Batterink *et al*. (2010) speak of "orchestrating innovation networks" and describe the following three functions to be fulfilled by an innovation broker: i) innovation initiation, ii) network composition, iii) and innovation process management. They further provide best practice examples of innovation brokers from four in-depth case studies in the Netherlands, Germany and France.

Innovation process management should also include that network actors continuously re-interpret the context in which they move. "This constant reflection […] needs to be supported by dedicated facilitators and monitoring and evaluation methods aimed at system learning. This implies, that agricultural innovation policies should, instead of aiming to fully plan and control innovation, foster the emergence of such flexible support instruments that enable adaptive innovation management" (Klerkx *et al*., 2010). Theoretical frameworks could be used as foundations for designing communication processes of innovation networks – either as a funder, participant or facilitator. Regarding the levelling of different interests, Tisenkopfs *et al*. (2014) point out the importance of issue framing and relationship framing and give suggestions how to facilitate such learning processes. They identify actor roles and methods that help agricultural networks to frame issues of common interest, deal with divergent interests collaboratively and align network members for concerted action. Sol *et al*. (2013, p.35) propose a theoretical framework for social learning, in which "trust, commitment and reframing are interrelated aspects and emergent properties in the process of social learning". Public or private advisory service providers of a region should be able to take up the following functions in networks: clarifying knowledge needs of farmers; sharing (brokering) of information (also outside the network), facilitating connections among actors; promoting learning and dissemination; translating data, information or knowledge into lay terms and monitoring network success.

Trust among actors is a main driver for enrolment and successful learning and innovation in a multi-actor network. Network events that include overnight stays, the opportunity to join dinner or other informal social interaction encourage trust among participants. Knowing each other before a project or a network starts is also a resource for trust, as in the case of the policy-induced innovation network in Brandenburg studied by PRO-AKIS. This revealed "a network of numerous personal relationships among individual project participants that date back before and go beyond the project. Those longer-term relationships contributed arguably to the high level of trust and cooperation in the network" (Boenning and Knierim, 2014, p.22).

The other side of such personal relationships beforehand is the danger of having a 'closed shop' as a network, where new or not-yet-known actors in the field are excluded. This should in particular be avoided when networks and their projects are funded by public money. Public support instead needs to enhance the inclusion of less voiced groups such as less skilled small-scale or 'less powerful on the market' farmers (e.g. social farming or farms from less powerful agricultural subsectors) and simultaneously support the participation of pioneer farmers which can contribute to the networks cohesiveness. A 'nursery period' (e.g. of six months) as suggested by some interviewees in the Scottish programme could be a helpful 'stepping stone' into the project. It could be used as a trust-building phase and aims to increase productivity during the formal project period, overcoming a lack of familiarity among all involved in the project and clarifying expectations of participants beforehand (Creaney *et al*., 2014).

7.3.3 Public financial support of networks

Providing financial support for rural multi-actor networks merits specific attention from an institutional perspective.

Networks can be used to fill gaps in national or regional AKIS resulting from structural weaknesses, but funded networks should be rather output-oriented; networks should not be funded because they are networks, but because of the added value of their project (i.e. a set of targeted activities rather than structures). This has implications for the interaction and cooperation dynamics between the actors involved, as project funding tends to strengthen production of outputs, and in some cases at the expense of relationship development.

The structure of funding schemes will impact the composition of actors and content. Funding of networks risks i) channelling funding to large established players, excluding smaller, less powerful players and ii) supporting 'closed shops', if the interaction with the broader audience and the transfer of generated knowledge is not an integrated goal of the network. Advisors can play an important role in reaching such goals by taking up functions in networks such as clarifying the knowledge needs of farmers; sharing (brokering) of information (also outside the network), facilitating connections among actors; promoting learning and dissemination; translating data, information or knowledge into lay terms and monitoring network success. But taking into account the pluralism of existing advisory service providers and the growing share of private advisors, who often operate on a fee for service basis only, specific attention needs to be paid on how to reach them and motivate them to be part of innovation networks. The case of the innovation network in Brandenburg shows that especially independent private advisors are not easily part of such networks and have to overcome a number of hindrances before becoming engaged[111] (Boenning and Knierim, 2014).

The question how sustainable a policy-induced network is or rather should be, becomes an increasing important question. All policy-induced networks have a certain 'life span' in which they are funded. Continuing the cooperation between the actors in new projects might be reasonable with regard to the project content, but new funding is not always accessible. Hence, continuing supports may be necessary, particularly for newly-formed networks. Ongoing support should be based on monitoring and evaluation of respective networks. National entities should take over the responsibility for monitoring and assessing the success (including inclusivity) of publicly supported networks. However, it always depends on the network's project goals and content. In the case of the Scottish monitor farms, part of the networks' success was new contacts between farmers in the community and therefore it could be observed: "whilst a more

[111] Private advisors in Brandenburg repeatedly argued, that time is a scarce source and participation in research networks is not income-relevant for them. Rewarding their participation out of the project budget might be one solution, but is contradictory to public advisors, who might participate because it is part of their work description.

structured, self-organized discussion group is unlikely to follow the formal monitor farm programme without facilitation support, the interviewees express hope that informal farmer collaboration will continue, in terms of information and knowledge exchange, building on the links established by the monitor farm network" (Creaney *et al*. 2014, p.37).

7.4 Summary and conclusions

Summarising, it can be concluded that although *pluralism* in AKIS as well as in advisory services is increasing and the size of public advisory services is diminished, public authorities have a range of responsibilities and many options for action. Their roles are changing and becoming more diverse towards governance of AKIS, creation of transparency, enhancement of linkages, targeting of public support according to public interests and quality assurance.

To govern AKIS successfully, public authorities should adopt the AKIS concept as an analytical and conceptual tool and need to develop new competences to conduct AKIS diagnoses in cooperation with relevant public, private and charitable AKIS actors in a region. Successful methodologies such as RAAKS exist. Conducting AKIS diagnoses as well as encouraging monitoring and evaluation of funded innovation networks, advisory services and interactions within a given region are the key responsibilities in governing pluralistic AKIS. The results of such analytical processes can be used to develop new or improve existing policies, in particular regarding advisory services within Rural Development Programmes or other funding schemes. Mechanisms for organising and funding advisory services for public goods issues need to be further analysed in a comparative way regarding their effectiveness. Current open questions for designing suitable policies for advisory services, which consider the ongoing societal changes in rural areas, are associated with mechanisms for public calls for funded advisory services and related criteria for the selection procedure.

Farmers in pluralistic AKIS need support for "finding their way around" among the diverse public and private providers of advice. Creating transparency and steering the competition between private independent advisory service providers is therefore the responsibility to be fulfilled by public authorities. Transparency about and (some) assurance of quality of advice providers can be created by supporting monitoring and evaluation measures and certification initiatives for advisory services. Within multi-actor innovation networks, public authorities can adopt different roles – they can be a powerful driver through the offer of financial incentives and the provision of infrastructures, an institutionalised facilitator of a network's process or a sole partner as any other. However, in whatever role public authorities are engaged, it is their task to create awareness for societal objectives and the maintenance of public goods as well as to support farming competitiveness and avoid land abandonment, and to enhance the integration of the diverse farmer groups into rural development processes.

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8 EPILOGUE

“Are AKIS fit for the future” is a question that has often been raised in the last ten years. In the background was in some cases a discussion on the future of agriculture (e.g. more or less multi-functional or specialised) and the role of AKIS in that reorientation, or a discussion on the ability of AKIS to deliver innovation and bridge the gap between scientific knowledge and practical challenges. But also discussions on the role of a public service versus advice to farmers from private organisations and the ability of AKIS to adapt to new challenges contributed to the question if AKIS are fit for the future.

In recent years more knowledge has been gained on the actual organisation and performance of the AKIS, especially in innovation, also thanks to several EU projects such as Solinsa, FarmPath, PRO-AKIS and Impresa. This knowledge has informed the discussion on the fitness of AKIS towards the future, but not fully answered the questions.

In this third report of the SCAR’s strategic working group AKIS, we have explicitly looked to the future, to contribute to discussions on the development of AKIS. Where the SCAR’s fourth Foresight exercise investigated the role of primary production in the bioeconomy and what this means for the programming and organisation of research and innovation, we decided to look to additional issues that could be relevant for the future of AKIS. Seen the fast development of ICT and its disruptive character in several parts of society, we have given this topic much attention. Chapter 4 explored the opportunities for ICT in agriculture, while chapter 5 focused on e-science. We also looked (in chapter 3) to the options for more integration between agricultural research (for Europe) and agricultural research for development (overseas) and the role of the government in governing the AKIS and supporting multi-actor innovation projects in chapter 7.

These developments were used in a scenario-analysis on the potential trends in agriculture up to 2050: High Tech, Self-Organisation and Collapse. For each of the scenarios we described the general and agricultural characteristics. This description then led to an analyses of the implications for AKIS towards 2030. We thereby reflected upon the possible implications for technology, knowledge and innovation on the one hand and knowledge organisations and actors on the other. The aim of our analysis was not to select a preferred scenario, but to understand what drives them and what actions would be needed to make the current AKIS more fit for the future.

8.1 Main recommendations

Given the fact that the future of agriculture and food production, including the way it is organised, is expected to be very different from the current situation, it seems fair to conclude that the AKIS from the past are not fit for the future. The challenges ahead demand a serious reflection upon the role of actors within the AKIS, the interaction between subsystems and with other themes, AKIS policies etc. From the analysis in the report we therefore make the following recommendations with regard to AKIS organisation and research and innovation policies. The purpose of the analysis was not to identify research topics but nevertheless we list two research related issues that were identified[112].

AKIS organisation

Public authorities have a range of responsibilities and many options for action when it comes to organisation and governance of AKIS. Their roles are changing and becoming more diverse towards governance of AKIS, creation of transparency, enhancement of linkages, targeting of public support according to public interests and quality transparency and assurance. The AKIS concept can be an analytical and conceptual tool for AKIS diagnoses in cooperation with relevant public, private and charitable AKIS actors in a region.

Farmers in pluralistic AKIS need support for "finding their way around" among the diverse public and private providers of advice. Creating transparency and supporting synergies and complementarities among advisory service providers, both public and private, is necessary. Transparency about and an indication of the focus and quality of advice providers can be created by supporting monitoring and evaluation measures and certification initiatives for advisory services. Improving linkages between existing advisory channels and targeted permanent training for advisors could be a step forward.

Big Data and other ICT developments will not only influence agriculture but also science, research and development and innovation processes in the AKIS. This goes much deeper than open access and linked open data sets in science. Where the past is characterised by doing research on data from one experimental farm or only a sample of farms (like in the FADN) that results into one set of advice for everybody, the future is characterised by doing research on data of all farms, in real time, that results in individually customised advice for individual farms. That blurs borders in AKIS between research and advice and advisors will need continuous training on these developments.

Agriculture should not be treated as an isolated entity, but AKIS should identify cross-overs with ICT, the food sector and the other sectors in the bioeconomy (such as chemistry, energy, logistics and waste management). Policies should stimulated such cross-overs. Such work on cross-overs will influence the AKIS itself in the sense that AKIS need collaborative and absorption competences to run cross-over research and innovation programmes. In the rural area also links with civil society and local administrations are important. Policy incentives for multi-actor groups and projects should focus on targeted inclusion of such cross-overs.

More efforts are needed to enhance explicit links between the knowledge system and the education system. It is important that children and students obtain the required basic knowledge and that therefore teachers have up-to-date knowledge on the practice and up-to-date scientific results. Future professionals should also learn and train the skills needed for managing participatory processes. In the education and permanent training of researchers and advisors, more attention is needed for the competences to be successful in multi-actor, systemic and transdisciplinary approaches.

[112] See chapter 6 for more details

Policy framework for AKIS governance

Research funding should not be limited to traditional approaches but should also facilitate cross-overs to other research fields, interactive, transdisciplinary innovation and transdisciplinary research and development processes. Using 'innovation in the wild' that reflects local needs and circumstances and the competences of an educated, creative population in a diverse European society is essential. Funding and research initiatives should seek interaction with the beneficiaries (in the broadest sense) for successful research and innovation programmes. New bottom-up models have to be designed and technology has to be adapted and sometimes redesigned to target diverse implementation levels and reach desired outcomes.

Public – Private Partnerships in research and innovation programmes for agriculture should be further explored. Many equipment companies and food processing companies are or could be involved in the AKIS, which asks for private-public partnerships in which the government focusses on the public issues at stake. A framework is needed that deals with the diversity of companies (from multinationals to SMEs). In particular the involvement of regional authorities and cities in research and innovation in agriculture and the food system should also be tried out. Governments should take responsibility for the public issues at stake in such partnerships and ensure that publicly funded knowledge is publicly accessible.

Excellent Research Infrastructures are relevant in the future. In several scientific areas Europe has created common Research Infrastructures, under the guidance of the European Strategic Forum for Research Infrastructures (ESFRI). Until now the concept has not been taken up in agriculture and food, although it could be an interesting approach to link facilities, including experimental sites, demonstration farms, on-farm research and soft infrastructure such as data networks or benchmarking of particular issues.

International collaboration with international partners (other continents) is attractive for very different reasons. The USA, Africa, China and India are attractive partners, although that should not rule out others like Brazil. Some of the developing countries (such as in East Africa) are digital pioneers in mobile banking and extension, implying that this is an area where Agricultural Research and Agricultural Research for Development could reinforce each other. Situations where European companies source from developing countries (e.g. cocoa) or sell inputs are another area for collaboration. This requires however a more unified and coherent thinking between different policies like agricultural science policy, international cooperation and trade policy.

A real European Research Area is a prerequisite for many of the actions suggested above. In the future, there will remain a need to better connect research programmes. With the European Innovation Partnership (EIP) for agricultural productivity and sustainability in Horizon 2020 and the CAP, this research area is becoming a little more advanced. The EIP includes processes in which farmers become aware of (applied) research done elsewhere in the EU. Multi-national farmers' cooperatives (nearly 50 cooperatives have members in more than one EU Member State, and others are also active cross borders) and input industries working in many countries also contribute to integration. Nevertheless the ERA is still a patchwork that leaves much to be desired. A starting point for this action would be to have a much more informed discussion in Europe on the need for a real European Research Area and how it should look like and function, with level playing fields for the players. Also bottom-up targeted efforts in specific sectors or on specific issues (e.g. the Horizon2020 Thematic networks and EIP networking) could contribute to a real European Research Area and need dedicated reflexion and further development in this regard.

Research is not the only instrument the government has to stimulate innovation. Open data, stimulating exchange of practical knowledge, regulation, support of start-ups and innovative procurement are some of the others.

Two specific research topics that emerged

Research on ICT including E-Science, and especially its governance and interoperability, is needed. The role of ICT and how information systems are used and governed is an important characteristic of the future. There is a need to investigate data ownership, the governance of data-exchange with common standards (interoperability) and, where needed, to create neutral platforms on which farmers, SME, consumers and others share data. Semantic technology can furthermore help in bridging the divide.

Social sciences, including economics, are an important discipline, not to be neglected in programming research. This includes more attention to business and policy models, design thinking (creative industry), the socio-cultural dimensions and the governance and the political economy of the bioeconomy. Besides some specific projects in these areas, these disciplines should make many projects more multi-disciplinary.

8.2 Towards AKIS-4

Although many topics and issues have been addressed in the first three AKIS mandates, the groups' dynamics, newly emerging topics and the further development of the EIP and a European AKIS structure advocate for a continuation of the SWG AKIS under a fourth mandate. In this context six specific activities are proposed for SCAR AKIS4:

(1) **Improve the integrated approach within the European AKIS and the Implementation of the EIP**. Emphasize on the connections/links between H2020 projects and OGs (and among H2020 project - especially Thematic Networks - and among OGs) and the regional and national dimension. Incentivize implementation of the interactive innovation model of the EIP AGRI through other funding mechanisms and programs at national and regional level.

A. Complementarity and synergies among funds (H2020-EAFRD-EFRD-ESF-Education). Identify good examples with experiences in the MS and Regions as well as bottlenecks and barriers. Develop pathways to improve the governance and its communication/Implementation. Small study and a few experts. (With DG REGIO & DG R&I).

   Deliverable: Best practices /policy recommendation for a synergistic approach of the EU and national funds within the EU AKIS.

B. Thematic interconnection and collection of expertise of interactive innovation projects at different levels

Deliverable: Inventory and communication about similar processes and groups (themes, approaches) at national and regional level.

C. AKIS supporting Infrastructures (Synergies between research infrastructure and facilities). Explore possible infrastructures and bottom-up initiatives which improve knowledge exchange between innovation projects within the food/non-food supply chain and linking to practice. Search for connections and interlinkages beyond borders.

   Deliverable: Policy recommendation for a more efficient use of infrastructures (including ERDF and other opportunities) in the Agri-food/bioeconomy sectors including ICT and Open Data Bases Infrastructures.

D. Further development of the EIP approach through mechanisms to collect practice needs, broaden communication of relevant info towards practitioners, design of peer review, stimulating interaction with EUFRAS, civil society and stakeholder engagement, etc.

   Deliverable: Communication on EIP (education/training content) to be communicated through the EIP-AGRI Service Point.

(2) **Learning and feedback from interactive projects approaches (multi-actors projects, thematic networks, operational groups).** Analysis and potential further development of the projects scheme/paradigms. Based on the previous experiences (arisen through the first H2020 projects) and AKIS group discussions, greater synergies and complementarities with other funds should be foreseen for boosting interactive approach and its potential evolution (rewarding mechanisms).

Deliverable: Insights for potential developments of these projects approaches (should be finalized before mid- 2017). Seek for interactions with the H2020 mid-term evaluation.

(3) **Better address the knowledge flows along the whole production/value/supply chain** in the AKIS for the future. Better address the vertical and horizontal relations through e.g. the application of the concept of Net Chain Analysis (Agrifood sector **-** Small chains – Food City -Urban farming policies).

Deliverable: Reflection on more "integrated" approach along the value chain.

(4) **Cross-fertilization with other EIPs and sectors:** identification and evaluation of experiences from other EIPs (Water, Raw materials, Bio-Economies, ICT, Health, Aeronautics, etc.) and other sectors not related for boosting and improving the AKIS.

Deliverable: Improved methodology (tools) fostering and boosting the Innovation processes.

(5) Analyzing **the perspective of AKIS in Food and Nutrition Security and Sustainable Agriculture across developing countries**. Based on the interactive innovation approach, explore (successful) experiences from other countries that could be scaled up and investigate how to

influence the research agendas. Small study and expertise needed, jointly with SCAR SWG ARCH and GFRAS.

Deliverable: mobilize the SCAR CSA to produce a paper on Multi-actor approach and dynamics in developing countries. Develop the interactive innovation model in this context through (pilot) activities and explore synergies with e.g. PRIMA, ARIM-NET II and H2020 - SFS-42-2016 Topic.

(6) **Monitoring interactive innovation policies and benchmarking for sustainability:** relevant input is expected in the coming period from MS EIP implementation and monitoring processes, from the **OECD country reports**, from the EIP evaluation study, from the FG benchmarking and from big data initiatives. This material can be collected and structured in a small study. On the basis of this, the SWG AKIS can analyze and discuss trends and evaluation systems and Try to formulate indicators for interactive innovation in collaboration with OECD.

Deliverable: policy recommendations to monitoring innovation processes and instruments.

ANNEX 1 - METHODOLOGY FORESIGHT AKIS

Introduction

Through its long-term focus, foresight is an excellent instrument for public research planning and public policy building. Foresight conclusions and recommendations have in the past been used by the European Commission in planning research coordination activities.

Scenarios represent external circumstances that are not under the influence of the decision maker, in this case the SCAR community. One could argue that the European Union could influence some of the developments that are important in the three scenarios, but in reality dossiers such as climate change, immigration, the future of the euro or the position of the UK or Greece in the EU are not fully under control of the European Commission, the Council or the European Parliament. Scenarios are not created to choose from, but to prepare for the situation that they might come true. Scenarios should be evaluated on the question if they contribute to a strategic conversation: "What are we to do now to make AKIS more robust for these futures? How can we make it future-proof?" The methodology for the scenario building was based on a basic version of Scenario Planning as used in business, originally developed at Shell (Van der Heijden, 2004) because of the recognition of uncertainties and identification of changes to stimulate adaptive policy management. The following six steps were conducted: 1) decide drivers for change and the assumptions, 2) bring drivers together into a viable framework, 3) produce 7-9 initial mini-scenarios, 4) reduce to 2-3 scenarios, 5) draft the scenarios and 6) identify the issues arising.

This process was carried out within the SCAR AKIS Strategic Working Group, as will be described in the remaining parts of this Annex. In addition, interactions of the Foresight Expert Group appointed by the EC with the SCAR Strategic and Collaborative Working Groups (including the SWG AKIS) and sectorial analytical documents have provided valuable input.

Step 1:Decide drivers for change and the assumptions

The scenario study was based on the Horizon Scan 2050 by the Netherlands Study Centre for Technology Trends (STT, 2014). That study made an inventory of "signals for change" (hereafter: drivers) for future changes in five categories: 1) societal, 2) technological, 3) ecological, 4) economic and 5) political. About 41 drivers from these lists were selected for the purpose of the AKIS-foresight as having a relevance for AKIS in Europe: eight in each domain and nine in the economic domain.

In a workshop of the SWG AKIS-3 (Bari, Italy, September 2014), 18 additional drivers for the AKIS were added. This list of 59 drivers formed the basis for an Internet consultation. The consultation was sent out to all members of the AKIS SWG and the experts of the Bioeconomy Foresight group with the request to also forward the survey to relevant colleagues. The final list of drivers for change was as follows:

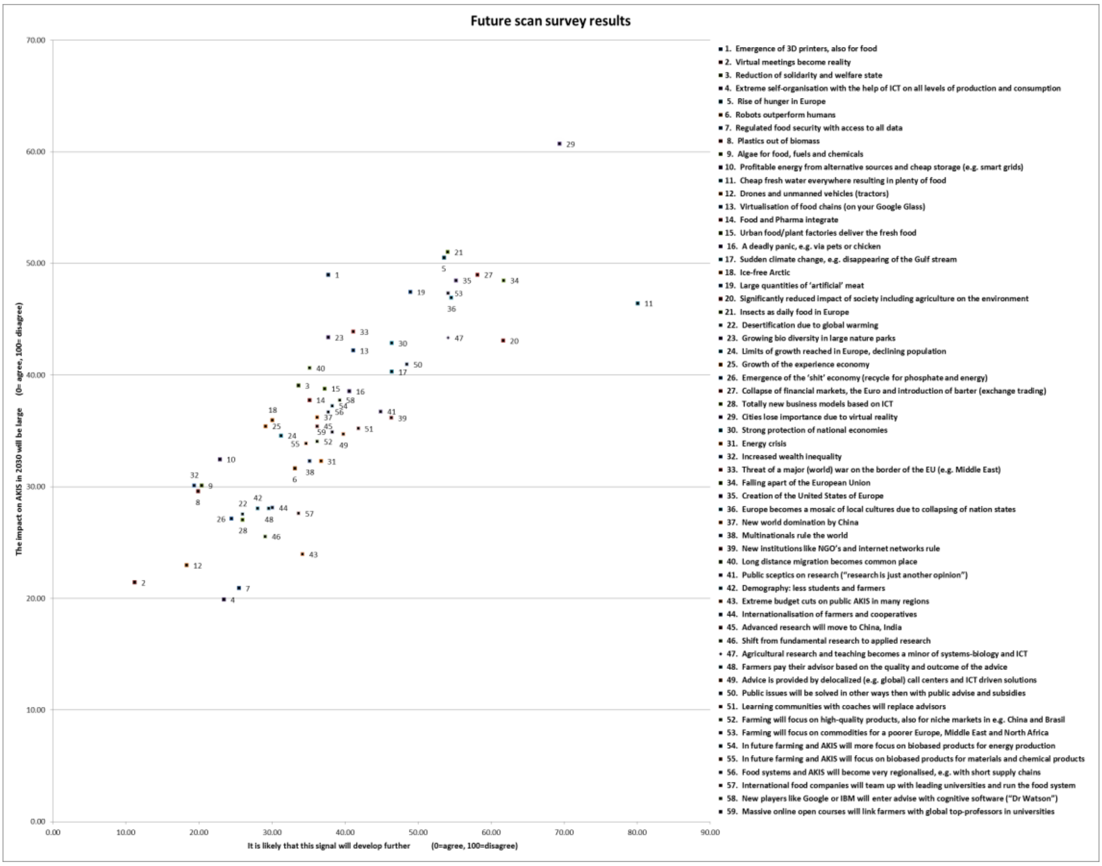
1	Emergence of 3D printers, also for food	31	Energy crisis
2	Virtual meetings become reality	32	Increased wealth inequality
3	Reduction of solidarity and the welfare state	33	Threat of a major (world) war on the border of the EU (e.g. Middle East)
4	Extreme self-organisation with the help of ICT on all levels of production and	34	Falling apart of the European Union

	consumption		
5	Rise of hunger in Europe	35	Creation of the United States of Europe
6	Robots outperform humans	36	Europe becomes a mosaic of local cultures due to collapsing of nation states
7	Regulated food security with access to all data	37	New world domination by China
8	Plastics out of biomass	38	Multinationals rule the world
9	Algae for food, fuels and chemicals	39	New institutions such as NGOs and internet networks rule
10	Profitable energy from alternative sources and cheap storage (e.g. smart grids)	40	Long distance migration becomes common place
11	Cheap fresh water everywhere resulting in plenty of food	41	Public sceptics on research ("research is just another opinion")
12	Drones and unmanned vehicles (tractors)	42	Demography: fewer students and farmers
13	Virtualisation of food chains (on your Google Glass)	43	Extreme budget cuts on public AKIS in many regions
14	Food and Pharma integrate	44	Internationalisation of farmers and cooperatives
15	Urban food/plant factories deliver the fresh food	45	Advanced research will move to China, India
16	A deadly panic, e.g. via pets or chicken	46	Shift from fundamental research to applied research
17	Sudden climate change, e.g. disappearing of the Gulf Stream	47	Agricultural research and teaching become a minor of systems-biology and ICT, so nothing special
18	Ice-free Arctic	48	Farmers pay their advisor based on the quality and outcome of the advice
19	Large quantities of 'artificial' meat	49	Advice is provided by delocalised (e.g. global) call centres and ICT driven solutions
20	Significantly reduced impact of society including agriculture on the environment	50	Public issues (such as sustainability) will be solved in other ways (e.g. regulation) then with public advice and subsidies
21	Insects as daily food in Europe	51	Learning communities with coaches will replace advisors
22	Desertification due to global warming	52	Farming will focus on high-quality products, also for niche markets in e.g. China and Brazil
23	Growing biodiversity in large nature parks	53	Farming will focus on commodities for a poorer Europe, Middle East and North Africa
24	Limits of growth reached in Europe, declining population	54	Future farming and AKIS will more focus on bio-based products for energy production
25	Growth of the experience economy	55	Future farming and AKIS will more focus on bio-based products for materials and chemical products
26	Emergence of the 'shit' economy (recycle for phosphate and energy)	56	Food systems and AKIS will become very regionalised, e.g. with short supply chains
27	Collapse of financial markets, the Euro and introduction of barter (exchange trading)	57	International food companies will team up with some leading universities and run the food system including innovation and advice
28	Totally new business models based on ICT	58	New players such as Google or IBM will enter advice with cognitive software ("Dr Watson")
29	Cities lose importance due to virtual reality	59	Massive online open courses will link farmers with global top-professors in

			universities
30	Strong protection of national economies		

Step 2: Bring drivers together into a viable framework

In December 2014 and January 2015 more than 120 experts scored the drivers for change on relevance ("It is likely that this signal will develop further") and impact ("The impact on AKIS in 2030 will be large") in an Internet consultation. A five-point Likert scale (strongly agree, agree, neutral, disagree, strongly disagree) was used. The results of that survey are printed below:



In a two-day workshop organised for the SCAR strategic work group AKIS-3 (Antwerpen, Belgium, March 2015) with 30 participants (researchers, policy makers and advisors) representing ten EU Member States, these drivers were used to build scenarios.

Step 3: Produce 7-9 initial mini-scenarios

Interpreting the graph above, we identified a number of drivers of change that are very likely to happen and have a clear impact on AKIS. We also identified a group of drivers ("wild cards") that are unlikely to happen, but were they to happen, they would have a clear impact. During the first two work sessions, we brought the drivers into a framework, as some drivers will happen together / are connected (e.g. plenty of water, cheap energy, abundance of food, no need for innovation), while others are contrary to each other (e.g. strong United States of Europe and mosaic of regional cultures). This was done by asking the participants of the workshop to develop mini-scenarios. Split up in small groups (4-5 persons), the participants bundled the drivers into mini-scenarios. They were asked to present them as short stories to the other participants.

The following drivers that will certainly have an impact on AKIS were used:

- 2 Virtual meetings become reality
- 4 Extreme self-organisation with the help of ICT on all levels of production and consumption
- 7 Regulated food security with access to all data
- 12 Drones and unmanned vehicles (tractors)
- 43 Extreme budget cuts on public AKIS in many regions
- 46 Shift from fundamental research to applied research
- 28 Totally new business models based on ICT
- 22 Desertification due to global warming
- 42 Demography: fewer students and farmers
- 48 Farmers pay their advisor based on the quality and outcome of the advice
- 44 Internationalisation of farmers and cooperatives
- 57 International food companies will team up with some leading universities and run the food system including innovation and advice
- **Plastics out of biomass**
- **Algae for food, fuels and chemicals**
- 32 Increased wealth inequality
-

The wildcards (drivers unlikely to happen but with a large impact) were used in a second similar exercise. They are the following:

- 1 Emergence of 3D printers, also for food
- 21 Insects as daily food in Europe
- 5 Rise of hunger in Europe
- 19 Large quantities of 'artificial' meat
- 35 Creation of the United States of Europe
- 27 Collapse of financial markets, the euro and introduction of barter (exchange trading)
- 34 Falling apart of the European Union
- 53 Farming will focus on commodities for a poorer Europe, Middle East and North Africa

- 36 Europe becomes a mosaic of local cultures due to collapsing of nation states
- 47 Agricultural research and teaching becomes a minor of systems-biology and ICT, so nothing special
- 20 Significantly reduced impact of society including agriculture on the environment

Step 4: Reduction to two or three (or four) scenarios

The number of mini-scenarios detected and developed during the previous stage was reduced to two or three or four larger scenarios. The challenge in practice was to come down to finding just a few 'containers' into which all the topics can be sensibly fitted. This was done in the workshop in Antwerpen in a central discussion with the whole group. The contours of three scenarios appeared out of the discussion by grouping all the mini-scenarios in a relatively easy way.

Step 5: Draft the scenarios

The scenarios were drafted with more detail in small groups (randomly put together, different from the previous working groups). The groups then presented their results to the others in a plenary session. In the subsequent discussion, tables were the basis for Tables A, B and C.

After the Antwerpen meeting, Tables A, B and C were polished and completed by the authors of chapter 5. The Tables were the basis for writing the scenarios as reported in chapter 5. A decision was made to write the scenarios almost as a series of alternative essays about the future. This is useful as the stories carry many meanings (stories within the larger story) and they are almost inevitably of a qualitative nature. As such, a written text provides space for some elaboration of the thoughts involved.

Step 6: Identify issues arising

The final stage of the meeting in Antwerpen was to examine the scenarios to determine what the most critical outcomes are. Which 'issues' arise from the scenarios for the AKIS in the coming 20 years? This analysis was also carried out in small groups (4–5 persons) and reported in a general discussion. The discussion focussed on what has to be done in the AKIS to make them robust for the developments in the different scenarios and adjust to the new reality of a scenario. Discussions focussed on typical issues such as: ERAnets, the role of SCAR for other sectors, attention to (e-)research infrastructures, public-private programmes, interactive innovation, collaboration with ARD, attention in the public system for commercial farming etc.

The general discussion led to a basic version of Table D that was later elaborated and polished by the authors of chapter 5.

The overall output of the process (draft of chapter 5 and this Annex) was further discussed in a meeting of the SCAR strategic working group AKIS in Brussel in June 2015.

Table A: Drivers from the group work and plenary sessions (drivers and mini-scenarios)113

Drivers	High tech	Self-organisation	Collapse
Economical			
2: Virtual meetings become reality	Global interaction, private 'summits'.	Regional interaction.	Locally oriented interaction.
32: Increased wealth inequality	Hunger among the poor – luxury food for the rich. Problems with nutrition and food access.	Like current situation.	(Nearly) everybody is poor.
26: 'Shit economy' recycling	High tech biogas installations.	Biogas installations and manure.	Manure is scarce and replaces fertiliser.
44: Internationalisation of farmers and cooperatives	Global food chains. Farmers are integrated with multinationals on big scale and highly technological. Trustful information is centralised on few websites. Sales through far away markets, optimised logistics.	Regional food chains, connected through import and export. Quite widespread, more 'close to home' than 'far away' food production and processing. Focus on trust building between regions and businesses.	Not widespread, local production. There might be some form of external (outside EU) support, like development aid from China to Europe.
46: Shift from fundamental to applied research	Specialised research disciplines.	Deregulated approach and best practices (demos).	Intensified farmer-researcher interaction – assuming that there is still money for research.
48: Farmers pay advisor based on results	When the innovation has succeeded ('you only pay when the customer is satisfied').	In different regions advisory systems are differently organised: regions with a private advisory system on the one hand, regions with publicly paid advisors on the other.	Advisors are scarce and powerful. 'Any advice can be fruitful.'
57: Multi-nationals team up with universities and run	ICT for control, day-to-day advice and reporting. Private	Not really of importance.	Not relevant.

113 Boxes highlighted yellow show the issues most stressed in the discussion, others have been added to complete the scenarios.

the food system	AKIS "Amazon.com selling food".		
5: Rise of hunger in Europe	For certain groups in society (poor in urban regions).	For certain regions with poor endowments.	General situation due to climate change and/or collapse in trade.
27: Collapse of markets (no euro): exchange trading (barter)	Not relevant.	Mosaic of cultures. Much debate on social inequality and nutrition. Perhaps (re)introduction of regional currencies.	'Citizens turn rural'. Local knowledge becomes more important.
53: Farming will focus on commodities for a poorer Europe, Middle East and Africa	Could be, but more likely focus will be on European value added products for a rich world.	From certain regions with a high food supply.	Not likely, no export.

Drivers	High tech	Self-organisation	Collapse
Political			
4: Extreme self-organisation	More large multi-nationals. Complex organisational structures, focus on seasonal food production in different locations. Knowledge brokers are important.	Regional and community collaboration.	Individuals and small communities engaged in joint learning.
7. Regulated food security	Private regulation led by big companies. Trust organised by auditing and laboratories. Big data, "E-bay kicks out government."	Public regulation but organised through participative governance.	Private regulation led by farmers. Trust in the farmer you buy from locally.
43: Extreme public budget cuts	Big companies take control of knowledge exchange, limited access for others.	Reduced knowledge exchange, private companies do not compensate this loss.	Farmers pay advisors. Fragmented relationships.
34: EU falling apart	More influence from USA, China and Russia.	EU and national institutions and subsidies disappear and give way to the regions.	Local sovereignty. Rising hunger. Production for self-sufficiency.
36: Europe: a mosaic of local cultures due to collapse of nation states	More room for EU and multinational companies to operate.	Leading to regional governments (comparable to the Swiss system).	Joint local collaboration. Peer-to-peer consultancy.
20: Reduced impact of society on environment (role of AKIS)	Environmental issues disappear due to control of high tech solutions (precision farming).	The government is dominant in taking care of environmental issues.	Due to lower production, there is less impact on the environment.
35: United States of Europe	Public private summits (large companies).	'Europe of the Regions' (stronger role regions).	Fragmented Europe instead of united.
Technological			
8: Plastics out of biomass	BIOBOOM stands for a high demand growth and a high supply growth. This may happen in the case of slow alternative technologies and	The BIOMODESTY scenario foresees a modest growth in demand for biomass. Possible reasons are non-competitiveness of biobased solutions or fast	The BIO-SCARCITY scenario is built upon a high demand growth but low supply growth. The scenario may occur in the case of slow development of alternative

	competitive biobased technologies, limited resistance to new technologies and products or when Africa rises its production.	breakthroughs of alternative solutions (e.g. solar).	technologies and competitive biobased technologies, negative impact of climate change on supply or high public resistance to new technologies (such as GMO) to raise supply.
9: Algae in food, fuels and chemicals	See biomass (8).	See biomass (8).	See biomass (8).
12: Drones and unmanned vehicles	Very strong focus and large scale use.	Variable usage at regional and local level.	Used by some individual farmers and small groups.
28: Totally new business models based on ICT	Global game changer: "fridge tells you what to do".	Great diversity, space for opportunity seekers. New regional food webs. Much social media usage.	Intensive consumer-farmer interaction. Freedom for individual solutions.
1: Emerging 3-D printing food	Supported by retailers; the technology is (relatively) cheap and mainstream.	Specialist usage in health situations etc. Expensive technology.	Not relevant.
19: Artificial meat	Mainstream, easy to make at high volumes e.g. in out-of-home consumption.	Resistance to use in some regions / groups but some acceptance in others because of sustainability issues or with regard to low prices.	Not relevant.
47: Agricultural research is minor to system biology and ICT	Large companies recruit also from other than agro disciplines and have internal training programmes.	Regional specialisation based on cross-overs between disciplines become more important.	Not necessarily relevant.
Social			
42: Demography: fewer farmers and students	Fewer farmers due to large industrial holdings. Fewer students seems unlikely (see also 47).	Depends on the region.	"Everybody becomes a farmer".
22. Desertification due to global	Yes, but a surmountable problem through high tech production and shifts to other	Production shifts to other regions.	One of the reasons for collapse of the system.

warming	regions.		
21: Insects as daily food in EU	Discussions rise on health aspects of insects, solved by regulation and labelling. Gourmet insects on large scale. Insects are discussed in a technical context.	New groups, comparable with driver 19. Regional debates. Insects are discussed in a social context.	'Tribal' discussions. Survival is the essence: insects are eaten if necessary. Depends on local context.

Table B: General characterisations of the three scenarios

General characterisations	High tech	Self-organisation	Collapse
Animal logo	*Octopus*	*Bee hive*	*Lone wolf*
European country relatively close to this scenario	*The Netherlands*	*Italy*	*Kosovo*
Economics			
Socio-economic model	Comparable to America, approx. 5% (extremely) rich upper class, 75% middle and (much) lower class, 20% poverty.	Comparable to Europe. Difference in income rates is mostly visible between countries and regions.	Money has no real value anymore, barter and division of resources (necessities) are leading. Collapse of global trade.
Scale	Global	Regional	Local
Knowledge and innovation	Technological developments and commerce are more important than science. Science is dominated by the needs of the commercial sector. Patents are important.	Knowledge is a tool for decision making. Open innovation systems, political debates based on scientific arguments. Also competitive between regions.	Knowledge = power. Knowledge is limited to a few. Storytelling, mouth-to-mouth. Leaders are either wise or are coached by knowledgeable advisors.
Cooperatives	Develop into shareholder companies, coops go to the stock exchange.	Classical cooperatives: one person – one vote. Tool to market products.	Way to survive, consumer cooperatives and labour cooperatives.
Political			
Power	Commercial competition	De-central	Non-existing

Geopolitics: who leads?	California	EU	China, India, Nigeria
Public budget	Budget cuts	Public institutions have money	External help (development aid)
Responsibility for the environment	Shared between multinationals and NGOs such as Greenpeace who attack the reputation of companies such as McDonalds (labelling, certifications).	Regional governments but many public-private covenants.	'Nature itself'. Also local people and (fragments) of governments. Direct feedback from consumers to farmers.
Risk management	Centrally shared, contracts, future markets, insurance.	Regional shared, through community based agreements.	Individual do-it-yourself (present everywhere).
Technological			
ICT- technology	Control (NSA)	Democratic / social media (WIKI)	Regional
Importance	High use of technology = the driver.	Technology = regulated and public-private ('polder model') discussions between NGOs, businesses, governments and other stakeholders. The driver is knowledge, not so much technology.	Low use of technology, existent knowledge used for rebuilding economies and societies.
Social			
Environmental problems	Solved through technologies and market incentives.	Regulation and public incentives vs cooperative solutions.	Difficult to solve in cases of overgrazing etc. Nature profits in low input farming
Communication: process	Virtual communities (social media, games, etc.).	Virtual and face-to-face.	Mainly face-to-face.
Fun / happiness	Controlled life Profit	Trust	Freedom
Demography	Cities; rural area depopulated	Rural renaissance: start-ups, more people in rural areas	Back to the rural areas
Lifestyles	Computer games,	Community	Hunting out of need

	fashion	oriented	
Health	Highly medicalised	Self-diagnosis based on apps with health information	Herbs, survival of the fittest

Table C: Agricultural (specific) characterisations of the three scenarios

Agricultural characterisations	High tech	Self-organisation	Collapse
Economics			
Bioeconomy scenario (4th SCAR Foresight)	Bio-Boom (high demand and high supply)	Bio-modesty (medium supply growth and low demand, business as usual)	Bio-Scarcity (high demand but low supply growth)
Type of agriculture	Highly specialised, one farm company operating in different countries.	Regional food, both organic and conventional products, high diversity in menus.	Permaculture, tightened to local circumstances, subsistence and small family farming.
Scale	Global	Regional	Local
Farm business type	Large scale, highly specialised, e.g. 400 ha broccoli in four countries. Contract farming. Farmers employed or controlled by multinational companies (franchises), no SMEs. International products.	Mixed farming system. A few high tech large scale farms, many cooperatives, many SMEs. Both specialised in high tech as diversified/ mixed agriculture. Mainstream/ bulk and organic. International, regional and local products.	Small, local for local, no large farms. Vegetable gardens and different animals grazing on small pieces of land: community farming.
Cooperatives	Multinationally organised. Develop into shareholder companies, coops go to the stock exchange.	Regionally organised. Tool to the marketing of products.	Small scale, temporarily based on individual trust. Way to survive.
Role of nature	Nature is created (e.g. nature parks). Nature becomes a business	In some farms nature is included in	Agriculture depends largely on nature (=

	model and is incorporated in certification schemes.	farming -> agro-forestry, high nature value farming.	leading).
Farm scale	Large farms, international.	Both large farms and SME's, depending on the economic competitiveness in and between regions.	Small scale. Some collaboration (joint ventures).
Human capital	Highly technically educated specialists, who do not necessarily have a farming background (10%) versus relatively low paid operational staff (90%) -> specialised.	Differences in education level. The farmer is an entrepreneur in the first place. Broadly educated, different skills rather than specialisation.	Traditional and basic knowledge, trans-disciplinary oriented (holistic).

Agricultural characterisations	High tech	Self-organisation	Collapse
Food supply	Very high. GMO technology is leading, brands + fashionable food.	High. Different food streams: organic, conventional, mainstream, cheap, brands, both technological processed food and demand for traditional 'granny' /homemade products.	Scarce. Natural, much organic (out of necessity), few technologies in food production.
Food demand	High but rather uniform.	High, coming from different food streams.	Modest. Self-sufficiency.
Political			
Power	Multinational food companies, NGOs and 'consumers' (under influence of marketing).	Cooperatives and chain management.	Local farmers (who has the resources).
Food problems	Food waste: supply is higher than demand.	Food waste: supply is higher than demand.	Food scarcity: demand is higher than supply.
Food safety	Very safe, consumer driven. Critical incidents through production failures (leading to bankruptcy of businesses).	Safe, privately driven by consumers and publicly controlled. (Critical) incidents form a societal problem.	Nutrition first, safety second (not very safe). Knowledge focus on hygiene (in the first place).
Responsibility for the environment	Shared between multinationals and NGO's such as Greenpeace who attack the reputation of companies such as McDonalds (labelling, certifications).	Regional governments but many public-private covenants.	'Nature itself'. Also local people and (fragments) of governments. Direct feedback from consumers to farmers.
Risk management	Competitive: the multinational that fails goes bankrupt or is taken over by a bigger predator. Risks are addressed through the juridical system as a liability issue.	Throughout the chain, cooperatives and public private covenants. Risks are easy to tackle because there is the assurance that the community will solve it. Risks are 'everyone's' problem, within a	Trust-building through communication between farmers and consumers. Risks are easily detected.

		certain frame.	
Technological			
Food technology	Highly technological, 3D printers for food, distance management (international).	Technology next to traditional crafts, room for creative innovation.	Downfall of technological developments. Technology used for rebuilding economies and societies, rather than food.
Social			
Farmer demography	Few big ones; rural area depopulated.	Rural renaissance: farmer start-ups, more people in rural areas.	Both urban and rural farmers, including subsistence farming.
Type of food	Industrial production of burgers; 'strange' food is fashionable: insects (only when eaten by celebrities).	Regional products. Dominant variety between diets (insects in Asia, potatoes in Western countries).	Discovery of new food and nutrition through urgency. Herbs, insects, etc. as necessary source for proteins.

Table D: Effects on AKIS

Characterisations	High tech	Self-organization	Collapse
Economics			
Geographical economic scale	Stronger internationalisation and more specialised orientation.	Stronger regionalism and more general orientation.	Stronger individualism and holistic orientation.
Finance	Large scale private R&D. Private industry does not compensate lower level of public R&D. Reduced knowledge exchange outside the large companies.	Mix public-private. Farmers pay for advice and new actors in AKIS. Linked to local governance. Stress by rapid change "everybody is challenged".	Small scale private R&D, some local awareness building. Individual but rising community thinking. Often tribal (family/area).
Role of consumer (feedback)	Consumer: indifferent in product choice; "it is all far away anyway" but issue management via NGOs.	Consumer: ad-hoc and incident oriented "problem-by-problem".	Consumer: essentials first (such as animal disease research).
Language used	English	Multi-linguistic actors and projects	Your own
Political			
Governance	AKIS centralised and privatised. No independent public funding.	AKIS decentralised and diverse (public-private collaboration).	AKIS fragmented and local (farm/food driven). Very specific and localised AKIS.
Government role and policy	Minor role of government, private multi-national business models dominate. Guerrilla type of resistance ('non-corporate AKIS' outside the establishment).	Government active on community level. Mixed public-private orientation and regional public finance. Grass-root research and innovation.	More local groups and individuals: fragmentation and "many internets". Rising status and importance of the farmer (food is the essence); farmer-driven AKIS.
Agenda-setting	Agenda set by business.	Agenda set by communities.	Agenda set by individuals.
Organisation of food safety	Trust: monitored by large companies. Certifications and global institutions important.	Trust in civil society high (farmers and agri-business integrated in AKIS): "arguments count, not positions".	Trust: about rebuilding institutions. Government fragments are important and influential.

Technology, knowledge and innovation			
Driver for innovation	International competition.	Regions in both competition and collaboration.	Individuals and small groups searching for new entries and ideas to farming.
Innovation-risk	Risk: Danger of exclusion (closeness) and controlled access. "Access for the few".	Risk: much "muddling through" and sense of "nothing is gonna change". Reduced capacity AKIS.	Risk: outside control of ICT (China). "Local survival of the fittest".
AKIS-skills / type of competences	"Up-skilling" through the need for specialised knowledge and skills in international networks and consulting: "network research".	"Multi-skills", area efficiency, territorial and value competition. Community representation, "peer consultation".	"Basic-skills", problem oriented towards the basics as food, soil and water.
Basic educational orientation / profession of farmer	Technologists, not land managers.	Land managers, not technologists.	Technology and land management.
Domain of AKIS	AKIS go for non-food (food already taken care of).	AKIS go diverse – increasing in numbers.	AKIS go for more community thinking: access to variety.
Internationalisation	Connecting the globe: centralised research; dominance by a few large companies.	Connecting regions, decentralised research, need for links to regulations.	Connecting people through applied solutions
Focus of AKIS	AKIS focus on global food chains and flows.	AKIS focus on adaptations in the regional setting (cooperatives).	AKIS focus on food composition (nutrition) and usage.

Characterisations	High tech	Self-organisation	Collapse
Tools in AKIS	Global tools & benchmarks, economic efficiency and labelling; thematic cross-overs.	Demos and regional network tools, institutional efficiency (best practices).	"Must reach all" interaction; small group learning processes; trial and error.
European Research programmes	Large PPP between EC and multinationals dominate (such as in Future Internet PPP and Bio-based PPP). JPI and KIC survive, ERAnets disappear (no national funding).	Very differentiated landscape of AKIS over Europe. Need to link them, but difficult to find good instruments. Role of EU becomes less important. Probably most influential in science and in research infrastructures. Coordinated by ERAnets	Not relevant, as EU is hardly relevant. Concentration on negotiating global deals with China (and US) on acquiring basic knowledge. Recruitment of the best students for the student exchange programme quota for China.
Cross-overs with other industries	Important (see ICT, Bio-based PPP). More beta science than social science. Strong specialisation in disciplines. Technology becomes more important than (traditional) agricultural research.	Multidisciplinary. Need for (traditional) agricultural research in combination with other disciplines. Technology / beta science is important, in combination with social science.	Urban farming, attention for farming and city development. Health science / research becomes important (new plants / food as medicines).
Knowledge organisations and actors			
University	Direct contact on research and education programmes with companies. Silicon Valley model, Innovation is part of the mission and business model (patents etc.): Third generation university (teaching, research and innovation). Students from all over the world through MOOCs and TEDx's. Only a few, big Life Science universities in	Many regional universities that collaborate and specialise (precision agriculture in Denmark, multi-functional agriculture in Baden Württemberg, Organics in Austria) Second generation universities (both teaching and research).	Reduced public funding, struggle to keep alive and stay relevant. Focus on the societal challenges of food security and climate change. Less money for research, focus on teaching. Back to first generation university (teaching).

	Europe.		
Applied research	Moves into (applied) *universities*. Companies find it more attractive to deal with universities. Public support declines.	Moves into applied (higher) *education*. More intertwined with experimental farms and advisory service (Teagasc model).	Relatively important over fundamental research. Gets part of its basic know how from fundamental research in China.
Experimental farms	Public funding ends, collective funding via commodity or levy boards ends. Some are saved by big farms.	See cell above.	Cater for the needs of local farmers.
Advisory service	Service is provided by multi-national food companies and input industry, and their computer-generated advice. Public extension disappears. Some independent consultants and coaches (facilitators).	Mix of public extension service and commercial advisory organisations. Linked with applied research and higher education.	Advisor and coach become the traditional extension-worker that gives instruction.
Operational groups / interactive innovation	Less relevant as innovation is more top-down driven.	The challenge is to organise multi-knowledge networks that integrate education and training.	Innovative farmers contribute to local innovation.
Education	More scientific. Gap between lower education and academic level. Higher education under threat. Emphasis on in-company training on the John Deere University.	International exchange programmes and minor programmes are important. Both initial and post-initial training. Focus on lifelong learning.	Higher education for advisors. Focus is on skills and crafts.

ANNEX 2: THE MAKING OF – INCLUDING A LIST OF PARTICIPANTS

The SWG on Agricultural Knowledge and Innovation Systems (AKIS) started its activities in 2010, after a proposal to the SCAR by France and the Netherlands to start and lead the SWG on the links between knowledge and agricultural innovation in Europe. During the first two mandates, Pascal Bergeret and Krijn Poppe were appointed as project managers / chairs. The work has led to the publication of two AKIS reports:

- "*Agricultural Knowledge and Innovation Systems in Transition – a reflection paper*" (2012) gives an overview of the thinking on innovation policy, the concept of AKIS and drew attention to the concept of social innovation. It documented experiences in the EU Member States and looked to the future;
- "*Agricultural Knowledge and Innovation Systems Towards 2020– an orientation paper on linking innovation and research*" (2013) focuses upon the collection and analysis of national and European experiences with interactive methods useful for fostering agricultural innovation. Topics addressed were – among others – innovative innovation policies, cross-border collaboration, incentivising stakeholders and researchers and the role of ICT in innovation.

The third AKIS mandate started in December 2013, under the lead of the Netherlands (Krijn Poppe, LEI Wageningen UR acting for the Dutch Ministry of Economic Affairs) and Belgium (Anne Vuylsteke, Government of Vlaanderen). The project plan included five work meetings (after a kick off meeting in Brussel, organised by Anne Vuylsteke from the Government of Vlaanderen):

1. EIP implementation in the Member States and EIP-AGRI uptake (March 2014, Krakow, organised by Monika Rzepecka of the Polish Ministry of Science and Higher Education in collaboration with the PRO-AKIS project)
2. Reporting on operational groups and AR-ARD workshop "Best strategies for intercontinental research and innovation partnerships - towards greater impact on global challenges" (May, Brussel, organised by the chairs of the SCAR AKIS and ARCH SWG in collaboration with the European Commission)
3. ICT and foresight for the AKIS (September 2014, Bari, organised by Eduardo Cuoco and Bram Moeskops from IFOAM)
4. Uptake of the interactive innovation model and ICT issues (November 2014, Oeiras, organised by José António dos Santos Pereira de Matos of the Instituto Nacional de Investigação Agrária e Veterinária)
5. Foresight for the AKIS (March 2015, Antwerpen, organised by Anne Vuylsteke from the Government of Vlaanderen)

The draft end report was discussed in a meeting in Brussel (June 2015, organised by Michael Kügler from EUFRAS and Karin Ellermann-Kügler from the Chambers of Agriculture) and finalised in a meeting in Brussel (October 2015, organised by Hans-Jörg Lutzeyer (DG RTD)

The European Commission (DG RTD) linked the PRO-AKIS project (managed by Andrea Knierim, ZALF) and the VALERIE project (managed by Hein ten Berge, WUR) with the work of the SWG. Both projects contributed their expertise to the SWG AKIS. The outcomes of two small studies by the projects are reported in chapter 5 an 7.

The writing of the final report was coordinated by Krijn Poppe and Anne Vuylsteke. Andrew Fieldsend (AKI) provided editing services and carried out the language correction of the final text. Hans-Jörg Lutzeyer of DG RTD managed the publication process.

The SWG finalised the text for this report in October 2015. Its mandate ended December 2015.

A list of participants to at least one of the SWG meetings is given below:

Adam Bedford	Adam.Bedford@nfu.org.uk
Adrien Guichaoua	adrien.guichaoua@acta.asso.fr
Alex Percy-Smith	alex@apsconsultingservices.dk
Andrea Knierim	knierim@zalf.de
Andres Montero Aparicio	amontero@inia.es
Andrew Fieldsend	andrew.fieldsend@aki.gov.hu
Anita Silmbrod	Anita.SILMBROD@lebensministerium.at
Anne Vuylsteke	anne.vuylsteke@lv.vlaanderen.be
Anton Stöckli	anton.stoeckli@blw.admin.ch
Bettina Heiman	Bettina.Heimann@agrsci.dk
Bram Moeskops	bram.moeskops@ifoam-eu.org
Carola Ketelhodt	cketelhodt@lksh.de
Cyril Koa	cyril.kao@agriculture.gouv.fr
David Cooper	David.Cooper@defra.gsi.gov.uk
Eduardo Cuoco	eduardo.cuoco@ifoam-eu.org
Elke Saggau	Elke.Saggau@ble.de
Emilie Gätje	e.gaetje@fz-juelich.de
Floor Geerling-Eiff	floor.geerling-eiff@wur.nl
Giulia Cuccato	Giulia.Cuccato@defra.gsi.gov.uk
Hans-Jörg Lutzeyer	Hans-Joerg.Lutzeyer@ec.europa.eu
Ines Di Paolo	dipaolo@inea.it
Inge Van Oost	Inge.VAN-OOST@ec.europa.eu
Inger Pehrson	Inger.pehrson@jordbruksverket.se
Isabel Bombal	ibombald@magrama.es
Jan van Esch	j.w.j.vanesch@minez.nl
Jasper Dalhuizen	j.m.dalhuisen@minez.nl
Jaume Sio	jaume.sio@gencat.cat
Jeanne Bormann	jeanne.bormann@asta.etat.lu
Jill Ebert	j.ebert@fz-juelich.de
José António Santos Pereira Matos	jose.matos@iniav.pt
Julie Ingram	jingram@glos.ac.uk
Jyrki Aakkula	jyrki.aakkula@luke.fi
Kaire Kasearu	kaire.kasearu@agri.ee
Karin Ellermann-Kügler	k.ellermann-kuegler@vlk-agrar.de
Kevin Heanue	kevin.heanue@teagasc.ie
Krijn Poppe	krijn.poppe@wur.nl
Leif Raun	lfr@vfl.dk
Lizzie Melby Jespersen	LizzieM.Jespersen@icrofs.org
Maria Joao Fernandes	MariaJoao.Fernandes@fct.pt

Michael Kügler	m.kuegler@vlk-agrar.de
Monika Rzepecka	Monika.Rzepecka@mnisw.gov.pl
Muhammet DEMİRTAŞ	mdemirtas@tagem.gov.tr
Pascale Riccoboni	pascale.riccoboni@agriculture.gouv.fr
Patricia Wagenmakers	p.s.wagenmakers@minez.nl
Paul Newell-Price	Paul.Newell-Price@adas.co.uk
Pierre Labarthe	pierre.labarthe@agroparistech.fr
Sahin Anil	sanil@tagem.gov.tr
Simona Cristiano	cristiano@inea.it
Sonia Ramonteu	sonia.ramonteu@acta.asso.fr
Tania Runge	tania.runge@copa-cogeca.eu
Trond Selnes	trond.selnes@wur.nl
Valerie Dehaudt	valerie.dehaudt@agriculture.gouv.fr

Annex 3: Some relevant EU Projects

Readers who want to keep up with the latest developments in European research projects, related to AKIS and linking innovation and research, will find below an introduction to projects that are currently running or ended recently.

Prospects for farmers' support: Advisory services in European AKIS - PRO-AKIS

http://www.proakis.eu/

European farmers need topical knowledge, training and support to remain competitive and respond to manifold demands in a continuously evolving environment. Functioning agricultural knowledge and information systems (AKIS) are needed to tackle challenges such as (i) giving small-scale farmers access to relevant and reliable knowledge, (ii) bridging scientific research topics and farmers' demands and (iii) offering appropriate support for diverse rural actors that form networks around innovations in agriculture and rural areas. Advisory services are one essential means to enhance problem solving, information sharing and innovation generating processes.

In a functioning AKIS these services can be provided by various actors, among them formal extension services, training and post-secondary education bodies, NGOs but also by members of administration or research institutions. PRO-AKIS is thoroughly reviewing international literature sources on AKIS and will provide an inventory of the AKIS institutions and interactions in the EU-27. Furthermore, PRO AKIS will highlight the mentioned challenges through a selection of case studies that are conducted for each topic in parallel in several member states. Comparative analyses and assessments of these cases will reveal successes, strengths and weaknesses of the specific knowledge flow systems. AKIS stakeholders and policy advisors will accompany PRO AKIS, share interim findings, and participate in workshops and seminars. They will be invited to intervene repeatedly in the course of the project and to contribute through feedback and in assessments of results. On these bases policy recommendations for the strengthening of European agricultural innovation systems will be developed and further research needs will be designated. A range of dissemination activities will assure that findings are timely and available for the interested communities and for the public at large.

Valorising European Research for Innovation in agriculture and forestry - VALERIE

http://www.valerie.eu/

Many EU and nationally funded research projects in the fields of agriculture and forestry provide excellent results, but the outreach and translation of these results into field practices is limited. The overall aim of VALERIE is to boost the outreach of research by facilitating the integration into innovative field practices.

The work in VALERIE consists of three major approaches. (1). Stakeholder-driven approach. Ten case studies set the central stage for the bottom-up approach of the project, aided by highly effective tools of web semantics and ontology. Cases are centred around a specific supply-chain, a farming sector or a landscape. The stakeholder communities (SHC) represent the natural networks engaged in innovation. They drive the process of articulating innovation needs, enabling the retrieval of precisely matching knowledge and solutions, and evaluating their potential in the local context. (2) Theme-driven approach. VALERIE retains six thematic domains that are at the heart of sustainable production and resource use. These six provide the backbone for structuring the annotation and summarising activities, which in turn will provide a vast body of knowledge accessible via the Communication Facility (CF). (3) Knowledge disclosure. VALERIE will launch a 'Communication Facility' (CF) for the EIP-Networking Facility. The CF supports communication among actors in the field and researchers. Next it injects new knowledge into the innovation process, by enabling users to retrieve highly relevant (tailored-to-needs) information, based on their own vocabularies. In offering tools for communication, as well as content structured for efficient knowledge retrieval, the CF fuses the advantages typical of 'learning networks' and 'linear' modes of knowledge sharing. The CF will be set up, tested and integrated into the EIP-NF platform, as a generic infrastructure for use by 'fresh' stakeholder communities, also beyond the life of the VALERIE project.

Future Internet Public Private Partnership

http://www.fi-ppp.eu/

The Future Internet Public-Private Partnership, short: FI-PPP, is a European programme for Internet-enabled innovation. The FI-PPP will accelerate the development and adoption of Future Internet technologies in Europe, advance the European market for smart infrastructures, and increase the effectiveness of business processes through the Internet.

Two FI-PPP projects are especially related to agriculture and food:

- Smart Agrifood: http://www.smartagrifood.eu/
- FIspace: http://www.fispace.eu/ that builds a collaboration service platform for businesses.

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The European Union's Standing Committee on Agricultural Research (SCAR) is mandated by the EU Council to play a major role in the coordination of agricultural, food and bioeconomy research efforts across the European Research Area (currently composed of 37 countries). This includes questions of advisory services, education, training and innovation. SCAR set up a Strategic Working Group of civil servants from the European Commission and the Member States to reflect on Agricultural Knowledge and Innovation Systems.

This report investigates if Agricultural Knowledge and Innovation Systems (AKIS) are fit to answer the challenges posed by the need to increase productivity and sustainability in agriculture and food production. The analysis focuses on potential disruptive changes due to developments in ICT and E-Science as well as in the bioeconomy and discusses the relation between agricultural research and research for development. Three scenarios (HighTech, Self-Organisation and Collapse) are developed as a foresight for potential future developments of AKIS. Recommendations on interactive innovation and the development of AKIS complement the analysis.

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