Current situation on data exchange in agriculture in the EU27 & Switzerland

SEVENTH FRAMEWORK PROGRAMME

agriXchange

network for data exchange in agriculture agriXchange

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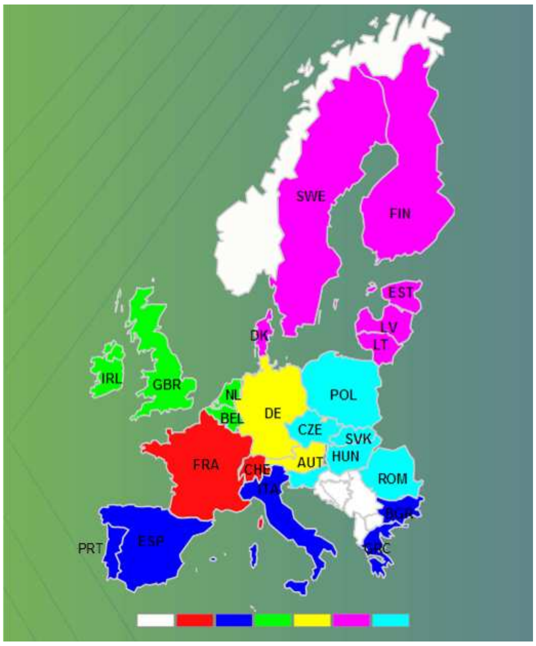

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Final report

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About the agriXchange project

agriXchange is an EU-funded project which is a coordination and support action to setup a network for developing a system for common data exchange in the agricultural sector.

Project summary

Within the knowledge-based bio-economy, information sharing is an important issue. In agri-food business, this is a complex issue because many aspects and dimensions play a role. The installed base of information systems lack standardization, which hampers efficient exchange of information. Which subsequently leads to an inefficient business processes and hampers adaption of new knowledge and technology. The exchange of information at whole chain or network level is poorly organized. Although arable and livestock farming systems have their own specific needs, there are many similarities in the need for an integrated approach. Spatial data increasingly plays an important role in agriculture.
The overall objective of this project is to coordinate and support the setting up of a sustainable network for developing a system for common data exchange in agriculture. This will be achieved by:

- establishing a platform on data exchange in agriculture in the EU
- developing a reference framework for interoperability of data exchange
- identifying the main challenges for harmonizing data exchange.

First, an in-depth analysis and investigation of the state-of-the art in each EU member states will be carried out. A platform will be constructed which facilitates communication and collaborative working groups. A number of representative use cases will be identified and guided by an integrative reference framework. The framework consists of a sound architecture and infrastructure based on a business process modelling approach integrating existing standards and services. The development is completed in close interaction with relevant stakeholders through the platform and international workshops. The results converge into a strategic research agenda that contains a roadmap for future developments around data exchange.

Project consortium:

- Wageningen University & Research Center (LEI, Livestock Research, Alterra) - The Netherlands
- Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) - Germany
- MTT Agrifood Research - Finland
- Wirelessinfo (WRLS) - Czech Republic
- Institut de l'Elevage (ELEV) - France
- Institut de Recerca i Tecnologia Agroalimentàries (IRTA) - Spain
- Teagasc - Ireland
- Universität Rostock -Germany
- Forschungsinstitut für Biologischen Landbau (FIBL) - Switzerland
- Altavia - Italy
- Poznan University of Life Sciences (PULS) - Poland
- ACTA Informatique - France
- Progis software - Austria

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Executive summary

AgriXchange is an EU-funded coordination and support action to setup a network for developing a system for common data exchange in the agricultural sector. In this network a reference framework for interoperability of data exchange is being developed. Analysis of the situation concerning data exchange in agriculture in individual EU member states (including Switzerland) is an integral component of this support action.

In this report the results of the analysis of the state of the art around agricultural data exchange in EU member states is discussed. The research is based on literature review and investigation in the 27 EU member states and Switzerland. The research concludes by giving basic recommendations on organizing data exchange in agriculture at general, regional and national levels.

The research was carried out using the methodology developed by Giachetti (2004). Giachetti provides a framework of for analysing the integration of information within and between enterprises such as agriculture. The framework was adopted in this research to analyse agricultural information exchange and its related systems within (intra) and between (inter) enterprises in the agri-food supply chain network. For both the intra and inter enterprise analysis, in a hierarchal manner, the lower level with regards to basic 'physical infrastructure' such as interoperability of devices and sensors, connectivity infrastructure, broadband internet amongst others was investigated. The next level, 'data sharing' was investigated to find out about how integration of data and standards takes place in and within agricultural enterprises; how data dictionaries, data definitions, data quality and security are aligned and integrated in agriculture. The next level in the methodological framework looked at 'inter-operability between applications' in and between enterprises, and related issues such as what standards are used and what web services are used by applications. In the final level the research found out about how 'processes are coordinated', which business processes take place, new technologies, skills and developng areas in the agri-food supply chain network.

For collecting literature on agricultural data exchange in the EU member states (including Switzerland), a meta structure was developed to ease classification. The developed file meta structure made possible to search the literature according to its <short source title>, <full title>, <authors>, <country of origin>, <English version or abstract>, <coverage/classification>, <keywords>, and <about or content>. The <coverage/classification> tagged the literature into <business level> (such as farm, agri-(food) business and agri- (food) chains), <coverage aspects> (such as economics, environmental, social and common levels), <agenda issues> (such as EU/European, National and EU Regional), and <agric area> (such as arable, cattle, spatial and common to all areas). The developed meta structure was used to collect literature from (more than 300) different sources all over Europe tackling, regional, European and country specific issues. The sources were classified and uploaded to the agriXchange platform, which can be accessed and searched via www.agrixchange.eu (following the menu: knowledge-literature).

A review of the collected literature gave an in-depth analysis of the issues and needs in agriculture in general and subsequently develop EU-wide recommendations based on these needs. The issues are derived from the main issues in the European agenda and cover economic (market), environmental and social aspects.

The first part is based on important work in strategically viewing a number of global and EU ICT agendas. Those ICT agendas are covered in the following:

a. The vision on the future value chain for 2016 by the Global Commerce Initiative;
b. The strategic research agenda of the AMI@Netfood project;
c. The research agenda of the European Platform for Food for Life;
d. The analysis of drivers by the Future Farm project;
e. The third SCAR Foresight exercise;
f. The Research Agenda and the Action Plan by the Technology Platform for Organic Food and Farming;
g. Vision, Strategic Research Agenda and Third Implementation Action Plan of the European Agriculture Machinery Industry (subplatform of the Technology Platform MANUFUTURE).

In the above-mentioned research agenda, information sharing, data exchange and related problems is are one of the key issues to be solved. Smooth exchange of information was noted to be needed across all sectors. While the different strategic platforms and networks have different visions, the analysis showed that they have a lot of similarities. The GCI mentions five areas of driving forces (economic, ecological, demographics new technology and regulatory issues) in the development of value chain from retailers' perspective. According to GCI, to develop value chains, There is a requirement for innovations built on information sharing, open networks and new services rather than products.
The AMI@Netfood group established the need for a sectoral-oriented approach on ICT in agri-food and rural domains. The group called for harmonization of the different RTD strategies in the EU to enhance especially collaboration, openness and information transfer with the sector.
The SRA of the European Technology Platform for Food for Life highlights issues like trust, research (to improved competitiveness by developing new processes) and development of new products and tools. The Future Farm addresses five drivers of influence on strategies in worldwide organizations and on markets. Some are trade and business based, like WTO and reform of Common Agriculture Policy (CAP), global competition. SCAR Third Foresight Expert highlights the importance of ICT as farm management tool in a world of scare resources. The Technology Platform for Organic Food and Farming emphasizes the importance of ICT for new information management systems. Others are addressing energy, climate change and social and demographical issues.

Strategic driving forces that create the need (structures and processes) for information in agriculture require an overview of the current issues and developments in practice. A literature review of the collected documents in agriXchange also reviewed the current "in field" situation regarding information exchange in the areas of livestock farming, arable and spatial.
Inter enterprise data exchange exists between farmers and breeding organizations such as milk recording agencies, artificial insemination cooperatives and herd books. Within the farming enterprise, the increasing use of automatic devices on farm such as automatic feeders, automatic milking systems (AMS), results in an increasing need for communication between devices and on farm management information system. Within the farm system, especially in dairy operations, there is a need to integrate data from different systems: feeding, milk performance, milk composition (quality), reproductive performance, health, heifer rearing (again, feeding, performance,

reproduction). For the livestock sector, different standards exist (ISO, government agencies, UN/CEFACT, national and international EDI associations), but maintenance, harmonization and coordination of these standards are limited which are maintained by different bodies at different levels.

In arable farming so called precision agriculture (PA) is one of the driving forces for data exchange and issues related to data froemats and interface standardization. Currently, new automation, ICT and GIS technologies provide solutions for steering and controlling site-specific production systems to fulfill requirements of safe, efficient, environment friendly and traceable production. To enable compatibility between different system parts that are needed in performing PA, an information management system which utilizes open system interfaces and ICT standards, such as ISOBUS, and efficient data transfer are required. Currently, information exchange between farm and other actors (e.g. advisors, government, processors) is also not sufficiently organized. Data exchange between machines at field level and management systems at farm level is supported by ISO standards (e.g. ISOBUS/ISO11873), however practical adoptation by farmers is low.

For both livestock and arable farming, spatial information is continuously playing an inportant role. Spatial information is needed for spatial location and monitoring of animals, virtual fencing for animals and machines, remote sensing for siols, crops and animals, fleet management and control of farm machines, unmanned aerial vehicles, auto steering and autoguidance, and for spatial allocation and timing of management applications. Much effort has been placed towards spatial data harmonization in the past and positive results are emerging especially in efforts towards standardisation work of the Open Geospatial Consortium, Inc. (OGC) and ISO/TC211 Geographic Information/Geomatics. Another relevant harmonization work is related to the INSPIRE Directive. The scope of standard development of ISO/TC 211 is also relevant and includes information technology, GIS, Remote Sensing (RS), Global Position System (GPS) and other advanced concepts, models, patterns and technical methods. Geography Markup Language (GML) identical to ISO standard 19136:2007 provides a variety of kinds of objects for describing geography including features, co-ordinate reference systems, geometry, topology, time, units of measure and generalized values.

The implications of ICT and data transfer in livestock production directly affect consumers in terms of awareness and knowledge of consumers, information transfer for food safety, animal health and welfare, efficuent plant and animal production and sustainability of production systems. Expected ICT developments in the coming years include developments towards external storage of farmer’s data to cater for increasing amount of data produced. Centralized mangement informations systems, with internet-based cloud support are foreseen. Technologies for documentation of production processes to enhance treaceability along the food chain will increase. Sensor technology, and sensing techniques and RFID as booster for new data and services. Geographical Positing Systems (GPS) is seen to become a of future agricultural technology in terms recording field data collection, yield mapping automated Variable Rate Applications (VRA) in seeding and fertinlzing amongst others.

The next step in the research examined the state-of-the art of ICT and data exchange in agriculture in the EU member states (incl. Switzerland). Research to find out what is happening in the EU region classified the region in to 6 focus groups. Focus group A examined the situation in France and Switzerland. Focus group B covered Italy, Spain, Portugal, Greece, Cyprus, Malta, and Bulgaria. Focus group C dealt with UK, Ireland, Netherlands, Belgium and Luxembourg. Group D focused on

Germany, Austria. Group E focused on Latvia, Estonia, Lithuania, Sweden, Finland, and Denmark, whist group F dealt with Poland, Czech, Slovenia, Slovakia, Hungary, and Romania. The investigation employed experts for quantitative and qualitative inquiry about the state-of-the art of ICT and data exchange in agriculture. The experts located in each country provided information about agricultural data exchange in their respective countries. For each country separate reports were prepared. In the analysis of the results, the framework by Giachetti (2004) was used to “map the current state of system and information integration in the research countries. The mapping covered processes, applications, data, and physical infrastructure in agricultural data exchange with particular reference to general characteristics of farming, the level of automation, data integration, ICT and technology usage.

Trends in farm characteristics: According the results of the research, arable farms are largest in the Czech Republic, Denmark, UK and France. In Bulgaria, Romania, Slovakia and Hungary more than 50% of the arable holdings have land areas of less than 2 ha. The largest dairy farms were in Denmark, Cyprus, Czech Republic and the UK. In Romania, Bulgaria, Lithuania, Slovakia, Latvia, Poland, Estonia and Hungary, more than 80% of the dairy holdings have less than 10 cows.

Farm automation level: By characterizing precision farming (PF) as a measure of farm automation, in most EU countries, PF is only used to a small extent by farmers. A lot of experts reported the existence of PF and the usage of Geo spatial data only in experimental (research) projects. However, there is a significant difference in areas across Europe, in Western and North Europe and for example in Czech Republic there is more progress in PF development. Manufacturers of agricultural machines are the main booster for adaptation of PF techniques in developed countries such as Germany, the Netherlands, Denmark and Finland.

Data integration: In general big differences all over Europe can be seen in data integration at process level. The availability and accessibility of (broadband) Internet in rural areas is an issue in most countries. Except from some countries like Germany, France, Denmark, Belgium and the Netherlands, no (private) unions or bodies are reported who take care of the organization of dataflow or standardization. Collaboration between private and public organization to advanced infrastructure is also low in countries like Romania, Slovakia, Czech Republic and Lithuania.
In many EU countries data definitions (semantics) have only public standards (XML schema’s and web services for example) mentioned. Standards definitions such as ISOBUS are available for example machinery (ISObus), milking equipment (ISO 11788 ADED), electronic animal identification (ISO 11784/11785/14223 and 24631) or forestry (ISO 19115). Syntaxes for EDI messaging from agroXML (Germany, some other countries), ISOagrinet (international), Agro EDI Europe and E-daplos (France), AgroConnect (The Netherlands) were reported. However, data integration along the whole food chain from farm to consumer is still lacking.

ICT and technology usage: Agricultural technology adaptation and developments are not always positive because of lack of young people in agriculture (Slovakia, Bulgaria, Italy, others). Countries having a lot of small (probably poor as well) farmers are facing severe problems in the capabilities of investing in automation. Fast developing agricultural countries like the Baltic States have high potentials concerning the building of new ICT infrastructure as they are not bothered by old systems and structures. Availability of broadband internet in rural areas is very often mentioned as a big issue that hampers ICT adaptation in agriculture.

Analysis of the European area points out that it can be divided into four different levels of maturity on data integration. The levels are; countries with none or hardly any data integration, those with poorly developed data systems, countries with rather well developed systems and countries with quite well developed data integration systems.

For each level, recommendations for further development or improvement are given. For the countries with none or hardly any data integration (such as BGR, ROM, MLT and CYP), there are hardly any private initiatives, and public (CAP) systems provide rather closed (registry-) databases. For these countries it is recommended that investment be made in broadband infrastructures especially in rural areas. These countries are encouraged to build reliable public (CAP) services and extend them with web services to provide private business with development opportunities. Education and demonstration about new technology adaptation, agricultural software, available databases and digital information sources can help farmers to develop usage possibilities. Also implementation of the (most easy) best practices from other EU regions in addition to utilization and connections to existing global standards is needed.

For the countries with poorly developed data integration (mostly Southern and Eastern, Baltic States), move towards data integration was noted to be initiated by CAP/Governments through interfaces. Some shared databases and portals are showing up. But still hardly any integrated private systems. Recommendations are that for these countries there is also need of investments in mobile broadband infrastructures. Furthermore companies and government bodies should be stimulated to develop of shared databases to ease data exchange. Private businesses need coordinated organization in setting up integrated systems for agriculture. Finally, countries with poorly developed data integration should demonstrate best practices in IT services for example in the setup and implementation of local/EU subsidies management systems.

Countries with rather good data integration (Scandinavian states, CZE, GBR, IRL, BEL, CH) were reported to demonstrate progressive involvement by private organization within the past years. Few data dictionaries are emerging for data integration. The recommendations are as also mentioned other levels investment in mobile broadband infrastructure and active organization of private businesses to collaborate with official systems on shared and integrated systems. These countries need work on adapting by demonstrating best practices in IT services. And also get involved in European or global standard developments and implementations.

The final level, level 4, are countries with fairly well developed data integration (FRA, DEU, NLD, DNK). In these countries, system assessment and move towards open/shared communities is already in place. Infrastructure based on hub structures (such as in communicating and transporting systems) are also available. There is existence of private standardisation bodies in addition to usage of national, private owned and global standards. Further developing towards integrated models is however needed. For the countries with fairly well develop data integration, recommendations are to combine/redesign the best of several standards in different nations, like EDI-teelt, agroXML, E-Daplos. Countries should take the lead in new international data integration initiatives and use international/global standardization bodies like UN/CEFACT. Initiate new private-public collaborations on redesigned shared data infrastructure. Direct this through private-public platform(s) for developing integrated business process models and coordinate discussions about directions to accelerate becoming an open EU information society.

From the review for country reports three clusters of countries with common characteristics and/or barriers can be derived leading to general recommendations applying to countries within these clusters. Although individual countries are pushing forward for harmonization and more effective data exchange, countries can be grouped into three clusters namely: “high-technology, high agricultural diversity cluster”, “Networking challenges cluster”, and “Infrastructure challenged cluster”.
The **high-technology, high agricultural diversity cluster** appears countries like Finland, Spain, Germany and Italy. They are characterized by a fairly high degree of organization among stakeholders in agricultural data exchange and good technical infrastructure availability. On the other hand, agricultural practices are either diverse in itself or there are different boundary conditions in different regions of the country having led to independent developments of public and supply chain services in the various settings. Harmonization on the supply chain level and in the public sector is therefore the most important challenge to tackle but also difficult to achieve. People in these countries are generally saturated with new technology and therefore need a clear demonstration of benefits before adopting new developments. One way to achieve this can be to make public databases available for developing new web applications for remote advisory service. Advisory agencies can then serve as facilitator in IT adoption. More advanced, distributed applications and services that are needed in these countries to make a case for further IT adoption and harmonization call for specific catalogues to find relevant services.
Networking challenged cluster includes countries like Belgium, Denmark and the Netherlands. Within these countries, open cooperation, also on the international level is an issue. Overcoming the situation can be achieved by forming open networks and enhancing exchange of knowledge, technologies and information between the public and the private sector. One of the means to achieve this is trying to foster open source thinking to initiate development of new agricultural software. Regarding international level cooperation, France and Germany tend towards this cluster. All of these countries can benefit from intensive public-private collaboration activities, on national as well as on international level. Developing cross-border data exchange mechanisms can serve as a means to an end with this regard.
The **infrastructure challenged cluster** consists of the countries Bulgaria, Greece, Ireland, Latvia, Lithuania, and Portugal. Within these countries, wireless broadband connectivity or even basic internet connectivity needs to be enhanced in rural areas. Information and education about agricultural software, available databases and digital information sources can help farmers to develop a view on benefits and usage possibilities. On a technical level, agri search engines could facilitate access to relevant information, but only as soon as a basic communication infrastructure is in place and widespread enough. On the organizational level, government can support harmonization and standardization in data exchange by providing central information systems on important issues in agriculture and by cooperation with IT companies for providing support for farm management, data handling and reporting to authorities.

To cater for the disparities technological adaptation in different sections in the EU regions, the following recommendations are given. In **regions with most small farms and poor farmers** usually no standardization and hardly any ICT is available, it is recommended that data structures should be organized by public services to get developments started. The import of systems and data standards through private business (through multinational trade) will help as well. Last recommendation for this region is to copy knowledge (learn) from obligatory public services from other countries with structured and standardized ICT systems for agricultural data transfer. For the **regions where a**

focus on ICT is highly related to basic local challenges for example challenges with water management, erosion (in Southern parts) or trade (more in Western- and Northern Europe). Some recommendations concerning the trade group are that business and governments should work on cross-border trade support by international adapted data integration systems. The setup of new standards upon or through international (not national) supported bodies is another helper. Regarding water management the implementation of best practices from other countries and the implementation of integration GPS and sensor data, smart phone apps for easier data access are mentioned. The **regions with problems related to aging of farmers** hence low rates of adaption of ICT by farmers, it is recommended in these countries that the effect of adapting new technology should be demonstrated, and reinforced by education, not only for learning purposes but also to create a new and enthusiastic working environment for younger aged workers. For new EU regions with fast **developing production areas which are relatively new countries in terms of agricultural IT** as well, stimulating the building of new internet infrastructure, especially mobile broadband will is crucial. Parallel to this, new and existing international standards should be adapted in a smart way. A last recommendation is to work on cross border trade and data integrated systems. Lastly, for the older industrialized **region with standardization history** ('old-fashioned' structures), it was noted that the old systems and structures on data integration can hinder progressive development. Based on this assumption, recommended solutions can be achieved through the renewing and redesign of old structures by private-public (cooperated) investments. Investments in open data infrastructures, stimulating by governments and stimulating of open innovation environment is worthwhile. This should be done by private-public investment on new common data exchange structures.

As an overview the following strategic recommendations are given to EU countries. **Countries need to demonstrate use new technologies**. Countries are urged to invest in new technology adoption through education & demonstration. Demonstrate best practices in IT services. Countries reported with monolithic and distributed stakeholder systems should organize discussions and organize integration by open networks. Get directions how to become an open EU information society. **Public-private collaboration** structures and platforms are needed. Countries should involve governments and the private sector in setting up common shared development and new structures. In order to build infrastructure for new applications and services needed for agricultural ICT, most EU countries need to **invest in mobile broadband** especially in farming areas. **To harmonize and enhance smooth communication** and data exchange along the agri-food supply chain network, countries should get involved in European or global standard developments and implementations. **Adaptation of (new) standards** is needed as well as building systems with existing global standards instead of always creating new ones. **Countries should show benefits IT** of technology (economics, time saving, etc.), Furthermore, invest in research and advisory services to explore and convince farmers and other users of the benefits of technology. For data **harmonisation** through **supply chain,** private business and supply chain active participation is needed in setting up harmonization and integrated systems that will benefit the sector as a whole. Build reliable public (CAP) services and extend them with Web Services to provide private business with development opportunities **for standardization and practical implementation CAP** in the EU countries. **International initiatives** are needed to and stronger countries in ICT should take the lead in new international data integration initiatives and use international/global standardization bodies like ISO or UN/CEFACT. Combine/redesign the best of several standards in different nations, like EDI-teelt – agroXML - E-Daplos.

In closing, the following general conclusions are given as big challenges in data exchange currently and in future. For improving **business** in the agri-food supply chain networks, investment is needed in creating trust and awareness in the chain, adoption of new technology by means of open innovations are needed, new collaborative and service-oriented infrastructure are to be developed, implementing business process standards and service-oriented approaches should be practiced, and standards set against the backdrop of current EU policy should set, chosen and adopted. As **policy** implications controlling efficient data inquiry for boosting CAP in the EU is crucial. EU or national governments should play active roles directing the development of data standards. Private-public partnership is needed to address issues with limited investment possibilities, especially in small domains and countries. Involvement of public organisations in the setup of (private-public) collaborative data infrastructure can be achieved through the initiation of common data structures in the EU, through the initiation of (further) research on the implementations of common data structures and through stimulating availability of (broadband) internet infrastructure and capacity in rural areas.

It is discussed that the investigation was meant to provide an overview of the state of the art in data exchange as bias for further project work. The identification of key factors for the added value generated by a common data exchange system was not precisely elaborated. The quantification of the benefits arising from overcoming these barriers is beyond the scope of this analysis. Discussion of the meaning and value of data exchange will continue in the course of the project.

Finally, as a recommendation, benefits arising from overcoming the barriers discussed in this report should be quantified through future research. The effect of adopting new technologies needs to be clearly demonstrated in EU countries and societies. Data integration through open networks should be actively organized in these near years.

Keywords: agriculture, ICT, information, data exchange, standardisation

Abbreviations

AEF	Agricultural Industry Electronics foundation
AET	Agricultural Engineering and Technologies
AGROVOC	Thesaurus of the food and agriculture organization of the UN (FAO)
AMS	Automatic Milking Systems
AWU	Annual Working Units
BSE	Bovine Spongiform Encephalopathy
CAP	Common Agricultural Policy
EDI	Electronic Data Interchange
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization
FMD	Foot-and-Mouth Disease
FMIS	Farm Management Information Systems
FTP	File Transfer Protocol
GCI	Global Commerce Initiative
GIS	Geographic Information System
GML	Geography Markup Language
GMO	Genetically Modified Organism
GPS	Global Positioning System
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technologies
ID CODE	Identification code
INSPIRE	Infrastructure for Spatial information in the European Community
ISO	International Organization for Standardization
ISOBUS	Communication protocol (iso 11783)
LPIS	Land Parcel Identification System
OF	Organic Farms
OGC	Open Geospatial Consortium
PA	Precision Agriculture
PDA	Personal Digital Assistant
PLC	Programmable Logic Controller
PPP	Point to Point Protocol
RFID	Radio Frequency Identification
RS	Remote Sensing
RTD	Research & Technical Development
SCAR	Standing Committee on Agricultural Research
SCC	Somatic Cell Count
SDSS	Spatial Decision Support Systems
SMLU	Small and Medium sized Livestock Units
SMTP	Simple Mail Transfer Protocol
SOAP	Simple Object Access Protocol
SRA	Strategic Research Agenda
SWE	Sensor Web Enablement
TCP/IP	Transmission Control Protocol / Internet Protocol
TP	Technology Platform
UAA	Utilized Agricultural Area
UAVS	Unmanned Aerial Vehicles
UN/CEFACT	United Nations Centre for trade facilitation and electronic business
WTO	World Trade Organisation
XML	Extensible Markup Language

1 Introduction

This report highlights the results of research on the current situation of data exchange in EU member states and Switzerland. The current situation is a compilation of a literature review and investigation of the state of the art in these countries.
Literature review is based on in-depth insight into the European information, communication & technology issues and needs in agriculture. Additionally, results on specific topics are discussed and in certain relevant circumstances, general recommendations are made.

Within the knowledge-based bio-economy, information sharing is an important issue. In agri-food business, this is a complex issue because many aspects and dimensions play a role. The installed base of information systems lack standardization, which hampers efficient exchange of information. This leads to an inefficient business processes and hampers adoption of new knowledge and technology. The exchange of information at whole chain or network level is poorly organized. Although arable and livestock farming systems have their own specific needs, there are many similarities, so there is a need for an integrated approach. Spatial data is becoming more important in because of the upcoming developments in precision agriculture.

The Global Commerce Initiative (GCI, 2006) described the meaning of information sharing and standardisation with the following words: *"Companies must be prepared to share standards-based data free of charge. Sharing information between trading partners will result in an improved information flow and, as a consequence, improved collaboration to better serve the consumer. A resulting collaborative information platform could become the basis for further supply chain solutions... "*

In order to contribute to a better harmonization of ICT development in European agri-business, the EU-funded project 'agriXchange' was started in 2009. The overall objective of 'agriXchange' is to coordinate and support the setting up of a sustainable network for developing a system for common data exchange in agriculture. This will be achieved by 1) establishing a platform on data exchange in agriculture in the EU, 2) developing a reference framework for interoperability of data exchange and 3) identifying the main challenges for harmonizing data exchange.
As a first step in this project, the state-of-the art of ICT and data exchange in agriculture in the EU member states (incl. Switzerland) has been examined and is reported here.

1.1 Guideline for reading the report

The structure of this report is setup by the following sections.

Chapter 2 describes the methodology used for literature review, and the investigating the state of the art of the current situation of data exchange in agriculture, is described.

Chapter 3 describes the literature review which is based on the three parts:

- current developments driving the need for information integration in agri-food. This part is mainly based on important work in strategic viewing and in summarizing the ICT agenda of the future.
- description of the current “in field” situation regarding information exchange in the sectors of livestock and arable farming, with special attention to spatial aspects.
- big challenges in data interchange in agriculture as the issues concerning the agenda for the future (both near and far).

Chapter 4 describes the results of the in-field investigation which has been carried out by 6 focus groups of the EU member states and Switzerland.

Chapter 5 analysis the state of the art on information exchange in Europe. In here not only the European area is explained on regional characterised differences but also by various levels of data integration. Regional and levelling views can be found here. Per view recommendations are given.

Chapter 6 draws general and specific conclusions for the different data integration at different levels and ends with a general outlook and recommendations.

2 Research methodology

In this chapter the methodology for the literature review and investigating the state of the art of the current situation of data exchange in agriculture is described.

This report is part of the work of WP2 of agriXchange which is evaluating the current situation in EU-27 and Switzerland concerning data exchange in agriculture in the EU. As a baseline for other work packages in the agriXchange project, it is important to know about the state of the art in the field of agricultural data exchange across the EU. Some of the key issues are: what are the general and more detailed needs and what are the current situations in the different EU member states?
The state of the art is evaluated based on a number of different components:

1. In-depth insight (based on literature) into the European information, communication & technology issues and needs in agriculture
2. Investigating the state of the art in EU-27 and Switzerland regarding data exchange in agriculture.
3. Basic recommendations on organizing data exchange in agriculture at a national and general level

This report presents results for these three components. First, based on literature review, an in-depth analysis of the issues, needs and problems of information, communication & technology in agriculture was made. These are derived from the main issues on the European agenda and are covering economic (market), environmental and social aspects in the EU-27 countries and Switzerland.

Secondly, the research methodology of the investigating of the state of the art in EU-27 and Switzerland is discussed. In the investigation, experts were used to quantitatively and qualitatively inquire about agricultural data exchange in the EU.

Finally, recommendations on organizing data exchange in agriculture on regional and general level are given. This work provides WP4 (agriXchange work package “Framework for analysis”) with information about the current ‘in field’ situation (based on literature) and WP5 (Strategic Research Agenda) with specific recommendations for the in EU-27 and Switzerland.

2.1 Integration framework as model

The current situation in EU member states and Switzerland was investigated by using an integration framework to distinguish levels of data integration. The framework was systematically used during the literature review as well as the EU country-wise investigations.
Wolfert *et al.* (2010) described data integration as the alignment of data definitions in order to be able to share data, and the provission of technical infrastructure to enable communication between hardware components (connectivity). Based on this description and the integration framework developed by Giachetti (2004), data integration can be considered at different levels (Figure 1).

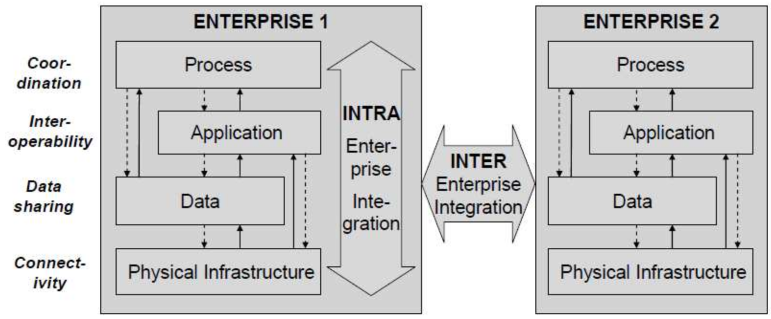


Figure 1. Integration Framework (adapted from Giachetti, 2004).

The different integration types are interdependent in two ways:

1. Conditional (solid arrowed lines in Fig. 1): to share data and couple applications, the physical infrastructure must be connected; to integrate applications, there must be common data definitions; for effective process coordination it must be possible to share data or to integrate applications.
2. Requiring (dotted arrowed lines in Fig. 1): a starting point is the need for integrated processes which defines the requirements for data exchange and application integration; application integration implies specific requirements for data to be exchanged; data exchange and application integration both require a supporting technical infrastructure.

Integration can be divided in the four levels:

- Physical
  interoperability of devices/sensors, collaborative infrastructure, broadband internet
- Data
  integration of data standards, alignment of data definitions and datadictionaries, data quality and security
- Applications
  choice for open standards, adoption of open web services;
- Process
  business process modelling as new skill, process approach picked up in new areas

Using the above-described framework, the research focused on farm-related data exchange and ICT related issues in connection with internal (on-farm), inter (within businesses) and extra (business-chain) processes. These relevant relations were taken into account in the review of literature and the analysis of the state of the art in agricultural data exchange in the EU-27 and Switzerland.

2.2 Meta structure for literature review

Literature related to agricultural data exchange was gathered all over Europe from different sources. Over 300 different literature references tackling common, European or country-specific issues were collected. These sources have been meta structured, classified and uploaded to the agriXchange platform, which can be accessed via www.agrixchange.eu (following the menu: knowledge-literature) to search them.

The developed file meta structure is:

<Short source title>

<Full title>
<Authors>
<Country of origin>
<English version or abstract>
<Coverage/classification>

Business level	Coverage aspects	Agenda issues	Agric. area
Farm Agri- (food) business Agri- (food) chains	Economics Environmental Social *Common level*	EU/European National EU Regional	Arable Cattle Spatial *Common*

<Keywords/issues in this source (list up)>

About... (more words for better understanding)>

2.3 Structure for investigating the state of the art

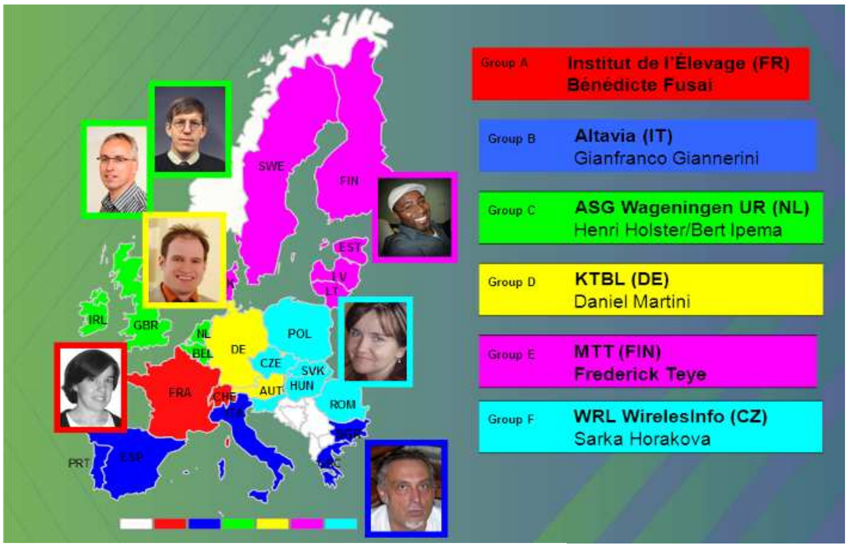


Figure 2. Focus groups and leaders

The aim of the investigation was to get an overview of state of the art of current data exchange in general within the EU and specifically within each EU region. The research has focused on farmers in connection with internal and external processes. External processes for example like (business) chain processes, and national and EU legislation. In general, the investigating part is built upon country reports were set up according to a specific template presented in deliverable 2.2 (D2.2. Research methodology for investigating the state of the art EU-27+Switzerland). In order to complete this research, the EU-27 and Switzerland were categorized into 6 focus groups, each with a consortium partner responsible for the conducted research (Table 1 and figure 2).

Table 1. Countries per focus group and responsible consortium partner.

Focus group	Regions / Countries	Responsible consortium partner
A	1. France 2. Switzerland	Institut de l'Élevage (FR) – BénédicteFusai

B	3. Italy 4. Spain, Portugal 5. Greece, Cyprus, Malta, Bulgaria	Altavia (IT) – Gianfranco Giannerini
C	6. UK, Ireland 7. Netherlands, Belgium, Luxembourg,	Wageningen UR Livestock Research – Henri Holster and Bert Ipema
D	8. Germany, Austria	KTBL(DE) – Daniel Martini
E	9. Baltic states: Latvia, Estonia, Lithuania, 10. Scandinavian states: Sweden, Finland, Denmark	MTT (FI) – Frederick Teye
F	11. Poland, Czech, Slovenia, Slovakia, Hungary, Romania	WRLS (CZ) – Sarka Horakova

For the investigation, semi-structured questioning (based on the template), followed by telephone interviews were used in this study. Each group leader planned his own work following the guideline that surveying was completed as much as possible by one-to-one contact. Experts were located in each country in order to answer questions which provided information for building country reports.

2.3.1 Country reports

For almost all countries, a report was created based on desk top analysis and interviews with experts. Some information in relation to specific agricultural characteristics was obtained from Eurostat (Anon., 2010) which mainly concerned information about developments in the structure of agriculture and ICT in general.
As far as was possible, data about farm automation, the level, and use of intra as well as inter enterprise were collected. These included information about the use of PC's, internet, mobile/handheld devices, farm management information systems, process automation systems, ISOBUS and e-business applications.

The country reports were composed based on a standard template, using the framework adapted from Giachetti (2004) (Figure 1) on data integration as a guideline for a systematic analysis of the existing situation.

The sectors tackled were arable and animal farming and special attention was paid to spatial aspects. Arable also includes horticulture while animal includes cattle, sheep, goat, pigs and poultry. The themes included in each sector were regional/country-wise agricultural characteristics, level of farm automation, process, application, data and physical level of data exchange. More details about the questionnaire can be found in the report "D2.2. Research methodology for investigating the state of the art EU-27+Switzerland"
Also use cases were discussed for each country. These use cases in the project were:

- LPIS (Land Parcel Identification System)
- Geo-farmer and fertilizing
- Animal registration
- Animal identification

2.3.2 Analysis

Focus group leaders delivered and shared their reports within the WP2 team. The draft reports were discussed and if necessary edited in this team.

After the evaluation of all available country reports a general overview was created of the European situation in agricultural ICT and data exchange. It was a qualitative overview of the state of the art in agricultural ICT and data exchange focusing on differences between regions, identifying and highlighting the main gaps and problems.

The relevance of particular use cases for each country was evaluated, eliciting information about interests, initiatives and/or challenges.

The results of the analysis for each country are presented in the next chapter under the headings:

- Trends in farm characteristics
- Farm automation level
- Data integration
- Europe and regions – remarkable area ICT issues
- Data exchange – maturity levels of data integration in the EU
- Meaning of standardisation
- Use cases and relevance in EU regions

3 State of the art on information exchange based on literature review

3.1 Developments driving the need for information integration in agri-food

In this section, current developments in agri-food sector are described that demonstrate the need for information sharing. Smooth exchange of information is needed, but as explained in the subsequent sections, in agriculture, this is not an easy task, neither in arable nor in livestock farming.

Current agri-food economy focuses on consumers and their food supply. The consumer should be enabled to make choices, based on aspects such as food safety, quality and sustainability (e.g. fair trade, CO2 emissions, etc.). Correct and complete information is crucial in this process. Moreover, Kinsey (2001) states that information becomes a competitive factor. This means that the business environment of agri-food production is dynamic, driven by various and changing needs of consumers and society. Production is becoming more demand-driven, has to be transparent and must meet high quality and environmental standards. Several incidents in the last decades (e.g. foot and mouth disease, swine fever, dioxin scandals) have made food safety one of the major issues for consumers and ultimately for producers. Trienekens and Beulens (2004) stated that governments, both national and international, respond by imposing new legislation and regulations and retailers react by new demands on their suppliers. Companies are forced to introduce sophisticated information systems focusing on identification, registration, tracking and tracing throughout the supply chain.

Meeting these requirements gives actors in the supply chain a ‘license to produce’. All this pressure comes at a time where there is significant pressure on EU producers by increasing direct and labour costs and costs generated by maintaining unsustainable land. One main answer to this development is to innovate towards a more demand-driven and knowledge-based production, which is in accordance with the overall objective of the EU knowledge-based bio-economy (KBBE).

3.1.1 Main strategic agendas describing the future needs with special attention to ICT

The general developments are addressed and elaborated in the investigated literature from a number of different perspectives. The majority of the literature mentions some developments in the motivation of the research and then focuses on the analysis or development of specific issues. Literature including a more in-depth analysis of driving forces includes:

a. The vision on the future value chain for 2016 by the Global Commerce Initiative (GCI, 2006);
b. The strategic research agenda of the AMI@Netfood project (AMI@Netfood, 2006)
c. The research agenda of the European Platform for Food for Life (Food4Life, 2007)

d. The analysis of drivers by the Future Farm project (Charvat, Dreger et al. 2009)
e. The third SCAR Foresight exercise (Freibauer et al., 2011)
f. The Research Agenda and the Action Plan by the Technology Platform for Organic Food and Farming (Schmid et al. 2009, Padel et al., 2010)
g. Vision, Strategic Research Agenda and Third Implementation Action Plan (2009) of the European Agriculture Machinery Industry (Subplatform AET of the Technology Platform MANUFUTURE

Below, the seven agendas on ICT are explained briefly. More extended explanation can be found in the report "D2.3 State of the art data exchange in agriculture in the EU27 & Switzerland".

<u>Sub a. Future value chain for 2016 by the Global Commerce Initiative</u>
The Global Commerce Initiative (GCI) has described the future value chain for 2016, in particular from a retailers perspective (GCI 2006). They identify several external driving forces, outside the direct control of industry, retail and consumer product companies that can be grouped into five areas:

I. Economic issues, including the reshuffling of the world's top economies, the growing gap between industrialized and developing countries, as well as a focus on social responsibility among the more developed countries in areas such as fair trading.
II. Ecological issues, including water, energy and fuel scarcity and efficiency, sustainability and waste management.
III. Changing demographics, such as the shift in global population, urbanization and cross-border migration.
IV. New technologies, such as virtual reality, quantum computers and information networks, have the potential to make data, people and objects accessible everywhere and immediately.
V. Regulatory forces, including extended legislation on health and wellness (for example, labelling of products) and privacy standards.

About information sharing they state the following:

> *Companies must be prepared to share standards-based data free of charge. Sharing information (such as supply chain events) between trading partners will result in an improved information flow and, as a consequence, improved collaboration to better serve the consumer. A resulting collaborative information platform could become the basis for further supply chain solutions, like demand-driven ordering and collaborative promotion planning.*

Thus, GCI envisions an open network, with flexible relationships between network partners, which implies less hierarchical, linear chain structures. This has consequences for innovation that will be developed within these open networks, together with changing, sometimes anonymous, partners. There will be less focus on the products themselves and everything is considered as a service. ICT could enable information sharing and thus facilitate and improve knowledge-based production.

<u>Sub b. The strategic research agenda of the AMI@Netfood project</u>
Related to this potential of ICT, fourteen organizations from different countries initiated the EU-supported AMI@Netfood project (AMI@netfood) in the sixth framework program. The project results showed that there is a clear need for a sectoral-oriented approach on ICT in agri-food and rural domains. Currently, such sectoral approaches are not effectively implemented in all EU regions, or as EU-RTD strategies. To achieve a more effective implementation of EU-wide RTD activities, it will

be necessary to harmonise the different RTD strategies in different regions. Currently, cross-regional collaboration is limited, and inadequately implemented. The AMI@Netfood working groups have highlighted the importance of supporting the new vision of Collaborative Working Environments in the agri-food and rural domains. They envisage a new collaborative environment oriented to directly supporting the activities of individuals and groups, allowing effective collaboration across diverse actors in the agri-food industry, consumers and the wider community, especially in rural areas.

Sub c. The research agenda of the European Technology Platform for Food for Life

The European Technology Platform Food for Life has developed a Strategic Research Agenda (SRA), presenting the priorities for research, communication, training and knowledge transfer in the food sector for the coming years. Eight research challenges are defined: ensuring that the healthy choice is the easy choice for consumers, delivering a healthier diet, developing quality food products, assuring safe foods that consumers can trust, achieving sustainable food production, and managing the food chain.

However, the platform states that for successful implementation of the programme further prioritizing is required. This has resulted into three key trusts, involving research that will lead to improved competitiveness of the agro-food industry by developing new processes, products and tools that:

- Improve health, well-being and longevity
- Build consumer trust in the food chain, and
- Derive from sustainable and ethical production

Sub d. The analysis of drivers by the Future Farm project

The Future Farm project has identified five main drivers which influence strategies in worldwide organizations and on markets. They are as follows:

1. WTO negotiations and reform of the Common Agricultural Policy
2. Global competition in production of agricultural commodities and the food market with focus on the business model and profitability of farmers.
    - Precision Agriculture technologies, adoption of technological-production models by farmers in specific areas in Europe with technological and knowledge support from service organization & Universities and Research organizations
    - Development and Improvements in agricultural productivity from RTD & Innovation in biotechnology and GMO crops
    - Development and improvements of Robot based technologies
    - Development and improvement of New Information and Communication Technologies and their adoption to Agriculture production in rural areas
3. Climate change and its increasing sensitivity to the impact of human activity on the environment as infinite resource
4. Addressing long-term energy security and sustainability challenges
5. Social and demographical changes: growing population and growing demand of food, urbanization, aging population and health issue, and ethnical and cultural changes in society

Sub e. The third SCAR Foresight exercise (Freibauer et al., 2011)

The purpose of the 3rd Foresight Exercise (FEG3) of the Standing Committee on Agriculture Research (SCAR) is to update the state of some critical driving forces and to focus on the transition towards an agricultural and food system in a resource-constrained world. Rising resource prices in recent years, combined with increasing global demand for resources due to a growing population and increasing wealth, have brought the issue of resource scarcity to the forefront of the political agenda. In light of agricultural production in a 30-40 years perspective, the following issues were identified as most critical: (1) “Classical” or “old” scarcities related to natural resource use: fertile land, freshwater, energy, phosphorus, and nitrogen, (2) “New” scarcities related to environmental limits that aggravate the “classical” scarcities: climate change including ocean acidification and biodiversity loss, and (3) Societal contributions that aggravate these scarcities but can also become important pathways for transitions to sustainable and equitable food consumption and production.

<u>Sub f. The Research Agenda and the Action Plan by the Technology Platform for Organic Food and Farming (TP Organics)</u>
TP Organics has published a Research Vision 2025 (2008) and a Strategic Research Agenda, with concrete research priorities (2009). The Implementation Action Plan considered how innovation can be stimulated through organic food and farming research and, crucially, translated into changes in business and agricultural practice. TP Organics argues for a broad understanding of innovation that includes technology, know-how and social/organizational innovations. Accordingly, innovation can involve different actors throughout the food sector.
The action plan also addresses knowledge management in organic agriculture, focusing on the further development of participatory research methods. A key role for ICT in particular is in providing new information management systems and better communication between the different actors. In the future, ICT will also play an important role in communicating values and providing tools for consumers to enable ethical decision making concerning food (already tested in the organic food sector in a pioneer phase).

<u>Sub g. Vision, Strategic Research Agenda and Third Implementation Action Plan (2009) of the European Agriculture Machinery Industry (Subplatform AET of the Technology Platform MANUFUTURE)</u>
The proposals of AET in their vision, Strategic Research Agenda and their Action Plan emphasise the need for research in the following areas:
Sustainable Plant Production: Smart Sustainable Agricultural Production Machines Systems and Architectures, Innovative power train technology in mobile working machines, Safe Workplace 2025 / Future Agri Human Machine Interfaces. Improved machine efficiency,
Sustainable Animal Production: Innovative and Animal Welfare related Milking Technology, systems for small and medium sized livestock units (SMLU) and organic farms (OF), Climatisation of animal facilities. Bioenergy and Renewable Materials: Biomass provision concepts for future biofuel applications. Harvesting and provision chains for new agricultural biomass residues, etc.
For these technological applications the use of information technologies and sensors play an important role.

3.1.2 Main ICT agenda in summary

Current developments in agri-food are making the issue of information sharing a crucial factor. The smooth exchange of information is needed, but in agriculture this is not an easy task. Technical challenges and organizational changes and cooperation should go hand-in-hand (Wolfert *et al.*, 2010). Several strategic platforms and networks have worked on ICT agendas, visions and strategy, specifically in agriculture and some of them more in general but very much related to the agriculture economic business. In table 2 an overview is made of the main internal driving forces per platform divided into technical and organisational aspects.

Table 2 Internal forces and challenges according to the main platforms and projects

Internal force / Platform	(technical) Infrastructure and services	Organisational, environmental and collaborations
GCI	Focus on services instead of products. Organizing and streaming large amounts of data (data warehousing). Accessible knowledge in right context Combining knowledge and data in meaningful models (e.g. in Decision Support Systems).	Information sharing (inter-enterprise). Open networking.
AMI@Netfood	Key issues: traceability of products and services ICT applications & infrastructure.	Sectoral-oriented approach and harmonize RTD strategies in different regions. Cross regional collaborations. Collaborative working environments. Innovation & developments in rural area.
Food4life	.	Improve health, well-being longevity. Sustainable and ethical production. Building trust. Awareness of impact of research on business efficiency, production costs and robust markets. Communication, training, knowledge transfer as means for building consumer trust and engaging industry.
Future farm	Global competition in agricultural production: • Precision Agriculture • Development and improvements by GMO and biotechnology • Robots based technology • New ICT and adoption	Reform CAP and WTO negotiations: Adoption of new ICT and Precision Agriculture. Climate change and impact on resources Long term energy security and sustainability.
Third SCAR Foresight Report	Importance of open source knowledge systems. Prerequisites that must be provided for better use of ICT: access, capacity (skills) and applications (services).	Better efficiency in resource use and substitution in a world of more scarcities and environmental limits. Empowerment of farmers in the innovation process with better farm management decision support tools based on ICT.
Technology Platform for Organic Food and Farming	Key role of knowledge management ICT tools for farm management as well as in communication in the supply chain (including consumers).	From top-down knowledge transfer to expanding (learning) networks or living labs supported by ICT. ICT also important to make informed choices and improve sustainability.
Technology Platform MANUFUTURE-AET subgroup	For sustainable plant production and animal production & bioenergy – key role of ICT for technological applications of the Agriculture Machine Industry. High potential to combine ICT, robotics and sensor technology.	

The internal driving forces in table 2 are based on technical and organisational issues. Regarding the developments driving the need for information integration in the agri-food sector, there are different visions, however in general they have a lot of similarities described from different perspectives. GCI for example mentions five areas of external driving forces (economic, ecological, demographics new technology and regulatory issues). There is a requirement for innovations which are built on information sharing, open networks and new services rather than products.

The AMI@Netfood group use words like traceability of products & services, collaborative working environments and innovation & development. The SRA of the European Technology Platform for Food for Life uses words like: trust, research (to improved competitiveness by developing new processes) and development of new products and tools. The Future Farm addresses five drivers of influence on strategies in worldwide organizations and on markets. Some are trade and business based, like WTO and reform of Common Agriculture Policy (CAP), global competition. SCAR Third Foresight Expert highlights the importance of ICT as farm management tool in a world of scare resources. The Technology Platform for Organic Food and Farming is emphasizes the importance of ICT for new information management systems. Others are addressing energy, climate change and social and demographical issues.

Strategic driving forces that create the need (structures and processes) for information in agriculture require an overview of the current issues and developments in practice. Subsequent sections present these practices.

3.2 Current developments related to information integration in agri-food

This section provides an overview of the state of the art derived from the literature review. First it describes the main domains of application, i.e. i) livestock farming including ISO-Agrinet, ii) arable farming and precision agriculture, and iii) spatial data. Next, a general analysis is provided. The current issues of information integration in agri-food are described at five levels: organisational, process, application, data and technology.

The states of the art in three domains are described. On the intra-enterprise integration level (‘in farm’) and on the inter-enterprise integration level.

3.2.1 State of the art in Livestock farming

For livestock production, the quantity of data exchange is numerous and various. Data exchange exists between farmers and breeding organizations such as milk recording agencies, artificial insemination cooperatives and herd books. Different EU regulations result in flows between farmers and the governments, for animal traceability (e.g. in cattle registration), and between farmers and their suppliers for food chain and tracability information requirements. The increasing use of automatic devices on farm such as automatic feeders, automatic milking systems (AMS), results in an increasing need for communication between devices and on farm management information system. Within the farm system, especially in dairy operations, there is a need to integrate data from different systems: feeding, milk performance, milk composition (quality), reproductive performance, health, heifer rearing (again, feeding, performance, reproduction).

In the future, the situation could become more complicated with the possible development of sensors connected with on-farm management system by electronic identification (for example through RFID). In addition, livestock farmers have, like arable farmers, to cope with data exchange for field information (spatial data). For these different cases, different standards exist, which are maintained by different bodies at different levels, but with limited and scattered coordination: ISO, government agencies, UN/CEFACT, national and international EDI associations. There is no general view or agreement of the needs from the farmer’s point and the different systems are usually not interoperable. The major part of the standards is focused on data dictionaries and message structure. They do not take into account the specific farmers business requirements. In other words, they are not always based on or build upon real business processes, which results in an additional burden of administrative work (Annevelink, Holster et al., 2004).

Intra-enterprise integration

Process automation technology is mainly applied in dairy cattle, housed in free stall barns. The technology controls in particular processes around the animal, like feeding and (robotic) milking control. In recent decades, many sensors have already been made available to assist in the daily management of a dairy farm.

An important break-through was the introduction of electronic identification in the mid seventies. This offered the possibility to approach and treat each animal in a herd individually. One of the first applications of individual animal management was in the provision of concentrates (Rossing, 1976).

Meanwhile, many more sensors are used in dairy farming, such as to record milk yield, milk conductivity and animal activity (Hogeveen & Ouweltjes, 2003). These are mainly used for monitoring milk quality and production and the health and reproductive status of individual animals. Software tools are available for processing the recorded parameters. Large deviations from the expected values are reported to the farm manager as an aid for daily management decisions.

In farm management systems all relevant farm and cow data are stored. In some cases connections are made with external databases for relevant data exchange.

An important mile-stone in the further development of individual cow management was the introduction of automatic milking systems. It is the ultimate example of how technology can be highly adapted to the cow. The first AM-systems on commercial farms were implemented in the Netherlands in 1992. From 2000 automatic milking became an accepted technology in the Netherlands and other European countries, but also Japan and North America. At the end of 2009, there were over 8000 commercial farms worldwide using one or more AM-systems to milk their cows (Koning , 2010).

Inter-enterprise integration

The traditional data-and information flows between the dairy farm and chain partners are generally well mapped and textured (Kuipers et al., 2005). The external processing of business data into specific management support information has an important position in dairy farming. A very important branch is the processing of accounting information into tax information and in addition with technical farm data into economic business indicators. Other suppliers, processors and service providers, processing and service providing organizations process farm data into farm management information.

According Regulation (EC) No 1760/2000 each EU Member State has to establish a system for the identification and registration of bovine animals comprising 1) ear tags to identify animals individually, 2) computerised databases, 3) animal passports and 4) individual registers kept on each holding. Each dairy holding has a unique registration code and each bovine is marked with two ear tags with a unique identifier (ID code) of the animal. The bovines are registered by the ID code in the computerized central database. Modifications in the herd (birth, death, buying or selling of cattle) should be reported to the database. There are various options for passing on modifications, online at a website, by telephone or by the reporting system of a third party, with each country having slightly different components within the system The database is designed in order that the government can perform all necessary analysis in case of a contagious animal disease outbreak or food safety problem.

In many countries farmers are required by the dairy processing industry to participate in a quality assurance schemes. With regard to animal health, farms need to have a registration system for recording health problems and applied veterinary medicines per case and animal.For guaranteeing the use of veterinary drugs and the animal health and welfare status of the herd, the farms are visited by a bovine veterinarian on a regular basis.

Animal health service organizations play a major role in monitoring animal diseases. The registration of contagious animal diseases like FMD, BSE, tuberculosis, brucellosis and leucosis are statutory duties. Information relevant for monitoring programs is collected from the laboratories and farm visits and is processed in expert systems and reported to the government.

Various data are collected on-farm, processed and made available to the farmers via the Internet. Fertility and milk production data at the cow level are the starting point of the services of breeding organizations to farmers. This information is often shared with other service providing experts like veterinarians or feeding advisers. Data on production levels, fertility and somatic cell count (SSC) are also made available for monitoring programs of the government.
Data on composition and quality of milk delivered by dairy farms to dairy companies are determined by laboratories and used for payment. The dairy industry provides milk payment data via the Internet. Per month overviews of delivered milk, fat and protein quantities with associated prices are given. Also information about the current milk quota situation of the farm can be consulted in this way.

The composition and quality of home-grown forage is on many farms determined by specilized laboratories. This information is used by the farmer or feeding adviser for optimizing the feeding ration for the dairy herd.

Due to EC Directive 91/676/EEC (Nitrate Directive) each farm is obliged to keep track of mineral flows (nitrates, phoshates) entering and leaving the farm. For a dairy farm this concerns for example fertilizers, feed, milk or live cattle. Feeding companies and dairy processing companies make this information available for the dairy farmer. Mineral quantities are calculated from the amounts and mineral compositions of the feed supplied to and the milk received from the farm. This information is available for the farmer through the internet. Together with information about changes in herd composition and forage, manure and fertilizer supplies an annual review of the mineral balance is composed for the official authorities. All of this information is stored in different databases and could be used by farmers to make decisions for complying with directives. For example, in Ireland between the Irish Cattle Breeding Federation, the milk processor, Agri trade merchant and the Government agricultural department all of the necessary information required for making submissions to comply with legislation is available.

Feed manufacturers provide the service to compose concentrates based on forage quality and milk yield and composition data. Invoices from the feed suppliers can be viewed via the Internet and can be retreived as an XML message and stored in the farm management system or forwarded to the accountant.

On dairy farms the farm management system is increasingly used for exchanging electronic messages with external data sources according EDI standards. These standards are for example available for exchanging information about individual cow milk monitoring, animal identification & registration events, insemination events, veterinairy treatments and milk deliverd to dairy processor.

Furthermore the regulations for organic food and farming EC Regulation 834/2007 and EC Regulation 889/2009 require a detailed documentation about animal treatments as well as the feeding, as to ensure that the requirements of the organic regulation is fullfilled through third party control and certification. Many accredited certification bodies have introduced ICT-based data collection, documentation and verification systems.

3.2.2 State of the art in Arable farming and precision agriculture

In arable farming, machines play an important role. Data exchange between machines at field level and management systems at farm level is supported by an extensive and widely adopted ISO standard (ISOBUS/ISO11873). However, data exchange between different systems at farm level is insufficient. Some examples of some point-to-point interfaces are found, but there are no common standards for data exchange at this level of integration. Information exchange between farm and other actors (e.g. advisors, government, processors) is also not sufficiently organized (Wolfert et al., 2010).

One path to put sustainable agriculture in place around plant production is to improve husbandry through better process control, so called precision agriculture (PA). This includes better accuracy in timing and spatial allocation of task execution. New automation, ICT and GIS technologies provide solutions for steering and controlling site-specific production systems to fulfill requirements of safe, efficient, environment friendly and traceable production. In order for efficient task completion, there is a requirement for user centred on line support. Efficient connections to support services are essential. To run data analysis and planning models, service providers need connections and data transfer between numerous data sources. To enable compatibility between different system parts that are needed in performing PA, an information management system which utilizes open system interfaces and ICT standards, such as ISOBUS, and efficient data transfer are required. At the moment, PA information management is based on PC software solutions, and data transfer between the management system and mobile unit, occurs through memory cards or sticks. Often, data transfer takes place in different versions of the proprietary ESRI 'Shapefile' format. However, a cost efficient solution for arranging support in task execution (task download, documentation upload) in the field is to maintain a wireless internet based remote support system, which can be used for communication between several parties (Pesonen et al., 2008). In these kind of systems data transfer takes place in XML format, organized using standardized schemas.

Steps in this development direction have already been taken with success (e.g. www.bitcomp.fi.). Real-time support, automated assistance and robotics in PA require distributed computing. Efficient data exchange is a fundamental requirement for such distributed data processing. Therefore, there is a need to harmonize or standardize data transfer formats, and to some extent also data models, for better economic efficiency. Closely related to precision agriculture and an important technological aspect of the monitoring of agricultural production is real time integration of *in situ* sensor measurement, remotely sensed data and tools for precision farming and agro-meteorological modeling in decision support systems for farmers. This integration requires deep knowledge of areas such as sensor protocols, handling of sensor data in an internet infrastructure, agro-meteorological modeling, etc. Another crucial element is interoperability across the information flow chain and the need to guarantee modularity of all solutions with the possibility to replace, add or modify single components and the applicability to multiple agriculture scenarios. Current issues in the use of sensors are:

- the immediate access to information and the rapid communication to farmers are the base for efficient decision making during crop production;
- the use of wireless sensor networks could contribute to increase quality and effectiveness of agricultural production. Sensors could be also installed in vehicles or even can be carried around in the field by personnel involved in surveillance and other activities;
- the sensor interfaces and application services may need to interoperate and be bridged at any of many locations in the deployment hierarchy;
- large-scale sensor networks impose energy and communication constraints, thus it is difficult to collect data from each individual sensor node and process it at the sink. The integration of sensor networks within the web environment may be based on a standards stack defined by the Open Geospatial Consortium (OGC) initiative called Sensor Web Enablement (SWE).

3.2.3 State of the art around Spatial information

Spatial data in agriculture is playing an important role in society and also in agriculture. Several areas of interest are discussed in this paragraph.

Interoperability and standardisation
Spatial Information is increasingly playing an important role in society and also in agriculture. For crop production machines, the ISOBUS standard adresses data exchange and compatibilty between hardware systems for crop production in agriculture. Although ISOBUS includes aspects such as the task controller and management information system data interchange that includes some information (ISOBUS XML) concerning location and spatial data integration, the specification is rather limited; does not cover all aspects of data communications between the working environment of agricultural machines. Furthermore, on the software level in the farm management information systems (FMIS), there currently exist no specified standards for spatial data format representation and communication between other systems. In 2012, the Agricultural Industry Electronics Foundation (AEF) has initiated harmonizing of interfaces between ISOBUS and FMIS systems.

In recent years, problems associated with interoperability and compatibility of spatial data between different software and agricultural systems has been the topic of discussion amongst the geographic information community. Much effort has been placed towards spatial data harmonization in the past and positive results are emerging especially in efforts towards standardisation work of the Open Geospatial Consortium, Inc. (OGC) and ISO/TC211 Geographic Information/Geomatics. Another relevant harmonization work is related to the INSPIRE Directive.

The INSPIRE directive aims to create a European Union (EU) spatial data infrastructure. This will enable the sharing of environmental spatial information among public sector organisations and better facilitate public access to spatial information across Europe.
The scope of standard development of ISO/TC 211 is also relevant and includes information technology, GIS, Remote Sensing (RS), Global Position System (GPS) and other advanced concepts, models, patterns and technical methods. Geography Markup Language (GML) is identical to ISO standard 19136:2007. GML is ‘‘an XML grammar written in XML Schema for the modelling, transport and storage of geographic information. GML provides a variety of kinds of objects for describing geography including features, co-ordinate reference systems, geometry, topology, time, units of measure and generalized values’’. (Botts et al. 2008).

Remote Sensing

Currently, remote sensing is a practical management tool for site-specific crop management. Remote sensing, today, incorporates new technologies that provide increasingly efficient, complete, accurate and timely information. Currently, different satellite data and properties vary in technique, spatial resolution, spectral range, and viewing geometry. Turner et al. (2003), Gillespie et al. (2008) provided several examples of identifying biodiversity and plant species based on the high spatial resolution imagery. In agricultural applications Nagendra and Rocchini (2008) summarized that hyperspectral data have been successfully applied in recording information regarding critical plant properties (e.g., leaf pigment, water content and chemical composition), discriminating tree species in landscapes, and fairly accurate identification between different species. Thermal remote sensing plays an important role in observation of Earth surface characteristics, and is very useful for research regarding analysis of biophysical Earth processes, in particular landscape characterization and measurement of land surface processes (Quattrochi and Luvall, 2009, Crow and Zhan, 2007). Constellation of Small Satellites of mass in the range of 1–500 kg has potentials for use in agricultural applications. With the launch of DMC (Disaster Monitoring Constellation), the concept of the Earth-observation constellation of low-cost small satellites has been put into action. It is capable of obtaining multispectral images of any part of the world every day (Goward et al., 2009, Goward et al., 2009). Light Detection and Ranging (LIDAR), also called Laser altimetry, is an active remote sensing technology that utilizes a laser to illuminate a target object and a photodiode to register the backscatter radiation. LIDAR was underlined by as one of the strong interests of the remote sensing community in ecology (Wang et al., 2010, Lim et al. 2003).

Spatial location and monitoring of animals

The extensive livestock industries are becoming increasingly interested in the application of remote sensing technologies for monitoring livestock and measuring biometric data without the need to interfere with the animal by mustering and yarding. In addition, considerable effort has been put into developing systems that can determine animal behaviour from 'on-animal' motion sensors and recent research has combined motion sensors with spatial information to predict behaviour. Research has also been undertaken into the potential for spatial data to predict the behaviour of livestock (Schwager et al. 2007). Movebank (www.movebank.org/) is one example of a web based spatial database that can be used by researchers to enable sharing of spatio-temporal animal movement data.

Virtual fencing

The idea of controlling animals and keeping them in a spatial enclosure, or excluding them from certain areas, without fencing started nearly four decades ago. Virtual fencing offers the potential for improving the efficiency in which grazing management is carried out. One major advantage is the flexibility in managing stocking density it can provide. Umstatter (2011) did a thorough review of the development of virtual fencing which is given here. The review stated experiments of Monod et al. (2009) between 1999 and 2003 with newly developed system, using collars and an insulated wire, with cattle. Quigley (1995) also describes a virtual fencing system for livestock such as cows, sheep, pigs, goats and horses. In Tiedemann et al. (1999) study were six pie-shaped pastures established with an electric fence. A virtual fence system based on tracking animals with GPS was trialled in the USA on cattle. Bishop-Hurley et al. (2007) used single animals with a neckwearable virtual fence system under experimental conditions and were "successful in eliciting a behavioural response from the cattle".

Fleet management and control

Spatial information plays an important role in the control and management of agricultural machinery fleet. The introduction of Fleet Management became widely adapted in industrial domains, such as the transport business from the end of the 1980's. Within this scope, fleet management applications can be for plant production vehicles and equipment, food transportation vehicles and unmanned Aerial Vehicles. Although farm management systems (FMS) software started as a simple means of managing companies' growing number of mobile transport assets, today it functions as a whole system with added value (Crainic and Laporte, 1998). One of the main reasons for the popularity of fleet management and control systems is its ability to improve efficiency and productivity of mobile vehicles for an enterprise or organization. Analysis carried out by Quinlan et al. (2011) has shown that there is still signifiant scope to reduce transportation costs in milk transport Ireland through optimising key components of the production chain. Fleet management chain in agricultural crop production consists of two main components a Transport Telematics; located on the vehicle, which serves and receives network information and an Software Application; running on a computer located in the outside world (Kelly and Hatfield, 2003, Borirug et al. 2009, Ruiz-Garcia et al., 2009).

Unmanned Aerial Vehicles

Unmanned Aerial Vehicles have been adopted for various agricultural applications in recent years. Techy et al. (2010) describe the use of a control strategy (coordination via speed modulation) to synchronize two autonomous fleet UAVs for spatial aerobiological sampling of the potato late blight pathogen, Phytophthora infestans. Göktoǧan et al. (2010) also presented a novel application of an autonomous rotary-wing unmanned air vehicle (RUAV) as a cost-effective tool for the spatial surveillance and management of aquatic weeds. Hunt Jr. et al. (2010) remotely controlled and monitored a small Unmanned Aerial Vehicles (UAVs) for winter wheat and the authors found a good correlation between leaf area index and the green normalized difference vegetation index. In their research Huang Jr. et al. (2010) presented an overview on the development of three UAVs for crop production management. Lelong et al. (2008) focused on the use of light-weignt UAV for remote sensing for precision farming.

Auto steering and autoguidance

The first GPS implemented automatic steering systems were introduced by companies already involved in machine control in the 1980's. Over the last 5 years, the market for automatic steering systems has substantially grown. The number of suppliers has grown and the tractor manufacturers have started to offer integrated ex factory steering solutions. ISO 10975:2009 specifies safety requirements for auto-guidance systems used in agricultural tractors and self-propelled agricultural machines. For total/autonomous navigation a number of prototype autonomous guidance systems have been developed but have not yet proceeded to commercialization (Zhang et al. (2002), Søgaard et al. (2005), Billingsley et al.(1997)). GPS and machine vision fused together or one fused with another auxiliary technology is becoming the trend development for agricultural vehicle guidance systems.It is forseen that application of new popular robotic technologies will augment the realization of agricultural vehicle automation in the future.

Sensor networks – spatial allocation and timing of management applications

The automatic sensors for monitoring growing conditions such as the soil moisture sensors with loggers or automatic weather stations have been available and used in agriculture for last few decades (Nittel & Stafanidis, 2005, Hart & Martinez, 2006). The Sensor Web Enablement (SWE) framework of Open Geospatial Consortium (OGC) have defined standard protocols, interfaces and web services to discover, exchange and processing data from different sensors and sensor networks and to task sensor networks (Botts et al., 2008). In crop production, sensor networks are most commonly employed in real-time weather monitoring for timing management practices, in supplying data on soil and weather conditions or yield to the farmers and in precision agriculture (Wang et al. 2006, Pierce & Elliott 2008, Lee et al., 2010). In site-specific irrigation management soil moisture sensors and weather stations are utilised in defining management zones, but also in deciding timing and amount of water applied and validating irrigation efficiency (Vellidis et al., 2007, Chavez et al., 2010). The potential benefits of sensor networks for agriculture are several; they have the potential to improve efficiency and productivity of agriculture and product quality while reducing unwanted environmental side-effect of crop production (Lee et al. 2010, Ruiz-Garcia et al., 2009, Vellidis et al., 2007).

3.3 Implications for ICT

Looking at the general challenges and developments in the agri-food sector as described in section 3.1 and on-going developments on information integration (section 3.2), several implications on the need for new ICT and data interchange structures can be identifed. Then next sections will describe these implications in more detail for arable and livestock farming and more specifically spatial aspects .

3.3.1 Livestock

In an inventory (Kuipers et al., 2005), dairy chain partners were asked about the most important information issues for now and in the near future. For the consumers, food safety, animal health and welfare and sustainability are high on the list. Dairy producers and processors need to take the lead in providing the consumers with the essential information.

Food safety – animal health

Several organizations revealed that the registration of drugs in the primary business (farmer-veterinarian) is not effective. To protect public health, there are continuous efforts by the Member States of the European Union to reduce the presence of undesirable residues of pharmacologically active substances in food of animal origin. An important aim in the field of antibiotics is the reduction of antimicrobial resistance. A more selective and restrictive use of antibiotics in the different livestock sectors is therefore needed. To achieve this, more information about the application of antibiotics in general but also on the level of individual farmers and veterinary surgeons should become available (Bondt et al., 2009). Benchmarking will lead to a stronger awareness and responsible antibiotics use on the livestock farms and among veterinary surgeons. With sufficient support in the sectors an obligation could be incorporated within the quality assurance system for livestock farmers or veterinary surgeons to supply already available electronic data on veterinary medicine use for storage in a central database.

Animal welfare and sustainability

Facing the increasing societal demand, initiatives at national or European level have been developed for the protection of farm animals. In parallel, also commercial strategies emerged sometimes as part of more general quality assurance labels ensuring food quality and safety or environmental issues. The European project Welfare Quality® developed assessment protocols for animal welfare on the farm or at the slaughterhouse (Botreau et al., 2010). This multicriteria assessment tool was developed with a view of helping farmers and slaughterhouse managers to identify welfare problems and monitor progress, as well as providing information to customers about the animals from which they buy products.

It is not always necessary to extend collective data systems or even to build complete new systems. Creation of smart links between existing data bases would provide the required information. In such system each party can make information or data available. Parties remain themselves responsible for the quality of the supplied data.

The processing industry agrees that welfare and sustainability are important issues. Any new developments around data and information exchange on these topics between producers and processing companies offer better opportunities for ensuring the quality of the raw materials.

Expected ICT developments

External storage and development of service will increase data exchange

Market forecasts (Stormink & van Buiten, 2009) speak about developments towards external storage of farmer's data in the coming years. The Internet will be used to have entrance to all the data, knowledge and services from all kinds of knowledge providers. Information for farmers will be increasingly tailor-made in applications such as benchmarking, complex decision support models (Mol *et al.*, 2007). This way of interactive use of data processing will encourage more and better registration, data collection and data exchange on the farm and in the chain.

Centralized storage and PDA/smartphone usage (FMIS on farmer's PC vs. Dairy Data warehouse)

Farm Management Information Systems are changing in its structure. In the near past, and still, it was quite usual to have a FMIS as a stand-alone application on the farmer's PC. Stand-alone in a way of storing the management data locally rather than being closed as they still can have a rich way of data exchange to all kinds of inter-enterprise organisations. Farmer's information systems storage is now moving to central places or the cloud. Central can mean central on the farm, which makes it possible to use together more (wireless) inputdevices, or as hosted storage on a distance where data of other farmers (and others) are stored. Benefits of centralized systems are evident, looking at the decrease of risks of storage damage, but also the availability of the data for other partners, and hence to other services, in the chain can be beneficial.

New FMIS systems with a kind of chain integration will likely come up and will probably get into competition with more farmer's dedicated systems.

Sensor technology and RFID as booster for new data and services

On-farm level radio frequency identification (RFID) for feeding concentrates to individual dairy cows is already in use for decades (Rossing, 1976). Experience gained during the foot-and-mouth disease epidemic in 2001 highlighted the need to establish traceability systems for cattle based on electronic identification of individual animals. Since January 2008, electronic identification is mandatory for sheep and goats (Regulation (EC) No 21/2004). In Denmark, electronic tagging of cattle is already mandatory from June 2010 (Hansen, 2010), more countries are expected to follow in the next years.

More effective and efficient ways of managing group or even individual animals, enabled by RFID technology, will lead to major economic improvemements and sustainability benefits. ICT makes it possible to increasingly take into account individual differences, offering shaping and controlling husbandry conditions for each animal. Also in the field of sensors interesting developments are expected. Using new software techniques, combining data and additional analysis of for example milk samples, will largely improve the interpretation of data from sensors.
Meanwhile, first systems are on the market for on-line analysis of certain bio-components in milk (Blom & Nielsen, 2009). The information is subsequently used for daily feeding and health management activities on the farm.
Sensors can produce large amounts of data, software tools signal when there are deviations from expected or normal values. Further developments do not only focus on signalling but give also advice for a treatment or can even manage automated actions.
Currently, ongoing research is identifying possibilities for clever agricultural applications of technologies that are already widespread in our daily lives (mobile phones, navigation systems). These wireless sensor technologies will again expand the available information about the production environment (climate, weather, housing) and production factors (animals, feed).

3.3.2 Arable

The idea of having robot performing agricultural field operations is far from new. As early as the 1950s and 1960s prototypes of 'driverless tractor' that use leader cable guidance systems were already available. The advancement and complexity of techology for arable agriculture have created the need to harmonize data exchange between systems. The following sections present some of the adapted technologies in arable farming.

Sensing techniques, unsolved issues

The availability of equipment with more computing power that are small in size and relatively inexpensive make it possible to utilize various sensing techniques such as global positioning systems (GPS), machine vision, dead-reckoning sensors, laser-based sensors, inertial sensors and geomagnetic direction sensors. Unfortunately, fully autonomous machines are not so common in open environments such as farm fields due to unsolved issues such as human-machine safety and reliability issues. Interoperability, data transfer and data harmonization are also one of the major hurdles to overcome as agricultural machines are chained and manufactured by different companies. ISO standard ISO 11783 specifies the data BUS communication standard between the tractor and implement chain. However, the integration of different networks from external intelligent systems such as environmental sensors amongst others is still not integrally available.

GPS as backbone

As reported by the FutureFarm EU project, geographical positing systems (GPS), is one of the backbones of future agricultural technology. There is the need for standardizing the input or recording, and field data collection, like field surveying, yield mapping and soil sampling. The output or reacting technologies, the Variable Rate Applications (VRA), especially for seeding, fertilizers and pesticides, have to be standardized in terms of all connecting databases and interfaces. Existing standards for the transfer and storage of geo-data has to be explored more for use in geo-location, sensor information, process data and decision support. Currently the relevant standards are defined by the OGC (Kresse & Fadaie, 2004, OGC, 2007): WMS (Web map service), WFS[-T] (Web feature service [transactional]), WCS (Web coverage service), WPS (Web processing service), GML (Geographic markup language), ISO 19115 (Metadata standard for geographic data sets), SFS (Simple features specification) and CTS (Coordinate transformation service).

Documentation of production processes

Documentation of production processes requires detailed information of each working process. Currently, almost all crop farming processes are machine aided, what makes automated process data acquisition on agricultural machines an important data source for management and traceability tasks. The concept of Agricultural Process Data Services (APDS) as a mean of traceability was introduced by Steinberger et al., 2004. This ADPS can deliver the information basis of raw material production and was developed in framework from the research project Preagro (Steinberger et al., 2006). The aim of this project was to develop a management system for site specific crop production, in order to increase the profitability of agriculture and to enhance the benefits for the environment.

Traceability

According to the actual regulation in the European Union (applicable since 2005), traceability is required in all stages of the supply chain, covering all food and feed as well as business operators without prejudice to existing legislation on specific sectors such as beef, fish, GMOs (genetically modified organisms), etc. A food business operator must register and keep information such as: (1) name, address of supplier, nature of products which were supplied from him, also, (2) name, address of customer, nature of products that were delivered to that customer and (3) date of transaction/delivery. Also, there is additional information which is highly recommended to be kept: volume or quantity, batch number and a more detailed description of the product. ISO (International Standards Organization) ISO/DIS 22005, focus on the same approach to traceability ("one-step-up/one-stepdown", giving the principles and specifies the basic requirements for the design and implementation of a feed and food traceability system (ISO 22005, 2007). Traceability within the food chain for the consumer means that, the source of food can be traced to the field where it was produced. Thus, the need for a common language of information; a standardization of data that will simplify not only tracking and tracing but inventory control, shipping and receiving, and all of the business operations along the supply chain to consumers.

Precision agriculture and process data for traceability

Precision agriculture provides aids for achiving data transfer within the food chain. Steinberger et al. (2006 and 2009) and Ruiz-Garcia et al. (2010) demonstrated this with the acquisition of agricultural process data using ISO 11783 equiped tractor in ISOBUS XML form, transfering the data to a Farm Management Information System, converting the data to AgroXML form with GPS and open web services based on OGC standards. This implementation was a demonstration of the concept of traceability. Added benefits of this form of data transfer within the food chain include the posibilities of integrating different sources for use also by agricultural machinery manufacturers for diagnostics, by authorities for obtaining farm operation and environmental documentations, by farm advisory for providing remote services and also for transmitting and connecting to different web services such as weather information for farm production.

But data, brokage, security and ownership with this kind of implementation still remain to be clarified. In addition, different manufacturing companies have proprietary formats for their internal processes using different technologies and management tools. In order to have a working and harmonized data exchange in the food chain for arable farming systemes, at least one step forward and one step backward for each organization in the chain following the EU regulations should be standardly addressed (Ruiz-Garcia et al., 2010).

3.3.3 Spatial

Precision agriculture requires the collection, storage, sharing and analysis of large quantities of spatially referenced data. For this data to be effectively used, it must be transferred between different hardware, software and organisations. These data flows currently present a hurdle to uptake of precision agriculture as the multitude of data models, formats, interfaces and reference systems in use result in incompatibilities (Nash et al., 2009).

Management of huge amounts of data

Management of huge amounts of data is a challenge. Sensors in the fields, buildings, vehicles or satellites provide data on high time-frequency and data accumulate fast. Without smart sensors and better developed data management (including data quality algorithms) the amount grows overhelming and remains unused (Vellidis et al., 2007, Wang, 2006). Spatial data quality is considered to consist of several aspects which may be categorizised as data completeness (amount of missing features), Data Precision (positional accuracy or degree of details), Data accuracy (attribute accuracy) and Data Consistency (absence of conflicts of spatial elements). Agricultural data often have also temporal dimension, thus called spatiotemporal data, consistency in time is also considered.

Spatio-temporal data are increasingly collected by remote or in-situ sensors rather than by field campaigns. The wireless communication have several benefits, but also poses challenges to the data exchange realiability and power supply. Sensor calibration and deployment as well as maintenance of sensors need resources and technical skills and increase the costs of data acquisition (Hart et al., 2006, Ruiz-Garcia et al., 2009 and Vellidis et al., 2007). Both increasing amount of data and awareness of data quality issues highlight importance that metadata are attached to sensor data.

Farmers are also data providers them selves, not only concerning their own farm. Number of farmers own e.g. weather stations and provide that data publicly available through web based voluntary services. In this participatory sensing or volunteered geographic information web is used to create, to assemble and to disseminate geographic information provided voluntarily by individuals, and also farmers are seen potential participators. Private citizens are not trained and act voluntarily and quality of results is not confirmed. Value of the data is that is publicly available and cheap, and sometimes it may be only source of information at the location (Goodchild et al., 2007). The latter may be the case of farmers weather station.

Standardization

Specification by the OGC enables interoperability between different brands and different kinds of spatial processing systems. Land Parcel Identification System (LPIS), spatial data which is particularly relevant for agriculture is nor particularly standardised. The commonly known OGC and INSPIRE does not define obligatory rules and standards on how to deal with property rights of spatial data and if spatial data has to be freely available. INSPIRE currently does not appear to be delivering the datasets which are most relevant for agriculture. However, INSPIRE is still in the first phase of development, and it is to be expected that relevant datasets will be made available within the INSPIRE framework in the future. It is therefore important to consider the demands and opportunities presented by INSPIRE and also in the possiblilties presented by the OGC when considering data exchange for agriculture.

Data integration

The availability of data and the benefits of Spatial Decision Support Systems (SDSS) in linking datasets together are seen today in different software and systems for farm management. To achieve this linkage the report recognised two essential factors: locational references, data documentation and exchange standards.

However, for application in FMIS systems and local and regional authorities, there are often problems with data not explicitly and strandardly spatially referenced, the data relate to a variety of different areas which do not match or nest into each other and the boundaries. Furthermore, there are often missing dictionaries or metadata documentations to enable easy data integration. The need for the documentation of data for future use was clearly emphasised if datasets were to be accessible by an audience wider than the organisation producing the data. Metadata provide summary information about a dataset describing: availability - data needed to determine the existence of data for a given location; fitness for use - data needed to assess if a dataset meets a specific need; access - data necessary to acquire a dataset; and transfer - data needed to process and use a dataset. Different users' computer systems - including hardware, software, and data structures - and communications equipment are incompatible (Jones & Taylor, 2004).

3.4 Summary of developments and ICT implications

Inter enterprise data exchange exists between farmers and breeding organizations such as milk recording agencies, artificial insemination cooperatives and herd books. Within the farming enterprise, the increasing use of automatic devices on farm such as automatic feeders, automatic milking systems (AMS), results in an increasing need for communication between devices and on farm management information system. Within the farm system, especially in dairy operations, there is a need to integrate data from different systems: feeding, milk performance, milk composition (quality), reproductive performance, health, heifer rearing (again, feeding, performance, reproduction). For the livestock sector, different standards exist (ISO, government agencies, UN/CEFACT, national and international EDI associations), but maintenance, harmonization and coordination of these standards are limited which are maintained by different bodies at different levels.

In arable farming so called precision agriculture (PA) is one of the driving forces for data exchange and issues related to data formats and interface standardization. Currenttly, new automation, ICT and GIS technologies provide solutions for steering and controlling site-specific production systems to fulfill requirements of safe, efficient, environment friendly and traceable production. To enable compatibility between different system parts that are needed in performing PA, an information management system which utilizes open system interfaces and ICT standards, such as ISOBUS, and efficient data transfer are required. Currently, information exchange between farm and other actors (e.g. advisors, government, processors) is also not sufficiently organized. Data exchange between machines at field level and management systems at farm level is supported by ISO standards (e.g. ISOBUS/ISO11873), however practical adoption by farmers is low.

For both livestock and arable farming, spatial information is continuously playing an important role. Spatial information is needed for spatial location and monitoring of animals, virtual fencing for animals and machines, remote sensing for soils, crops and animals, fleet management and control of farm machines, unmanned aerial vehicles, auto steering and autoguidance, and for spatial allocation and timing of management applications. Much effort has been put in spatial data harmonization in the past and positive results are emerging especially in efforts towards standardisation work of the Open Geospatial Consortium, Inc. (OGC) and ISO/TC211 Geographic Information/Geomatics. Another relevant harmonization work is related to the INSPIRE Directive. The scope of standard development of ISO/TC 211 is also relevant and includes information technology, GIS, Remote Sensing (RS), Global Position System (GPS) and other advanced concepts, models, patterns and technical methods. Geography Markup Language (GML) identical to ISO standard 19136:2007 provides a variety of kinds of objects for describing geography including features, co-ordinate reference systems, geometry, topology, time, units of measure and generalized values.

The implications of ICT and data transfer in livestock production directly affect consumers in terms of awareness and knowledge of consumers, information transfer for food safety, animal health and welfare, efficient plant and animal production and sustainability of production systems. Expected ICT developments in the coming years include developments towards external storage of farmer's data to cater for increasing amount of data produced. Centralized mangement informations systems, with internet-based cloud support are foreseen. Technologies for documentation of production processes to enhance traceability along the food chain will increase. Sensor technology, and sensing techniques and RFID as booster for new data and services. Geographical Positing Systems (GPS) is seen to become a of future agricultural technology in terms recording field data collection, yield mapping automated Variable Rate Applications (VRA) in seeding and fertinlzing amongst others.

3.5 Issues at various information integration levels

As described in 2.2 the data integration framework is used to distinguish several levels of data integration. Issues per level of integration are discussed here. But first about those levels of integration:

- Physical: interoperability of devices/sensors, collaborative infrastructure, broadband internet;
- Data: integration of data standards, alignment of data definitions and datadictionaries, data quality and security;
- Applications: choice for open standards, adoption of open web services;
- Process: business process modelling as new skill, process approach picked up in new areas

3.5.1 Physical infrastructure issues

Standardization of the physical communication infrastructure makes it technically possible to connect products, hardware, machines, devices and their operating systems. There are two groups of supporting standards:

1. Interface standards
   to make physical systems accessible by information systems (e.g. PLC interfaces for

machine control) and product identification standards (particularly barcode scanning and Radio Frequency Identification, RFID (GS1, 2009a);

2. Communication standards
   network protocols (e.g. TCP/IP and PPP), transport protocols (e.g. HTTP, FTP, SMTP, SOAP). In general, standardization at this level is very mature, although new technologies are emerging, requiring new standards (e.g. RFID).

On one hand the demand (pull factor) for information and on the other hand new technology will lead to an explosive growth of data exchange in agriculture. Pull and push will come together and will strengthen each other if supported by the right and accurate infrastructure.

Issues for physical infrastructure are:

1. *Lack of interoperability of devices, sensors and other techniques.*
   The number of devices and sensors are exploding, making the problem of interoperability even worse, but also making the free choice of (farmers) consumers more difficult and hence not stimulating market competition (keeping the cost price high). It is clearly seen in
   a. Sensor technology, the rapid occurring of new devices and sensors.
   b. Electronic identification technology (like RFID for individual identification of animals)
   c. Robots and machinery
   d. Spatial techniques like fine spatial resolution and other sensor techniques
   e. Precision farming as instrument in sustainable production

   De facto interface standards (like USB in PC devices industry which gave a boost to innovations) are missing or not widely adopted by industry on a hardware level.

2. *Maturity of new technology, including costs*
   On the level of devices, new technology has often to overcome some immature problems. For example, wireless sensors are facing problems with power supply. Others are too expensive when they are just coming into a new market and missing yet market perspective. Small satellites, identification chips.

3. *Availability of (broadband) internet infrastructure*
   Data integration and data sharing are highly dependent on the availability of broadband internet in remote areas like the rural environment and in house (stable) situations. Not only in well agro-ICT developed countries but also in emerging ICT countries the availability of mobile data communication structure plays an extremely important role for innovations based on mobile solutions.

4. *Lack of collaborative (EU) data infrastructure*
   For several reasons a more open data market infrastructure is needed or at least helps innovations. The lack or regional or domain specific (and interconnected) collaborative infrastructure is now hampering a smooth cross border trade. But it also makes it almost impossible to create an accurate private-public infrastructure where public (even EC) can efficiently connect to the private data (with great benefits for private).

5. *(older) Embedded systems are limited in handling data and standards*
   Especially for farmers' conditions, rather inflexible embedded computer components (for example from machinery, feeding equipment) can't deal with modern infrastructure. They are limited in the amount of data or software storage. They are not capable of integrating in new (eb-)XML structures and stick to older and less flexible ways of communicating.

6. *Adopting standards*
   Although standardization is explained as quite mature on a communication level it is not always adopted by industry as quickly as it should.

3.5.2 Data issues

Data integration standardization (data exchange) focuses on the format of messages and data definitions. XML has succeeded EDI as the leading standard for message specification. It is applied both at intra- and inter-enterprise level. Examples of data definition standards at enterprise level are identification standards of GS1(formerly EAN/UCC; GS1, 2009b) and the international Standard for the exchange of product data (STEP; Pratt, 2001). At inter-enterprise level standardization focuses on one level of informationexchange. EDI-based standards are widely implemented,e.g. EDIFACT (UN/CEFACT, 2009) and ANSIX12 (ASC X12, 2009), but at the moment ebXML is emerging as its successor. EbXML provides a catalogue of information elements in XML format ('core components') that have to be exchanged in eBusiness processes (OASIS, 2006a). It consists of several sub standards, including ebXML Messaging Services (ebMS), aligned with SOA, BPSS (Business ProcessSpecification Schema), ebXML Collaboration Protocol Profile andAgreement (CPPA) and ebXML Registry.

Issues for data are:

1. *Bad integration of data standards in countries*
   Although standards are widely implemented, they are not in all countries and not always in a very good integrated way implemented all over the added value chain.
   EDIfact (ebXML as successor) and for example ANSI X12 are often seen in the added value chain from industry to retailer, but far more rare in the area of producers (farmers). Although ebXML suits in a good way of process-to-process communications, it's still rarely used in agriculture.

2. *Poor alignment of data definitions and datadictionaries*
   Semantics, and hence data dictionaries, are playing an important rol in well implemented standardization. It's about communicating the same language, but it is often not very well developed in practice. Data standards are very common based on bilateral messaging of data, which means that a few business partners are making agreements on the exchange of data entities (and its definitions) rather than on the business processes and data.

3. *Data quality and security*
   Data quality and security are increasingly becoming an important issue. The validation process can be partly a piece of the data standards, it even should be metadated. Like in the spatial domain where there are problems with data not explicitly and strandardly spatially

referenced, the data relate to a variety of different areas which do not match or nest into each other and the boundaries. Quality in general is about reliability in:

   a. Data accuracy
   b. Data consistency
   c. Data precision

4. *Availability of public data sets and schemas (authentic databases)*
   It would help if other (public) data sets could be exposed to private users, and often it does already. Sometimes the data are not available at all because of privacy or property rules, like in the case of geo-referenced data. The most advanced situation is where the public provides software suppliers with the data as well as the metadata (data scheme).

3.5.3 Application issues

The successive type is integration of applications: one application calls another and receives direct, on-line response. Different software applications within one organization or from different organizations are considered as components of one aligned system. From the 1990s on, at intra-enterprise level focus has shifted from customized point-to-point interfaces to implementation of standard Enterprise Resource Planning (ERP) systems. Nowadays application integration based on web services technology is emerging. Web services are autonomous, reusable software components that are based on XML message technology can be described, published and invoked over the network (typically Internet) using open standards (adapted from Leymann, 2003; Tan and Lee, 2004). Comparable to ebXML, it consists of several sub-standards including WSDL (Web Services Description Language; W3C, 2001), BPML (Business Process Modeling Language; Arkin, 2002) and BPEL (Business Process Execution Language; OASIS, 2007), WSCI (Web Services Choreography Interface; W3C, 2002), UDDI (Universal Description, Discovery, and Integration; OASIS, 2006b).

The evolution from intercommunicating applications to ERP systems and now web services doesn't mean this is the common road ICT-agro should follow.

Application issues for Agri-ICT are:

1. *Local vs. centralized storage of applications data*
   Data don't need to be stored at a central location, but it helps in collecting data from several input locations and in linking the data to other external applications. FMIS applications are making these steps.

2. *Adoption of open web services*
   Definitely, web services are coming up in agri-ICT as they can have a major impact on the development of data exchange since they can be rather simple and open to communicate. But web services are not yet commonly used and are therefore not communicating to the outer world and are currently incapable of setting up quick data exchange settings.

3. *Open standards by software industry*
   Especially small software developers (in sometimes small markets) have to decide in which

new standards they will invest in terms of knowledge and tools. Having sometimes too many choices in standards is frustrating this progress and hence the overall development of the market. It would help if there was a bit more of a directive, from industry platforms and or from national or international governments (also playing a role on the 'information' market as demander for data).

3.5.4 Process issues

The final integration is around the integration of processes (alignment of tasks) by coordination. Therefore, activities and interactions between processes must be defined in process and data models. There are several reference process models that support the design of integrated intra- and inter-enterprise business processes (Verdouw et al., 2010). Some well-known integrated intra-enterprise models are CIMOSA (Open Systems Architecture for CIM-systems; Kosanke,1995), GERAM (Generic Enterprise Reference Architecture andMethodology; Bernus and Nemes, 1996), ERP reference models of among others SAP (Curran and Ladd, 1999) and Baan (nowadays Infor; Verbeek, 1998), ISA-95 (formerly S95; ISA, 2008). Some well-known inter-enterprise models are VERA (Virtual Enterprise Reference Architecture; Tølle and Bernus, 2003), SCOR (SupplyChain Operations Reference-model; Huan et al., 2004) and the CPFR-model (Collaborative Planning, Forecasting and Replenishment; VICS, 2004).

Process issues in agri-ICT are:

1. *Business Process modelling as new skill for developers.*
   Developers have to learn new skills on business process modelling, where they could in the past make their way through much quicker shortcuts in defining datastandards on message level. Agri-ICT developers are sometimes rather small businesses and have to invest. Modern and new tools, like BPM and UML-tools will help them.
   Business in new skills process modelling is advancing but is not yet commonly used in ICT – agri.

2. *Process approach only picked up in new areas*
   In ICT-agri, especially at the inter-enterprise (farming) level, the process modelling is so far only introduced in new data exchange areas. New business processes are not found very often as they are to software developers in agriculture very much related to short term profitable new applications or modules.

3.5.5 Organizational issues

Looking from a point of view of data integration levels is not explaining all of the issues. Innovations and improvements do have a strong dependency on more soft conditions, like social and organizational issues.

Organizational issues in ICT-agri are:

1. *Trust*
   Awareness and trust on the impact of a change (i.e. by research, implementing new technology and accompanying standardization) could make on business efficiency, cost of production and increasing market access. But not only from the market and production perspective, also trust is very relevant for consumer behaviour. However, trust can be difficult to manage and requires considerable investment of time, resourses and probably the introduction of other innovation approaches.

2. *Adoption of new technology*
   Although new technology is sometimes very promissing, adoption of it is not always evident. Cost of a product is an issue, but can be overcome by increasing the communication and training around a product. Learning and further developing of services and products (based on the technology) in a rather safe innovation environment (pilots for example), and co-creation by more stakeholders are other critical success factors.

3. *Limited investment possibilities, especially in small domains*
   Many SMEs have limited investment possibilities, especially in small domains. Small domains with specific solutions are not able to benefit from big scale (market) opportunities and have in this way more difficulties in investing in new and sometimes risky products. For some countries in the EU the situation is worse, as the consumers of the products have quite limited possibilities to buy due to scale and cost.

4. *Lack of public involvement in collaboration (private-public collaborations)*
   Not only private collaborations but also the involvement of the public can be a key factor affecting the succes in the setup of well organised data exchange in the European community. In some countries, like The Netherlands, national government invests in open standardisation, publishing public datamodels (probably in the future even data schemes) of the mandatory data inquiry.

5. *CAP implications*
   The European common agricultural policy implies the control of several main themes like animals and its movements, mineral management, land parcel usage, food safety. Even animal health care and welfare and ways of responsible production of food and feed are already or will be monitored in near future. The implication of this is that the EU is a market player in the field of information sharing. If the EU is only collecting and sharing data, and not offering services back, it will be identified as a burden by farmers and will not be advanced as efficiently as it could be.

4 State of the art on information exchange based on field research

Investigation of the state of the art has been carried out in the EU member states and Switzerland. As described in chapter 2 it was mainly done by qualitative inquiry by experts in each country.

4.1 Trends in farm characteristics

From 2003 to 2007 there was a small decrease in the total utilized agricultural area (UAA) in the 27 EU member states (Table 3). However, the number of agricultural holdings decreased in the same period by 1.3 million (more than 8%). This resulted in an increase in the area per holding of more than 9%. In the same period the number of annual working units (AWU, labour force directly employed by the holding) decreased across the EU from 13.4 million in 2003 to 11.7 in 2007. Also the number of AWU per holding decreased, resulting in a 14% increase in the agricultural area per working unit.

Table 3. Trends in farm characteristics from 2003 to 2007 (Anon., 2010)

Farm characteristic	2003	2007	Trend 2003-2007 (%)
UAA (x 1,000,000 ha)	172.8	172.5	*- 0.2*
No. of holdings (x 1,000,000)	15.0	13.7	*- 8.8*
UAA per holding (ha)	11.5	12.6	*+ 9.4*
AWU (x 1,000,000)	13.4	11.7	*- 12.4*
AWU per holding	0.89	0.85	*- 4.0*
UAA per AWU (ha)	12.9	14.8	*+ 14.0*

It is important to emphasize that there is significant variation in farm characteristics between differing EU member states.

Figure 4 shows the average size of arable farms (in UAA per holding) and dairy farms (in cows per holding) in the different EU member states. Arable farms are largest in the Czech Republic, Denmark, UK and France. In Bulgaria, Romania, Slovakia and Hungary more than 50% of the arable holdings have land areas of less than 2 ha.

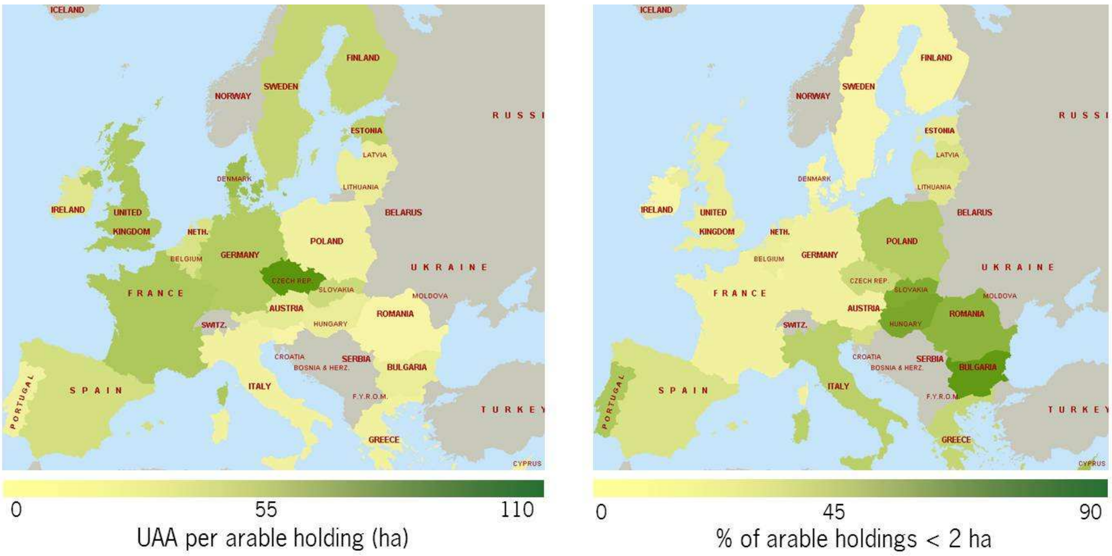


Figure 3. Average size of arable farms (UAA per holding) and percentage of arable holdings with less than 2 ha in the 27 EU member states.

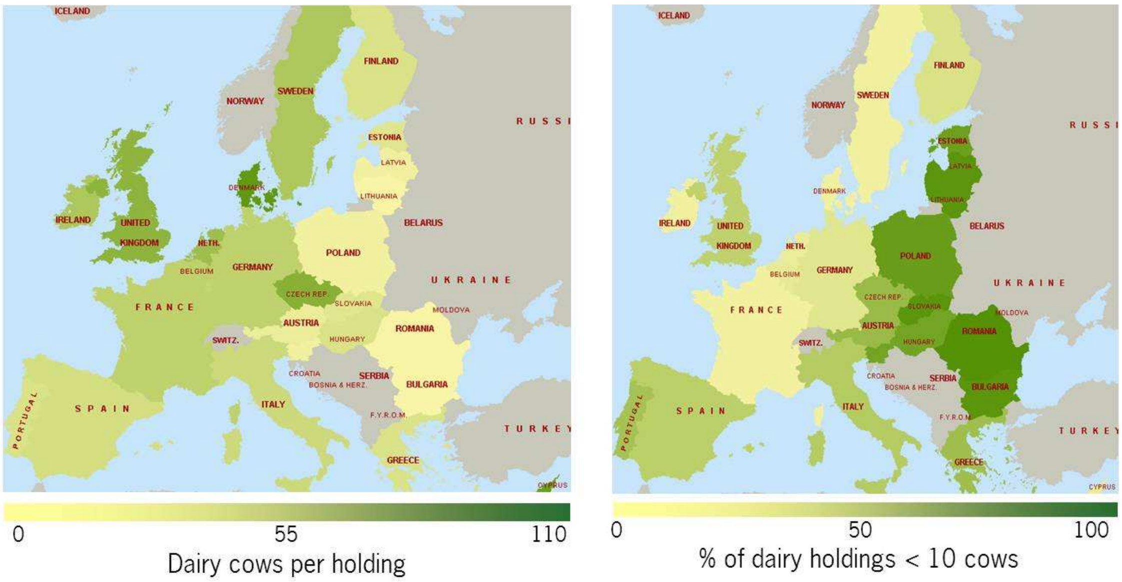


Figure 4. Average size of dairy farms (cows per holding) and percentage of dairy holdings with less than 10 cows in the 27 EU member states.

The largest dairy farms are found in Denmark, Cyprus, Czech Republic and the UK (Figure 4). In Romania, Bulgaria, Lithuania, Slovakia, Latvia, Poland, Estonia and Hungary, more than 80% of the dairy holdings have less than 10 cows each.

4.2 Farm automation level

Detailed statistics about the automation level in the agricultural sector of the EU-27 states is not available, except from some countries such as The Netherlands (Stormink et al, 2009). However, from the country reports available, it can be concluded that in agricultural enterprises, farmers' internet access ranges dramatically between countries at 20 to 95%. Comparable statistics show that in January 2009 an average of 93% of all enterprises in the EU had access to Internet (Smihily and Storm, 2010). This suggests there is a big difference between 'regular' and agricultural enterprises in terms of accessibility to the Internet. Mobile internet connections were used by 28% of all enterprises in the EU with the lowest use in Greece, Cyprus and Romania.

Some countries mentioned that the adaption of new technologies was lower within the cohort of older farmers than in the one of younger farmers. Lööf and Seybert (2009) observed that more than 66% of the females and 70% of males in the age groups below 55 years used the internet at least once a week, while in the group above 55 years these percentages were between 26% and 38%.

When analysing mobile data infrastructure from several countries it is reported that the usage of mobile phones and even smart phones (with real internet capabilities) is rather high or expected to increase drastically in the coming years. The information received, showed that more than 90% of farmers are using 'mobiles' in countries like Italy, Ireland and Spain, which is in contrast with the figures of internet access through the PC in these countries. It should be noted that in these countries, often mobile devices are used more as cell phones rather than for mobile applications based on data communication. However, it is expected by some experts to change rapidly over the coming years. Experts estimate the usage of mobile application for business purposes is currently between 2-5% in these countries.

Availability of broadband internet in rural areas is very often mentioned as a big issue that hampers ICT adoption in agriculture. A summary of the level of ICT and technology adaptation in some of the EU countries and Switzerland is presented in Table 4.

Table 4: Level of ICT and technology adaptation in the EU countries and Switzerland

Country	Farm PC	Internet access	FMIS Farm Mgt Info System	Phones/ Handheld	LPIS relevance	Geo Fertilizing	Animal Registration
Belgium	High	High	Average	High	High	Average	High
Bulgaria	Low	Low	Low	-	Average	-	-
Czech Rep.	High	High	High	Low	Average	Average	Average
Denmark	High	High	Average	High	High	Average	High
Estonia	High	High	Average	-	Average	Low	Average
Finland	High	High	High	High	High	Average	High
France	High	Average	Average	High	High	Average	High
Germany	High	High	Average	High	High	Average	High
Greece	Low	Low	Low	Average	Average	Low	Average
Hungary	Average	Average	Low	Low	Average	Low	Average
Ireland	Average	Average	Average	Average	Average	Average	High
Italy	Average	Average	Average	High	Average	Average	High
Latvia	Low	High	Low	-	Average	Low	High
Netherlands	High	High	High	High	High	Average	High
Poland	Average	Average	Average	-	Average	Low	Average
Portugal	Low	Average	Low	Average	Average	Low	Low
Romania	Low	Low	Low	Low	Average	-	Average
Slovakia	High	Average	Low	Low	Average	Low	Average
Slovenia	Low	Low	Low	Low	Average	-	Average
Spain	High	Average	Average	High	High	Average	High
Sweden	High	High	Average	High	High	Low	High
United K.	High	Average	Average	Low	Average	Low	High
Switzerland	High	Average	Average	Low	Average	Average	High

If characterizing precision farming as a measure of farm automation, in most EU countries precision farming is only used to a small extent by farmers. A lot of experts reported the existence of precision farming and the usage of geo-data in general only in experimental (research) projects. However, there is a significant difference in areas across Europe, in Western and Northern Europe and for example in Czech Republic there is more progress in development. The usage and impact has grown, with the techniques and data exchange brought in by manufacturers of agricultural machines.

4.3 Data integration

In general, big differences all over Europe can be seen in data integration at process level. In many countries in Europe data integration at process level is hardly organised at intra-enterprise and inter-enterprise level. Some Western European and Northern European countries can be considered as rather well data-integrated countries; however this depends on the definition of data integration.
Due to EU CAP legislation, obligatory registering of parcels and animals has been set up in all member states. In most of the countries, databases for registering land parcels are shifting towards open systems, portals or shared databases, where others (farmers and private business) can have access. Clear impacts can be observed from the CAP policies where they are boosting instrumentation of data integration in countries where private data interchange was hardly practiced previously. Even launching new online public services, based on the inquiry of parcel or animal registration data, is boosting not only the digitizing of farmers but is also boosting other software and service suppliers. In Eastern European countries it is often expected that these technologies should boost advisory and management services (like in Hungary, Czech Republic, others). Common public systems are relatively open compared to private systems. But still many systems and databases are closed.

In the following sections, the levels of data exchange are discussed in detail.

4.3.1 Physical infrastructure

This part is in relation to the technical infrastructure (e.g. what is available and how is it organized)? Keywords in this section are broadband infrastructure, database structures, information hubs/brokers.

Internet infrastructure
The availability and accessibility of (broadband) Internet in rural areas is an issue in most countries. Most of the southern and eastern countries reported that it was sparse if present at all in rural areas. However it was also reported that the availability of broadband Internet is in a lot of countries growing rapidly (in ways of stable/cabled Internet (ADSL, etc.) or as mobile 3G internet solutions (UMTS, HSDPA)). Some countries reported specific national or regional policy on building strong network infrastructure (Hungary, Latvia, Italy, others).

Collaborative private-public advanced infrastructure
Depending on trade and business there is always a need for information. In many countries there is a growing understanding that one country or two countries cannot organize this on their own. A collaborative tuned model develops where some private organizations take the role of information broker (or clearing house). In countries where centralized systems are more common, public

organizations can take this role of information broker; a kind of renewing role to get and transfer data to all kind of services, providing the authentication, authorization and adding value.
Databases which facilitate the collaborative tasks can be called ‘hubs’. Several kinds of databases and hubs are being created, or connecting to, the ‘new’ system. A rapid developing evolution out of existing old business is being developed. Parts of it can be:

- (Private) information broker and authentication servers;
- Authentic (public) record databases, like parcel database, I&R, basic administration of people;
- Farmers management information systems;
- Services of information suppliers;
- Databases of industry, retail, which are communicating with each other;
- Public registration databases (data inquiry).

First advanced architecture models of this kind are showing up in some countries (The Netherlands, France, Germany, others).

Organisational issues

In most EU countries government (ministries of agriculture) are somehow leading, or at least play an important role, in the organization of farmers’ data flow. Except from some countries like Germany, France, Denmark, Belgium and The Netherlands, no (private) unions or bodies are reported who take care of the organization of dataflow or standardization. In countries where national agriculture bodies on data exchange exist they are mostly private business (software and hardware suppliers, service and chain organizations) driven, sometimes with involvement (membership) of the government. For historical reasons the maintenance of national and specific agricultural standards must be maintained.
Influences and uses of other standards from other sectors lead to contributions and connections to other kinds of standardization bodies, like GS1, UN/CEFACT (TBG 18 Agriculture) or ISO (TC 23/ SC 19 Agricultural electronics).
Specific national and agriculture standardization bodies seem to move toward policy and strategic issues, leaving the (rather technical) standardization tasks to others.

Other issues

Some experts are reporting the e-recognition, e-authorization and e-authentication as challenges of the near future. In infrastructures where connecting databases and having data flow in a number of directions it is becoming very important to have good systems to tackle the complexity. Farmers are increasingly not in a central position regarding their data (flow), but are considered to be still the owners of their data. An approval mechanism in order that the data can be used by others is a key issue, which is often reported.

4.3.2 Data level

Data integration on data level is about the availability of data definitions in order to be able to share data. Common descriptions are made. Keywords here are syntaxes, semantics, organization, maintenance, availability, bottlenecks.

Semantics/ data definitions

In many EU countries data definitions (semantics) have only public standards (XML schema's and web services for example) mentioned. Some report no definitions at all. But looking more in depth at all places ISO definitions are there for machinery (ISObus), milking equipment (ISO 11788 ADED), electronic animal identification (ISO 11784/11785/14223 and 24631) or forestry (ISO 19115). These are just examples.

Looking at the ICAR (International Committee for Animal Recording) survey on data exchange and standards a lot of breeding, milking recording organizations, cattle registration offices and dairy industry are using dictionaries like ADIS/ADED or others. This is confirmed by the agriXchange investigations.

The Netherlands, Slovak Republic, Denmark, Czech republic, Sweden, France and Finland reported the existence of data dictionaries. The Dutch dictionary TAURUS is used in the Netherlands and in France.

Syntaxes

Syntaxes which are used for data exchange are reported from all countries. Less structured messaging is based on CSV format, FTP (file transfer), VSE format (old) or SQL communications. Also e-mail and http are mentioned as carriers for data. More advanced mostly XML based syntaxes are used by EDI messaging structures from or owned by agroXML (Germany, some other countries), ISOagrinet (international), Agro EDI Europe and E-daplos (France), AgroConnect (The Netherlands). Web services and SOAP protocols are advancing rapidly.

Organisational and other issues

In general, a lack of common semantics is reported. Cross border data exchange is difficult. Most national developed syntaxes have problems to be exported abroad.

Other issue is the lack of openness in which standards are provided to developers. Sometimes organizations that take care in maintaining and distributing standards do not use the policy of freely available standards. Agro EDI Europe (France) and AgroConnect (Netherlands) are using a membership fee to be allowed to use the standards. Although the reason for this is obvious, the funding of the maintenance and development of new standards is against the growing ideas of developing an open innovation environment where standards are freely available. New business models for maintaining standards should be developed.

4.3.3 Application level

It is rather difficult to discuss the application level, like the existence of so many databases and software. Farm management information systems (FMIS) can be observed in more than one system and are available in all countries. Sometimes from national or local suppliers, but also systems from Denmark, Finland, Germany, Austria and The Netherlands are seen abroad. Most of them are from specialized agricultural firms; just a few are sold by large ICT firms.

Most of the countries databases are rather closed but shared systems or portals are emerging. Public registration databases are generally serving applications of farmers or other service organizations. Web service orientated parcel information systems provide others with not only the opportunity to insert or correct parcel boundaries, but also providing the data to other applications.

The same can be observed from other (registration) databases such as animal registration, meteorological or climate databases. In just a few cases a real interactive (2-way) communication with the FMIS is developed, where also parcel information is inserted in the LPIS direct from the FMIS.

Challenges which are coming from the country experts are:

- How to go to real open systems;
- The organization of web based technology and centralized databases on behalf of the farmer (his ownership);
- Adopting (new) EU standards;
- Challenging interoperability problems, especially with more sectors.

4.3.4 Process level

Various business processes in several countries are facilitated by more or less structured data exchange. Over the years, animal production breeding organizations, milking recording authorities, dairy industry, feed industry and slaughterhouses have cooperated in Western Europe to organize standardized dataflow. Several message structures served the quality of not only farmers' management but also of the core businesses of those companies.

From a historical perspective the public sector came into the 'information market' in a later phase, first by digitizing the paper work for farmers (e-forms). Over the last 5-10 years, E-government is boosting the public sector business (inquiry, controlling, subsidies, etc.) through electronic data exchange. Public registers are playing an important role in this.
In the meantime other markets and society-driven issues for farmers have emerged. Food safety, sustainable production, animal welfare and health care are boosting the demand for new and more data flows. At the same time new technology will facilitate the development of better controlled production, and new products. However, this will take place when technology, knowledge (including knowledge model) and even co-producers are positioned together in more open innovation environments. New and other kinds of demands for data exchange are rising.
Primarily this is a concern for private business and market, but more and more of mutual interest for private and public. This statement can be elaborated by the following examples.

Public
In Ireland the nitrate directive of the EC led to the development of an integrated system with combined data from parcel and animal registration, FMIS and slaughterhouses. Others are reporting the existence of e-government services carried out by private intermediates. Administrations and registrations around subsidies are electronically organized in several member states rather well.

Animal production
FMIS systems or portals share data with a lot of other organizations and processes. Data systems from veterinarian boards and even the tracking and tracing system of the EU (Traces) are mentioned. In Denmark an advanced centralized system is serving farmer and other organizations with a lot of other services and advisory. In almost all countries breeding and milking recording agencies are mentioned as a basis for data exchange.

Arable

In the past, data flow in arable farming has been based on crop management (pest, irrigation, fertilizing control). Recently, quality, food safety , tracking and tracing in the chain are becoming more important. Precision farming and the development and feeding of advanced decision support systems (DSS) are often mentioned as key developments in this. In addition, legislation and accountability are mentioned as major issues which are calling for better organized data exchange. Considering the overall picture of data exchange in arable farming in most countries is still under strong development. Precision farming is often mentioned as interesting and promising but most of the time is found only in pilot farming environments. Despite the investment in hardware level by the machinery and tractor industry (like ISObus), adoption of precision farming is still low.

Bottlenecks and challenges

In general the lack of (EU and global) standardization is mentioned which hampers the development of a good way of communication between intra-enterprise and cross-border processes.
On inter-enterprise level, experts believe information transfer and communication in machinery or milking equipment (including available and new sensors) is not smooth or in some cases not available at all.

The reductions of data inquiry duplication, and the development of single point entry systems, are seen as challenges.

4.4 The role of standardisation

Concerning the meaning and value of standardization, experts have the opinion that standardisation should be done at the business service layers and not on processes, because of competitive surroundings. A focus should be put on demonstrating how processes can work, but keep them flexible and hence keep them out of the rigidity of (formal) standardisation processes. A proposal for technical methods for achieving this is using technologies for formalized descriptions of semantics, i. e. describing the meaning of data items in a machine readable way, so that different sets of processes can use the same data sources. This places the focus less on standardization, as an instrument for data integration. One technical component of such scenarios are vocabularies and ontologies like the AGROVOC from the FAO. The semantic web is aiming at publishing data using formal vocabularies providing a network of so-called linked open data. GCI (referred to in the introduction) envisions an open network, with flexible relationships between network partners, which implies less hierarchical or linear chain structures. This has consequences on innovations that will be developed within these open networks, as well as the ever changing anonymous partners in the system. There will be less focus on the products themselves and everything considered as a service.

These visions have led to a different focus in the agriXchange project, which is less based on standardization as such, but more on interfaces between different processes and applications.

4.5 Use cases and relevance in EU regions

In the agriXchange project, four use cases were chosen for developing and evaluating the agriXchange framework:

- Land Parcel Identification System
- Geo farmer and fertilizer
- Animal registration
- Animal identification

Investigating the state of the art in the EU member states included some questions about the existence and relevance of the use cases in those countries. In this paragraph, summaries are made from the data; some more detailed information on the use cases can be derived from the country reports.

4.5.1 Land Parcel Identification System

LPIS (Land Parcel Identification System) is a system in which a farmer collects spatial data of her/his new field parcel boundary lines. The farmer sends parcel boundary data to the LPIS service provider for updating the national LPIS. The national LPIS prepares the further data delivery between different LPIS and parcel information utilizing agricultural services or software applications, taking into account the criteria of INSPIRE. Special attention is paid to the quality representation and assurance of exchanged data; proven data acquisition and data handling processes, and the content of metadata. From the following countries, information has been reported on LPIS:

BGR	LPIS is since 2008 introduced in Bulgaria
CZE	LPIS is on the good level of usage
DNK	MIA is the central system for LPIS, based on exchange of cadastral data with licensed surveyors. Farmers can provide authorities with boundary data
EST	Farmers are collecting boundary data. Updates are done through national LPIS
FIN	Updating parcel information/boundaries. Special attention has to be paid to exchanged data: proven data acquisition and data handling processes and metadata --- INSPIRE
FRA	It already exists
GER	LPIS is under responsibility of the federal states. The degree of integration with farmer’s software differs across the systems implemented. Also, there are different reference systems of area/field identification in use across Germany
HUN	LPIS is an ongoing activity – it supports area based subsidy applications
ITA	SIAN developed advanced system with JRC, about: land use, EU subsides; cross compliance (environmental), emergency management
LVA	LPIS is responsibility of local authorities. Distribution of spatial data by LV portal
NLD	LPIS is important to interoperate between land use and public administrations. Electronic delivery of parcel usage from FMIS in the LPIS and the other way around delivering validated coordinates/boundaries of parcels to all kind of parcel based systems
POL	Agency for restructuring and modernization of agriculture is responsible

ROM	Yes, it is of interest to improve quality and field crop production (scarcity of animal feed)
SVK	Some services are available
SVN	LPIS is relevant for Slovenia
ESP	Based on quite good system of the Spanish Rural Cadastre
SWE	LPIS is there
CHE	Very relevant to integrate for payments reasons (integration by the work done by the several cantons)

4.5.2 Geo farmer and fertilizer

Geo-farmer and fertilizing is a use case of dataflow and services based on precision fertilizing, fed by data from external sources and services from several service providers. It is best explained by next case example: a German farmer, who uses a Czech farm management system, requests a site specific fertilizer advice, for a specific field. Field parcel boundary information is retrieved from the national LPIS. The advice service is based on a French knowledge-based advice module and it uses satellite data (LAI map) from a Dutch service provider, soil analysis data from the local soil laboratory and "FutureFarm" compliance to standards check functionalities to produce a to standards compliant fertilizer map in ISO 11783 format for the task file needed in fertilizer application.
The executed fertilizer application is documented to the farm management information system, where the information is transferred to government's database in connection of administrative reporting.

From the following countries, information has been reported on Geo farmer and fertilizer:

CZE	Geo fertilizing is in strong development (area 300 000 ha, 350 companies use it)
EST	This is very rare so far
FIN	Equipment suppliers in Finland are keen on standardised communications with tractors. Software and service suppliers are looking forward to such structures
FRA	It already exists
GER	For fertilizing, planning methods with integration of external data sources are not very widespread. The reason for this is good availability of direct on-site methods like N-sensors regulating fertilizer spreading directly during the process. External data integration is currently more widespread in pest control.
HUN	Some companies are active in this field
ITA	Precision fertilizing is only done in cereals. There are 100 harvest machines with data loggers and sensors
LVA	Some implementation are there (like from supplier enAgro)
NLD	Interfacing between FMIS and LPIS. ' GEOboer' is a pilot where FMIS, soil analysis, satellite (LAI data), advisory services, LPIS and board computer (ISO interface) are working together in exchanging data and producing knowledge and new advisory services for the farmer
ROM	Yes it is relevant to improve quality and field crop production
SWE	It is sometimes used
CHE	Only a few famers are using it up till now

4.5.3 Animal registration

Animal registration, where an animal is transported from a farm in one EU country to another for growing, and to a third country for slaughter. In connection to every movement the animal registers are updated in both delivering and receiving countries.

From the countries next information has been reported on animal registration:

DNK	Denmark has a comprehensive system for animal identification and registration. The data are recorded in a central database (Central Husbandry Register), owned by the Ministry of Food, Agriculture and Fisheries
EST	Registration is done by the central system ARIB
FIN	Cross border transport is minimal, large number of inter-country movements with sheep, goats, bovine and swine
FRA	Registration is done by several offices. In the EU every country has its national database but no EU orders to let them communicate for importing/exporting. Under UN/Cefact umbrella a three country project (NLD, GER, FRA) has been started.
GER	Registration is done by a central office, the HI-Tier database. There is an open, well documented interface specification available that is used by farm management system providers to directly interoperate with the database. Automatic cross-border data exchange is in place with Austria.
HUN	Hungarian bovine I&R system exists since 2005
ITA	BDN takes care for this
LVA	Done by the agricultural data centre
NLD	Settled but only on national scale. Cross border data interchange is a bottleneck, for trade and costs of administrations (exporting/importing) but also for EU regarding the tracking of animal movements (diseases control)
POL	The database exists, but it has only importing possibility
ROM	Yes this is important to improve production
SWE	Registration is done

4.5.4 Animal identification

The identification devices could be able to communicate with other farm equipment. Some of the devices specifications are itemized by an ISO standard, most are not. For interoperability between livestock identification devices a proper standard is required, and need to be supported by all animal farm device interfaces and the additional electronic information standards.

From the following countries, information has been reported on animal identification:

DNK	Cattle registration follows the EU standard. Every bovine animal is marked by an ear tag; the number is used in the farmers DHIA-database and the ministry database. Since 2010 electronic identification for cattle is mandatory. It is expected this is improving Food safety and farmers economy in different ways
EST	Some farms have responders

FIN	A couple of farmers is using transponders, slaughterhouses prefer transponders instead of barcodes
FRA	Identification data are necessary during the whole animal life and needed to be transferred to several databases. The development of the electronic identification can help this but it needs to have standards to help the different systems to read it.
GER	Cattle is identified following the EU standard for ear tags, identification numbers are recorded in the HI-Tier database. RFID based systems are in experimental use.
IRL	Important for Ireland due to exporting of calves and heifers to Europe. Inter-country data exchange is rather important.
ITA	Full implemented in theory. RFID has been boosted by the IDEA project in 2000
NLD	Through individual identification lifelong managing, taking care and monitoring animal and his production. Tracking and tracing, adding new opportunities for sustainability reasons (environment, health, welfare, production/income)
SVK	It is relevant
SVN	It is reported to be relevant

5 Analysis of the state of the art on information exchange in Europe

Analysis of the data of the investigation, with special attention to difference within the European area, is made and discussed in this chapter. For each group of countries or area general or specific recommendations are made.

5.1 Europe and regions - remarkable ICT issues

The expert teams of the countries reported some remarkable ICT issues which can be considered as bottlenecks and challenges.

In the first place, focus on ICT and data integration in European areas is highly related to local challenges. It is obvious that in economically active agricultural countries (like Denmark and The Netherlands) the development of cross border data exchange is an important issue. The lack of cross border (standardized) data exchange, which hampers smooth trade between countries, is very often mentioned as a big challenge. But in the East or South of Europe it is hardly mentioned, rather issues like irrigation and water erosion (like Spain, Italy) or lack of market transparency (like Bulgaria) play a major role in ICT actions and issues.

Concerning demographical issues, the aging of farmers is often mentioned as playing a key role in ICT adoption. Except for the North and North-West part of the EU, where it is no or a minor problem, this is a real emerging problem. Farmers belonging to the generation that 'left school more than 20 years ago' have more problems adopting new technology. Developments are not always positive because of a lack of young people in agriculture (Slovakia, Bulgaria, Italy, others). But this problem will probably be resolved as time passes by. Countries having a lot of small (probably poor as well) farmers are facing severe problems in the capabilities of investing in automation. In some (South) Eastern countries like Bulgaria or Romania the flow of people out of the rural area is an issue of increasing concern. Automation should replace labour in these countries, but farmers do not have the capacity to invest.

Fast developing agricultural countries like the Baltic States have high potentials concerning the building of new ICT infrastructure as they are not bothered by old systems and structures. Some of those member states have high priority governmental policy for fast development of ICT markets, which will affect agriculture as well (Latvia, Lithuania).

Europe can roughly be divided into regions with a standardisation past and areas without any past in this field. The latter group, not hampered by existing structures, is able to skip the old-fashioned way of structuring. This can, however, only be achieved if the countries are able to create high-speed broadband internet infrastructure, which so far in most 'ICT underdeveloped' countries remains a big issue. This is mostly valid for the South and Eastern countries, but in North Eastern countries a lot of effort has been put in building new mobile data infrastructures by mobile operators, supported by governments.

Availability of broadband internet in rural areas is very often mentioned as a big issue. Broadband internet provided by cable, (A)DSL or satellite is missing in rural areas in large parts of Europe, especially in the Southern and Eastern member states. In the future this might be a minor issue when nations can replace or even switch to mobile network infrastructures. As stated before, end device infrastructure such as smart phones are common in a lot of countries but farmers are unable to use it for mobile business applications due to lack of $3^{(+)}$G (UMTS/HSDPA for mobile data communications) coverage in rural areas. Total coverage of mobile internet infrastructure is a real problem in almost all countries, but for the Northern and Western countries it is mostly more of a qualitative problem in rural area in terms of not providing a total coverage of high qualitative and fast data infrastructure rather than fully missing rural mobile infrastructure as in other EU countries.

With regards to organisational structures, differences are identified in the degree of involvement of private business in ICT and standardization as compared to public involvement.
A way of classifying countries by data infrastructures is the division into (1) no or hardly any infrastructure, (2) centralized data infrastructures (like Denmark and Sweden for animal data) and (3) countries developing real hub-based, or even private-public, data sharing infrastructures (The Netherlands, France and Germany are examples of this).
It seems that centralized structures, which are mostly owned by public sector (or partly, sometimes public-private), are making data exchange much easier to organize. Public sector can take the lead in making appointments about the way data are exposed or communicated.
Having a view on some data flow makes this clear, the example of the Netherlands appears to be much more complicated as the picture from Denmark where in latter example it is all organized by national and centralized data registers. Figure 5 is only an example of the structure and services around the cattle database where figure 6 shows dataflow on all kind of processes in agriculture, but obviously in a more spaghetti-like ('mess') situation.

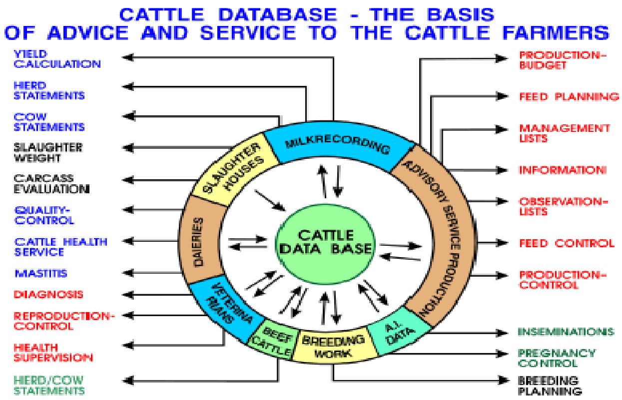


Figure 5. Danish centralized database structure

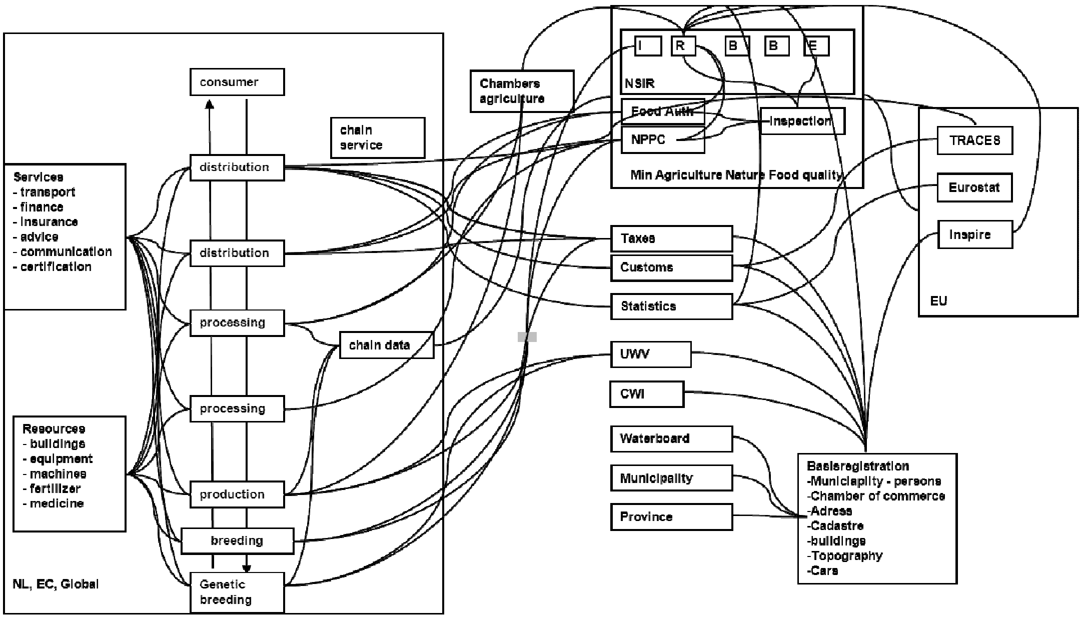


Figure 6. Dutch dataflow picture, like a spaghetti mess

5.2 Data exchange – levels of maturity in data integration in the EU

Having a look at the development stage of countries in data integration, Europe can be split up in 4 levels. Below the levels and a short characterizations (Figure 7).

Level 1	None or hardly any data integration (like BGR, ROM, MLT, CYP) No private initiatives, public (CAP) providing rather closed (registry-) databases.
Level 2	Poor developed (mostly Southern and Eastern, Baltic States) A move towards data integration has been initiated by CAP/Governments through interfaces. Some shared databases and portals are showing up. But still hardly any integrated private systems.
Level 3	Rather well developed (Scandinavian states, CZE, GBR, IRL, BEL, CH) Involvement by private organization is evolving. A few data dictionaries are showing up and used.
Level 4	Quite well developed (FRA, DEU, NLD, DNK) System assessment and move towards open/shared communities. Existence of private standardisation bodies. Usage of national, private owned and global standards. Infrastructure based on hub structures (communicating and transporting systems). Further developing towards integrated models.

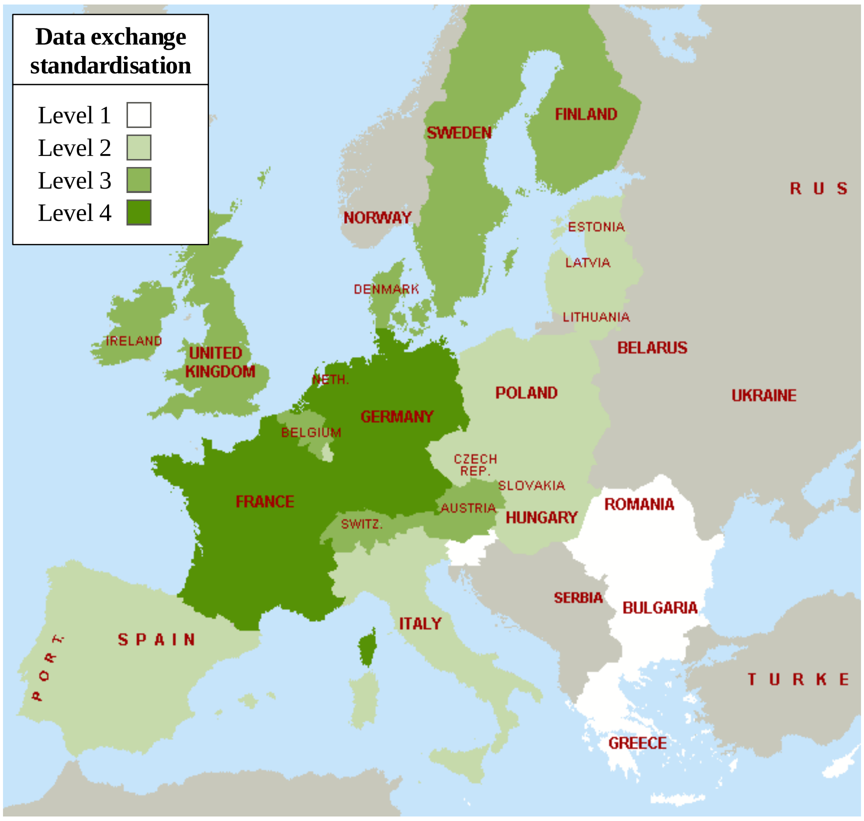


Figure 7 Levels of maturity in data integration in the EU member states

Referring to data integration model (Figure 2), presently even level 4 is far from perfect with regards to data integration. Data integration at inter-enterprise level is often well organised but from intra-enterprise point of view there is hardly any efficient and structured infrastructure. Data exchanging processes are drawn like a spaghetti mess.
Future integrated models are evolving towards an infrastructure more or less made up of open hub systems where those hubs have the functionality not only to transport data in a highly efficient way but also to be the place to add value and distribute it through services and in markets.

5.3 Recommendations per level on data integration

Regarding the levels on data integration in Europe next recommendations per level can be given to policy and business.

Level 1: None or hardly any data integration

I. Invest in mobile broadband infrastructure
II. Build reliable public (CAP) services and extend them with web services to provide private business with development opportunities
III. Invest in new technology adaption through education & demonstration
IV. Implement the (most easy) best practices from other EU regions
V. Connect to existing global standards

Level 2: Poorly developed data integration

I. Invest in mobile broadband infrastructure
II. Stimulate developing of shared databases

III. Demonstrate best practices in IT services (through local/EU subsidies)
IV. Organize private business in setting up integrated systems

Level 3: Rather good data integration

I. Invest in mobile broadband infrastructure
II. Activate and organize private business in collaboration on shared and integrated systems
III. Work on adapting by demonstrating best practices in IT services
IV. Involve governments/public in setting up common shared structures
V. Get involved in European or global standard developments and implementations

Level 4: Fairly well developed data integration

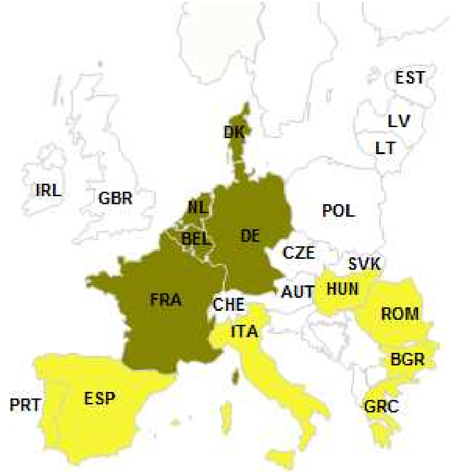
I. Combine/redesign the best of several standards in different nations, like EDI-teelt-agroXML-E-Daplos
II. Take the lead in new international data integration initiatives and use international/global standardization bodies like UN/CEFACT
III. Initiate new private-public collaborations on redesigned shared data infrastructure. Direct this through private-public platform(s)
IV. Develop integrated business process models
V. Organize discussions and get directions how to become an open EU information society

5.4 Regional views

Looking at data integration in Europe it can be mapped in several regions following some specific characteristics which carry their own challenges and recommendations.

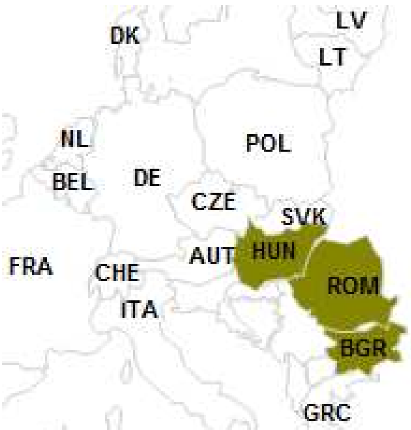
Region with most small farms and poor farmers.

In this region there is no standardization and hardly any ICT. Here data structures should be organized by public services to get developments started. The import of systems and data standards through private business (through multinational trade) will help as well. Last recommendation for this region is to copy knowledge (learn) from obligatory public services from other countries with structured and standardized ICT systems for agricultural data transfer.



Region where a focus on ICT is highly related to basic local challenges.

For example water management, erosion (in Southern parts) or trade (more in Western- and Northern Europe).
Some recommendations concerning the trade group are that business and governments should work on cross-border trade support by international adapted data integration systems. The setup of new standards upon or through international (not national) supported bodies is another helper. Regarding water management the implementation of best practices from other countries and the implementation of integration GPS and sensor data, smart phone apps for easier data access are mentioned.

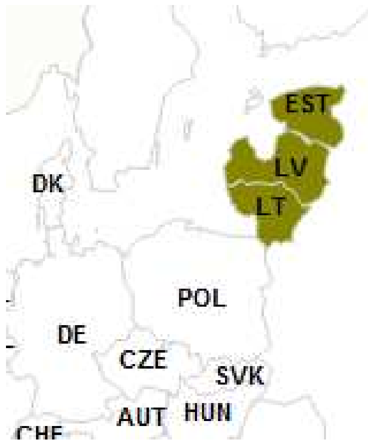


Region with problematic aging and so adapting ICT by farmers.

In these countries the effect of adapting new technology should be demonstrated, extended by education, not only for learning purposes but also to create a new and enthusiastic working environment for younger aged workers.

Region with fast upcoming production areas which are relatively new countries in agri IT as well.

Here stimulating the building of new internet infrastructure, especially mobile broadband will is crucial. Parallel to this, new and existing international standards should be adapted in a smart way. A last recommendation is to work on cross border trade and data integrated systems.



Region with standardization history ('old-fashioned' structures).

Old systems and structures on data integration can hinder progressive development. Based on this assumption, recommended solutions can be achieved through the renewing and redesign of old structures by private-public (cooperated) investments. Investments in open data infrastructures, stimulating by governments and stimulating of open innovation environment is worthwhile. This should be done by private-public investment on new common data exchange structures.

5.5 Overall view per country table

Table 5 gives an overview of nine general recommendations and if they are applicable to individual countries, based on the results in this report. This means that this overview might be incomplete or obsolete because of new knowledge or fast-changing developments. It provides however some general anchor points to start working on different issues in various countries.
The nine general recommendations are explained below:

1. **Demonstrate NT** (new technology)
   Invest in new technology adoption through education & demonstration. Demonstrate best practices in IT services.

2. Organize integration by **open networks**
   Organize discussions and organize integration by open networks. Get directions how to become an open EU information society.

3. **Public-private** collaboration structures and platforms
   Involve governments and the private sector in setting up common shared development and new structures.

4. Invest in **mobile broadband**
   In order to build infrastructure for new applications and services.

5. **Adapt** (new) **standards**
   Connect to existing global standards. Get involved in European or global standard developments and implementations.

6. **Show benefits IT** of technology (economics, time saving, etc.)
   Invest in research and advisory services to explore and convince farmers and other users of the benefits of technology.

7. Data **harmonisation** through **supply chain**

Activate private business and supply chain in setting up harmonization and integrated systems.

8. **Standardization CAP**
   Build reliable public (CAP) services and extend them with Web Services to provide private business with development opportunities.

9. **International initiatives**
   Take the lead in new international data integration initiatives and use international/global standardization bodies like ISO or UN/CEFACT. Combine/redesign the best of several standards in different nations, like EDI-teelt-agroXML-E-Daplos.

Table 5 Recommendations assigned to countries

	1. Demon-strate NT	2. Open network	3. Public-private	4. Mobile broadband	5. Adapt standards	6. Show benefits IT	7. Harmonization on Supply Chain	8. Standardi-zation CAP	9. Internatioal initiatives
AUT	X								
BEL	X	X	X		X		X		
BGR	X			X		X		X	
CZE					X		X		X
DNK		X	X						X
EST	X					X		X	
FIN				X		X	X	X	
FRA			X				X		X
DEU	X					X	X	X	X
GRC	X		X	X		X		X	
HUN								X	
IRL	X			X	X				
ITA	X					X	X	X	
LVA	X			X	X			X	
LTU	X			X	X			X	
NLD		X	X				X		X
POL	X	X	X			X	X	X	X
PRT	X			X		X	X		
ROM	X							X	
SVK	X							X	
SVN	X			X		X	X		
ESP			X		X		X	X	
SWE	X	X	X				X		
CHE			X						
GBR	X	X	X				X		

5.6 Recommendations analysed

Apart from issues that are specific for individual countries, a number of general patterns and commonalities can be observed, leading to several clusters with similar sets of properties and recommendations. These are described in the following sections.

5.6.1 High-technology, high agricultural diversity cluster

This cluster includes countries like Finland, Spain, Germany and Italy. They are characterized by a fairly high degree of organization among stakeholders in agricultural data exchange and good technical infrastructure availability. On the other hand, agricultural practices are either diverse in itself or there are different boundary conditions in different regions of the country having led to independent developments of public and supply chain services in the various settings. Harmonization on the supply chain level and in the public sector is therefore the most important challenge to tackle but also difficult to achieve. People in these countries are generally saturated with new technology and therefore need a clear demonstration of benefits before adopting new developments. One way to achieve this can be to make public databases available for developing new web applications for remote advisory service. Advisory agencies can then serve as facilitator in IT adoption. More advanced, distributed applications and services that are needed in these countries to make a case for further IT adoption and harmonization call for specific catalogues to find relevant services.

5.6.2 Networking challenge cluster

This cluster includes countries like Belgium, Denmark and the Netherlands. Within these countries, open cooperation, also on the international level is an issue. Overcoming the situation can be achieved by forming open networks and enhancing exchange of knowledge, technologies and information between the public and the private sector. One of the means to achieve this is trying to foster open source thinking to initiate development of new agricultural software. Regarding international level cooperation, France and Germany tend towards this cluster. All of these countries can benefit from intensive public-private collaboration activities, on national as well as on international level. Developing cross-border data exchange mechanisms can serve as a means to an end with this regard.

5.6.3 Infrastructure challenge cluster

This cluster includes the countries Bulgaria, Greece, Ireland, Latvia, Lithuania, and Portugal. Within these countries, wireless broadband connectivity or even basic internet connectivity needs to be enhanced in rural areas. Information and education about agricultural software, available databases and digital information sources can help farmers to develop a view on benefits and usage possibilities. On a technical level, agri search engines could facilitate access to relevant information, but only as soon as a basic communication infrastructure is in place and widespread enough. On the organizational level, government can support harmonization and standardization in data exchange by providing central information systems on important issues in agriculture and by cooperation with IT companies for providing support for farm management, data handling and reporting to authorities.

5.6.4 Individual recommendations

Apart from recommendations applying to groups of countries, several tasks and activities can be proposed for individual countries. This list of additional recommendations or activities can serve as an example to apply to other countries that are not listed here.

ITALY

- Work on automation on farms, adoption of Precision Agriculture
- Work on more reliable internet communications in rural areas and wireless broadband infrastructure where cables are too expensive
- CAP as a key trust for IT adoption at farm level

SPAIN

- Change the data security policies and improve standardized mode of serving data from governmental systems
- Work on precision farm techniques adoption

FINLAND

- Need for centralized monitoring services for gathering, analysing, storing farmers data for FMIS
- Create open source thinking to initiate development of new agricultural software
- Boost quality and availability of internet (broadband)
- Make data available for developing new range of (real-time) applications for remote advisory services

DENMARK

- Reduce rigidity of data exchange interfaces and resistance to change data security or standardized mode of serving data from governmental systems.
- Work on more reliable internet communications in rural areas.

SWEDEN

- Provide more information about the agricultural database arrangement
- Provide good interoperability between private-public systems

ESTONIA

- Upgrade agricultural data exchange system so that there are automated and standard interfaces between farm automation and authorities.
- Government and private partnerships are needed in the area of agricultural data exchange in Estonia.

LATVIA & LITHUANIA

- Work on automation on farms, adoption of Precision Agriculture.

CZECH REPUBLIC

- IT awareness in agriculture (to increase information availability about innovations and newt IT technologies)
- IT tools for funds and subsidies in agriculture (searching for information, accounting, audit)
- Support on-line data exchange (inside of the farm and towards to central administrative authority)
- Using web services for data sharing (to prevent data redundancy)
- Utilisation of the Galileo system (support technologies with GPS navigations, satellite data analysis)
- IT infrastructure investment – mobile broadband extension,
- Improve the data security policy

FRANCE

- Increase the harmonization in data exchange

- software developers have to take more in account the possibilities of data exchange with other systems
- Improve the data security policy
- Go on increasing automation in farms and adoption of precision Agriculture
- Boost quality and availability of internet in some rural areas

NETHERLANDS

- Provide good private-public systems for authentication and authorization
- Stimulate further innovations on precision farming

BELGIUM

- increase the harmonization in data exchange
- Improve the data security policy
- Go on increasing automation in farms and adoption of precision Agriculture
- Boost quality and availability of internet in some rural areas

SWITZERLAND

- Extend the use of electronic exchange of data
- Improve connection between the on-farm data and the central organization
- Improve coordination between data exchange systems
- Improve data security policy
- Increase linkage between different databases

6 General conclusions and outlook

Based on the literature review and field research, implications for business and policy can be derived and final recommendations can be made.

6.1 Business Implications

Having a look at chapter 3 and the main agenda issues, the real big challenges for ICT in agri- and food business can be formulated as follows:

1. *Investing in awareness and trust*
   Awareness and trust on the impact of improvements (i.e. by research, implementing new technology and accompanying standardization) could improve business efficiency, cost of production and establish more robust markets. Industry and business should take the responsibility to invest in increased trust.

2. *Adoption of new technology by means of open innovations*
   Adoption of new technology is increasingly challenging in a complex world. Beside the issue of cost price (always difficult in case of introducing new technology) awareness of the future benefits and the requirement for good training and support is important. Learning and further developing of services and products (based on the technology) in a rather safe innovation environment (pilots for example), and co-creation by more stakeholders are other critical success factors. Open innovation is a keyword in an increasing complicated market system.

3. *Join in developing new collaborative and service-oriented infrastructure*
   Private, and even public business, should invest in new collaborations and collaborative infrastructures. New data structures should be developed where data can be gathered, distributed, used for producing (new) services. In its architecture it will be in a form of datahubs connected to each other by web services. Further attention has to be paid at the pre-competitive and more secured commercial layers to provide a means of securing proerty rights in an open space. Authentication and authorisation should be handled in a proper way. Although national and EC governments should play a key role in initiating and financing (as users) this infrastructure the main ownership should remain with private business and industry.

4. *Implementing business process standards and service-oriented approach*
   Agriculture and the food industry appear to be quite similar in its processes. Common or non-agri data standards can be used in agriculture. As data integration would become more and more complicated, linking to several processes (and organisations) at the same time, the business process modelling approach will have evident benefits on a longer term. The

same can be seen for service orientation. On both sides its very worthwhile to invest in knowledge and collaboration.

5. *Choosing the standards*
   Not all (sub-)domains or business processes can be tackled by the same standards. It depends on the involved actors, history, flexibility of current structures and knowledge of standardization. Some further investigation should be carried out to find out what's the best roadmap. It is recommended some (a few) open standards are chosen to get the most clear roadmap in investing in new standards by sometimes small software developers. This task can also be picked up (initiated) by national or international governments to enhance industry standardization in agriculture.

6.2 Policy Implications

Implications on ICT-agri policies are:

1. *CAP implications and controlling efficient data inquiry*
   The European common agricultural policy implies the control of several main themes like animals and its movements, nutrient management, land parcel usage, food safety, biodiversity. Even animal health care and welfare and ways of responsible production of food and feed will be monitored in the near future. The implication of this is that the EU is an increasing major market player in the field of information sharing. If the EU is only inquiring data, and not offering services back, it will have an effect on the effort, and administrative burden of farmers. This should be managed to avoid this negative effects. One of the key issues is also to reduce the administrative burden for farmers and operators. Many of the state and private requirements can be satisfied with better harmonisation and combined data and control systems.

2. *Role for EC or national governments in directing data standards*
   The EU has the potential to be proactive in relation to the standards which it uses. But with the impact for private business to get a more reliable and sustainable choice in what directions in standardization to invest on. For the EU this can be for example the data schema of the webservice for exchanging data with E-traces.

3. *Limited investment possibilities, especially in small domains*
   Many SMEs have limited investment possibilities, especially in small domains. Small domains with specific solutions are not able to benefit from big scale (market) opportunities and are having in this way more difficulties in investing in new and sometimes risky products. For some countries in the EU it's even worse, as the consumers of the products have quite limited possibilities to buy. There is potential to harmonise packages across the EU thus ensuring the maximum market and return is achieved for the investment.

4. *Organizing public involvement in the setup of collaborative data infrastructure (private-public collaborations)*
   Investing in infrastructure cannot been completed by private individuals only, it's too

expensive in time and money and general directions should be best managed by public (or private-public). Not only private collaborations but also the involvement of the public can be a key factor of the succes in the setup of fair well organised data exhange in the European community. But they are mostly not involved or can do far better. In some countries, like The Netherlands, national government co-invest (industry is still the major financer) in open standardisation, publishing public datamodels (probably in future even data schemas) of the obligate data inquiry.
The role of nations or even the EU can be initiating, facilitating or stimulating. As a player itself on the information market it should even invest and take responsibility in (co-)steering the setup and maintenance of collaborative data infrastructure.

5. *Initiating common data structure in the EU*
   There is a lack of a common structure for data exchange in the EU. Some areas are having hardly any structure; others are having their own structures for data exchange. This hampers the cross border trade and further developments of one European economic transparent market. The EU should stimulate and initiate new common data structures.

6. *Initiating (further) research on the implementations of common data structures*
   The agriXchange project initiates the networking of ICT experts and starts working on a framework of new common data structures. More research should probably be done on new structures and facilitating of the implementation over regions of Europe in a joined knowledge project. This could be completed using a common EU wide goal as a use case, for example calculating carbon numbers for dairy products.

7. *Stimulating availability of (broadband) internet infrastructure and capacity building in rural areas*
   Data integration and data sharing are highly dependent on the availability of broadband internet in rural areas. Not only in well agro-ICT developed countries but also in emerging ICT countries the availability of mobile data communication structure plays an important role for innovations based on mobile solutions. In regional areas it should be used to stimulate an increased requirement for broadband (mobile) internet access. Furthermore it is important to improve the capacities to use ICTs and to ensure the affordability of the ICT applications, for smaller farmers and companies.

Innovations are identified based on the keywords of information sharing, open networks or collaborative working environments and innovation & development and new services rather than products. Trust in sharing information (inter-enterprises), research (to improved competitiveness by developing new processes) and development of new products and tools are other keywords in challenging the future of new ICT structures and adoption of it.

6.3 Findings in the field

Based on the analysis of the state of the art in the present report, we have identified challenges for future research and development of data exchange in the European agriculture network. The most important findings identified were:

1. An aging population of farmers which manifests itself through the lack of adaption and investments on new technology, especially in Southern and Eastern countries.

2. Broadband availability in rural areas. For most countries in a quantitative sense, but for more ICT developed agricultural countries in qualitative way.

3. Mobile infrastructure in most countries not capable of sustaining the potential of using mobile computing based on data communications by mobile devices (smart phones and others) which are very promising.

4. There is potential for countries that are developing quickly to adapt new data exchange infrastructural models and skip the complex and inefficient structures that currently exist in some EU countries.

5. There are substantial differences across the EU in relation to the level of data integration and standardization. Member states can be divided in 4 levels from none or hardly any data integration to quite well developed (France, Germany. The Netherlands and Denmark).

6.4 Discussion

Within the CSA project agriXchange this investigation was meant to provide an overview of the state of the art in data exchange as bias for further project work. It should not be seen as purely scientific reporting; the identification of key factors and indicators for the added value generated by a common data exchange system were not precisely or quantitatively elaborated.
Knowing the most important findings and sometimes barriers, some opportunities for solutions will be discussed.

A number of barriers to technology adoption have been identified in this study for example the aging nature of European and the lack of broadband in rural areas. It's not one issue on its own that contributes to adoption but a combination of issues. These issues cannot be solved by individuals or groups of individuals; there is a requirement for a collaborative approach which includes all stakeholders. There is also a requirement to further evaluate each of the barriers from all of the stakeholders' viewpoint creating a collective framework that would have a sole objective of facilitating increased ICT use in Agriculture.

There is significant potential of rolling out new techniques (such as mobile computing) in agriculture; however, there are significant challenges in some regions around the mobile network. This underlines that the infrastructure will have to meet high quality standards before this role out will be successful. In each individual country the question will be asked who is going to finance this development. Speeding up innovations and developments seems to be hampered by the underdevelopment of data exchange structures in most areas in terms of missing architectures, infrastructure and data standards. If structures can be copied from one place to another, this will speed up the process. However, often it is not just a matter of copying structures as the effectiveness of it is very much related to regional infrastructural conditions. It is not yet clarified which structures fit in certain areas.

Discussion is conducted about the way and level at which standardisation should be done. Experts argue it should be at the business service layers and not on processes, because of competitive surroundings. Focus should be put on demonstrating how processes can work, but keep them flexible and hence keep them out of the rigidity of (formal) standardisation processes. For better understanding and recommendation more should be done on identification of the available key factors or indicators.

At the end people imagine an open network, with flexible relationships between network partners, which implies less hierarchical or linear chain structures. This has consequences on innovations that will be developed within these open networks, as well as the ever changing anonymous partners in the system.

6.5 Outlook and recommendations

The challenge identified in this study is how to overcome the identified barriers and to understand the factors that will lead to increasing the speed of adaption.
Recommendations are

1. Quantify the benefits arising from overcoming the barriers through future research.
   This should include the identification of key factors and indicators which will result in increased value added which would be generated by a common data exchange system and subsequently developing the underlying infrastructure to promote this. The indicators may then be used to quantitatively describe the effect of changing certain key factors like e.g. the internet connectivity in rural areas or the proportion of ISOBUS-enabled equipment in a country or the region.

2. Demonstration of the effect of adapting new technologies
   Including their effect on the overall system. This will encourage users to have faith in any new systems that are developed therefore increasing the subsequent use.

3. Organizing data integration through open networks
   Open networks with flexible relationships between network partners will facilitate successful integration of the systems. The importance of agricultural data exchange in the EU has broadly been recognized, however all service providers and users need to be convinced of the benefits.

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Annex: Helping guideline for the inquiry framework

Underneath a description of the different levels and corresponding (kind of) questions. A more detailed guideline with helping questions per level can be found in deliverable D2.1 “In depth insight into the European information, communication & technology issues and needs in agriculture”.

Regional/country wise agricultural characteristics

Give the agricultural characteristics of the country or region regarding the mentioned sectors. Use, where possible, the latest official EU statistics.

Key words:

number of farms, size, size distribution, labour, crops, animal numbers, production volumes.

Farm automation level

Give a description of the country or region regarding the level of farm automation for intra as well as inter-enterprise use.

Key words:

numbers, percentage, PC, internet, mobile/handheld devices, farm management information systems, process automation applications, ISObus, positioning systems, on-farm networking systems, e-business applications

Data exchange: process level

Which relevant data exchanges are used at process level (bottlenecks, challenges)?

Key words:

farm process automation vs. information systems, farmers IT vs. national/EU systems, farmers IT vs. extension services, farmers IT vs. production chain systems

Data exchange: application level

Concerning the processes mentioned in 3, what (kind of) applications can be mentioned? Describe this in common and if relevant by (some) processes.

Key words:

software, databases

Data exchange: data level

Are data definitions available in order to be able to share data? Describe this in common and if applicable on earlier mentioned processes.

Key words:

syntaxes, semantics, organization, maintenance, availability, costs, bottlenecks

Data exchange: physical level

Give information about the technical infrastructure. What is available? How is it organized?

Key words:

broadband infrastructure (adsl, sdsl, cable, satellite, isdn), network protocols (FTP, e-mail/smtp, http, XML), database structures, information hubs/brokers

Use cases and relevance in EU regions

Also the relevance of the Use cases should be discussed for each country. Which of these use-cases are relevant for your country? Describe which interests there are. Who is interested, what initiatives, which challenges?

LPIS

Updating of LPIS (Land Parcel Identification System), where a farmer collects data spatial data of her/his new field parcel boundary lines. The farmer sends data to LPIS service provider for updating the parcel boundary lines in the national LPIS. The national LPIS provider does the update to the system and prepares the further data delivery between different LPIS and parcel information utilizing agricultural service or software application, taking into account the criteria of INSPIRE. Special attention is paid to the quality representation and assurance of exchanged data; proven data acquisition and data handling processes, content of metadata.

Geo farmer and fertilizer

Geo-farmer and fertilizing, where a German farmer, who uses a Czech farm management system, requests a site specific fertilizer advice, for a specific field. Field parcel boundary information is retrieved from the national LPIS. The advice service is based on a French knowledge-based advice module and it uses satellite data (LAI map) from a Dutch service provider, soil analysis data from the local soil laboratory and "FutureFarm" compliance to standards check functionalities to produce a to standards compliant fertilizer map in ISO 11783 format for the task file needed in fertilizer application.
The executed fertilizer application is documented to the farm management information system, where the information is transferred to government's database in connection of administrative reporting.

Animal registration

Animal registration, where an animal is transported from a farm in one EU country to another for growing, and to a third country for slaughter. In connection to every movement the animal registers are updated in both delivering and receiving countries.

Animal identification

The identification devices could be able to communicate with other farm equipment. Some of the devices specifications are itemised by an ISO standard, most are not. For interoperability between livestock identification devices a proper standard is required, and need to be supported by all animal farm device interfaces and the additional electronic information standards.

Other remarks

Finally relevant issues (gaps) not mentioned so far should be mentioned and discussed.
Key words:
data protection, data ownership, privacy, teaching, learning.


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