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QUO VADIS PRECISION FARMING

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Abstract. *The agriculture sector is a unique sector due to its strategic importance for both citizens and economy which, ideally, should make the whole sector a network of interacting organizations. There is an increasing tension, the like of which is not experienced in any other sector, between the requirements to assure full safety and keep costs under control, but also assure the long-term strategic interests of Europe and worldwide. In that sense, agricultural production influences, and is influenced by water quality and quantity, ecosystems, biodiversity, the economy, and energy use and supply. The seasonality and ubiquity of agriculture make agricultural practices and production amenable to efficient synoptic monitoring. The effectiveness of each production, including agriculture, is determined by the ratio of the value of the production outputs to the value of production inputs. For agricultural production the efficiency is affected not only by the internal factors of the production process, but also by external factors (climate, subsidies, the situation in the global market, etc.). The nature of agricultural production does not simply allow pure reducing of energy intensity; in fact the production is affected by many other factors such as: Crop rotation requires several years interval* *between growing certain crops on the same land repeatedly or specific crop sequence is required, Selection of crops variety is affected by market demand, Agricultural production is greatly influenced by the subsidy rules, Some operations can be operatively affected by climatic conditions., The use of waste biomass energy potential is influenced by the structure of crops and the technology used on the farm. Acquiring knowledge about the energy and carbon intensity of different crops on different lands, how the farm processes work, and how to take care of the variability within fields in a single farm is very demanding using traditional approach of farming. Considering large area of agricultural lands, new technologies are demanded for collecting sensitive data and evaluating these data, No optimization processes can be performed without sufficient and objective knowledge.*

Keywords. *Precision Farming, Energy, Environment, Economy, Big data, Knowledge Management*

Preface – What is Precision Agriculture/Farming

There exist a number of definitions for what Precision Farming is. Glen C. Rains (Rains, 2009), use the main focus on economy of production and defined Precision farming (PF) as a management practice with the potential to increase profits by utilizing more precise information about agricultural resources. The aspects of precision agriculture are described by Pierce et al. (Pierce & Nowak, 1999) They defined precision agriculture as “the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality”.

Similar approach was used by Gnip P. (Gnip, Charvat, Holy, & Sida, 2002), where Precision Farming was defined as a new agriculture technology designed to monitor, analyses and control plant production to optimize costs and ecological effects. The basic principle is positional control of fertilization with an accuracy of a few meters. To control the process a huge amount of data has to be collected and analysed. Important is focus not only on economy, but also on ecology of production.

On CEMA (CEMA) is summarized currently used broader approach for Precision farming, which includes:

- **High precision positioning systems (like GPS)** are the key technology to achieve accuracy when driving in the field, providing navigation and positioning capability anywhere on earth, anytime under any all conditions.
- **Automated steering systems:** enable to take over specific driving tasks like auto-steering, overhead turning, following field edges and overlapping of rows.
- **Geomapping:** used to produce maps including soil type, nutrients levels etc. in layers and assign that information to the particular field location.
- **Sensors and remote sensing:** collect data from a distance to evaluating soil and crop health (moisture, nutrients, compaction, and crop diseases). Data sensors can be mounted on moving machines.
- **Integrated electronic communications** between components in a system for example, between tractor and farm office, tractor and dealer or spray can and sprayer.
- **Variable rate technology (VRT):** ability to adapt parameters on a machine to apply, for instance, seed or fertiliser according to the exact variations in plant growth, or soil nutrients and type.

According to the Oerke & Gerhards (Oerke, Gerhards, Menz, & Herbert, 2010) precision agriculture relies upon:

- Intensive sensing of environmental conditions in the crop.
- Extensive data handling and processing.
- Use of decision support systems (DSS).
- Control of farm machinery in the field.

In our paper, we would like more extend his understanding of Precision faming and look on Precision farming like a complex knowledge management combining economic and environmental aspects.

Introduction

The world population will reach 9 billion in 2050. But the land is a resource, which is strictly limited. Moreover, in reality there is less and less land available for farming due to other anthropogenic processes. Farmers have to care not only about their production, but also about environment, soil protection, water protection, biodiversity protection etc. As mentioned above, PF goal is limited incomes (chemicals, lands, water) and increased production. In order to drive sustainability and profitability goals, farms have more and more improve their knowledge management, ultimately increasing the power and influence of the farmer within the entire value chain. Farmers become bigger. As a result, it is more and more difficult to manage all the required information from numbers of data sources, which has to be integrated into decision support. Sensors, imagery and other technologies are all working together to give farmers details about soil content, weeds and pests, sunlight and shade, and other factors. The challenge, however, is that not only does putting this data to use require a fair about of synthesis; it is also only applicable to the farm on which the data was collected. Any farm decision depends on availability of relevant information and knowledge. To improve farming decision it is necessary to guarantee effective utilization of existing information and knowledge has to be derived from available data sets. Large datasets are available on different levels, but they are heterogeneous: in some cases also unstructured, hard to be analysed and distributed across various sectors and different providers.

Future farm knowledge management systems have to support not only direct profitability of farms or environment protection, but also activities of individuals and groups allowing effective collaboration among groups in agrifood industry, consumers and wider communities, especially in rural domain. When having such considerations in mind, the proposed vision lays the foundation for meeting ambitious but achievable operational objectives that will definitively contribute to fulfil identified needs in the long run. A farmer has to have either if able to handle easy to use tools that allow with a few clicks to solve all these problems or (s)he gets support by new models of farm advisory systems that are able to solve his needs. The existing extension services are only partly able to keep updated with the farmer’s common needs. A modern farm management system offers the potential to fundamentally alter agricultural decision-making. The use of large machinery and hired labor has caused many farmers to think of large fields as the basic management unit. Information technologies permit the modern grower to obtain detailed explicit information at a small scale common to farming practices of earlier times but with considerably more information, enabling them to efficiently manage the land at these finer scales. The basic principle of modern knowledge management allows more accurate production.

Future Drivers agriculture production

In order to build vision for future knowledge management in arable farming, there were analyzed examples of existing knowledge management systems and also drivers, which will have in future potential influence on farming sector. Within the Future Farm project a trans-European investigation has led to the definition of the key objectives needed to realize this vision of a new concept of farming knowledge management respecting changing conditions and demands. FutureFarm (Charvat K. , Gnip, Vohnout, & Charvat, 2006) defines next groups of drivers, which will have influence on farm management and which could also eventually stimulate new demand for knowledge management:

- Climate changes.
- Demographic (Growing population, Urbanisation and land abandonment).
- Energy cost.
- New demands on quality of food (Food quality and safety).
- Aging population and health problems.
- Ethnical and cultural changes.
- Innovative drivers (Knowledge based bio economy, Research and development, Information and communication, Education, Investment).
- Policies (Subsidies, Standardisation and regulation, National strategies for rural development).
- Economy (Economical instruments, Partnerships, Cooperation and Integration and voluntary agreements).
- Sustainability and environmental issue (Valuation of ecological performances, Development of sustainable agriculture).
- Public opinion (Press, International Organisation, Politicians).

The results of Future Farm project analysis (FutureFarm) defines three levels of Knowledge management on farms:

- Macro level, which includes management of external information, for example about market, subsidies system, weather prediction, global market and traceability systems, etc.)
- Farm level, which include for example economical systems, crop rotation, decision supporting system.
- Field level including precision farming, collection of information about traceability and in the future also robotics.

It is necessary to consider previous analyses for suggestion of future knowledge management system functionalities and their interrelation. The basic principles of interrelation could be expressed by Figure 1.

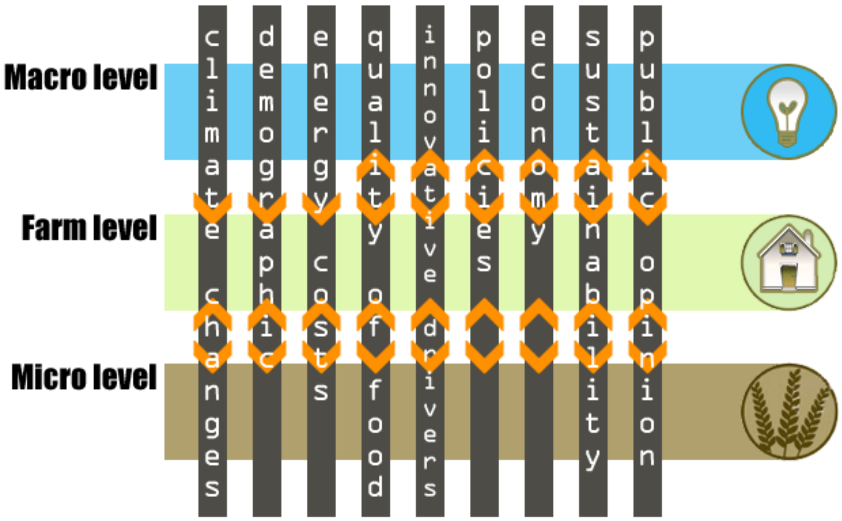


Fig 1. Farming information flow

The whole process requires a big amount of data to be collected; this data enables a control of the whole process and also introduces information about the situation outside the farm (economical information). For an even better understanding, the whole process requires to improve access to this data and make analysis of such data. Mathematical and statistical analyses and usage of spatial information retrieved from this data can bring new quality to the whole process of future farming. The real end-users of the technologies are not only farmers and agriculture managers, but also advisors and eventually service organizations. Part of knowledge could also be available for the food industry, market and direct consumers. The limitation of better utilization of knowledge is, unfortunately, their limited effective sharing of knowledge. It is necessary to improve access to these data and the possibility of using new information sources. (Charvat, Gnip, & Krocan)

Knowledge management systems for generation of homogeneous information for traceability transfer and business as well as integration and management of such information are thus specifically complex issues in this sector. Therefore, the challenging problem is twofold. Firstly, how to assure the full security and safety of products when minimizing costs. Secondly, how to provide benefit to the food sector networks of organisations enabling them to interoperate, to exchange information and data and to fully integrate miscellaneous business functions along the value chain. These problems (partly valid for a number of other sectors) are increasingly becoming critical and difficult in the Agri-food sector.

Future challenges

agriXchange (Charvat, et al., 2012) identified a number of future challenges; some from them are coming from previous activities and are related to PF in broader sense:

- Collaborative environments and trusted sharing of knowledge and supporting innovations in agri-food and rural areas, especially supporting food quality and security - the concept of the trust centres has to represent an integrated approach to guarantee the security aspects for all participants in the future farm. There will be a growing importance of protection of privacy and IPR. Trust of information is one from the priorities for all rural communities. Pan European social networks have to support trust centres and enable such technologies as cloud applications and which will have to guarantee knowledge security - trusted access to information is extremely important in relation with aspects, which will be discussed in next chapter Big Data.
- ICT applications for the complete traceability of production, products and services throughout a networked value chain including logistics - to develop world-class network management solutions that facilitate communication and co-operation between networks of SMEs and large enterprises in the agrifood and rural development domains. These solutions will enable the management of food supply chains/networks, virtual and extended enterprises through collaboration and knowledge exchange – future precision farming has cover not only filed operation, but be focused of fuel consumption reduction, but also on quality monitoring
- New generation of applications supporting better and more effective management of agriculture production and decision making in agriculture - Future farm knowledge management systems have to support not only direct profitability of farms or environment protection, but also activities of individuals and groups allowing effective collaboration among groups in agrifood industry, consumers and wider communities, especially in rural domain. The added value chain will play important role in future PF
- ICT applications supporting the management of natural resources - with better understanding of the environmental relations, the necessary valuation of ecological performances will become possible. Pilot projects and best practice samples will be the key to demonstrate for a wide auditorium the benefits of environmental caretaking. New model of payment of the different groups of beneficiaries have to be worked out (local, regional, national, continental and worldwide) as well as the best practice between today's "government owned" environment or "private owned with social responsibilities" has to be worked out (Brynjarsson, Stokic, Sundmaeker, & de Juan).
- ICT application supporting adoption of farming production on climatic changes – it is important to support monitoring of influences of climatic changes on farming production, analysis of influence of climatic changes in regions and advisory systems for farmers. Monitoring of influence of climatic changes could be provided using earth observation, sensor measurements, but mainly using crowdsourcing methods. Important are also social spaces, where farmers will have possibility to discuss methods of farm adoption – to be able react on climatic changes is important task for future PF.
- ICT applications supporting agrifood logistic – the focus has to be on the transportation and distribution of food, sharing online monitoring information from trucks during the transport of cargo, a flexible solution for on-demand dock reservation and an integrated freight and fleet management. In general, all the selected applications have the same practical benefits as cost reduction, better coordination and better information for decision making, and the proactive control of processes leading to increasing efficiency and effectiveness (smartagrifood. eu) - logistic on farm level and also food level will influence bot economy and environment.
- ICT application supporting energy efficiency on farm level - the problem of energy efficiency in agriculture hasn't been taken into account. Agriculture production uses energy in two ways – directs energy consumption is in arable farming mainly related to machinery energy consumption, indirect energy consumption is related to production of chemicals used in agriculture. Environmental effects of savings on direct and indirect energy use in agriculture are integrally considered, as energy use efficiency also implies reduction of greenhouse gas

emissions. Applications has to be focused on development of hardware and software solutions supporting complex energy and chemicals intensity reduction in crop production, operational decision about protection of crops and logistics optimization in agriculture company (farm) based on advanced sensor monitoring. By improving the energy and chemicals balance and better targeted protection of crop production and optimization of logistics system the project will contribute to increasing the competitiveness of farms not only through cost reduction, but also by increase in labor productivity.

Big data

What's the role of Big Data in the farming ecosystem? Farmers need to measure and understand the impact of a huge amount and variety of data which drive overall quality and yield of their fields. Among those are local weather data, GPS data, ortophotos, satellite imagery, soil specifics, soil conductivity, seed, fertilizer and crop protectant specifications and many more. Being able to leverage this data for running long and short term simulations in response to "events" like changed weather, market need or other parameters is indispensable for farmers in terms of maximizing their profits. From a regulatory perspective tracking and tracing products throughout the supply chain or Country of Origin labelling provides additional Big Data challenges.

Technologies for data gathering and statistics to support the new needs (could be at policy level or farm level) already exists, applications will be extended with the objective (depending on spatial and time frequency of the observation) of monitoring / control (indicators-administrative) / land management / statistics. Satellite remote sensing depending on the spatial/time resolution will deliver applications with lower costs and more effectiveness than in the past PF technologies (drones, micro sensors, positioning systems, portable communication technologies…etc.) will be used more at local level to improve productivity, decrease input costs and mitigate GHG (Greenhouse gas) emissions.

Now with developing of new satellites (Copernicus Sentinel data) earth observation data available with higher frequency (e.g.3 days revisit in Europe), higher spatial coverage and high resolution. This data are also often open and free at world level for everyone. Already now amount of data is at the edge of big data. There is growing data processing needs in terms of multi-temporal geospatial analysis and also growing number of external data for Geospatial analysis

Second area generates future big data in Agriculture are IoT (Internet of Technology) including field sensors and machinery monitoring. The experimentation in FarmTelemetry project demonstrates that one average Czech farm (i.e. around 1'000 hectares) could generate daily 20 MegaBytes of data. This could be only for Czech Republic something between 30 and 50 GB per one day. We may easily reach Terabytes of data a day from agricultural basic monitoring by sensors in Europe. Together with satellite data agriculture will need to manage extremely large amount of data.

Big data are not only a subject of interest for farmers. Such data are interesting for agribusiness companies, suppliers and manufacturers of agricultural machinery, weather stations and laboratories, traders and industry partners and technology and solution providers.

On one side there is growing whole ecosystem with a strong need to secure Big Data from different repositories and heterogeneous sources. In some cases, sharing of data could be common interest, but on other side, there are also different interests and data could help to one part of value chain to take bigger part of profit. From this reason Big data are sensitive topics and trusting of producers about data security is essential. The producers of seeds and chemicals want to maximize their business with farmers. Manufacturers of agricultural machinery are collecting data for their purposes. They are focused on machine optimization monitors, the productivity of the machines and try to figure out how the machines can be made more efficient and simultaneously farming logistics data helps farmers control the growing farms and the ever-expanding machine fleet. But this data could be also used by food industry against farmers.

So there is necessary to build such strategy for Big data in Agriculture, which will support collaboration in the whole chain, but which will also be trusted by producers. There is necessary to build strategy for Big data in Agrifood chains: a perspective, which prepared recommendation for future utilisation of Big data. Big data in Agrifood chain has guarantee a more complex role. It includes food safety and security, energy, waste management, recycling and the environment. This may lead to increased information collection and flow and in the needs to use ICTs in a more optimal form. There will be calls for greater integration of information flows that include data and information on biomass, water and other natural resources across the agrifood chains to achieve whole systems efficiencies. Current technologies indicate how the new ICTs and information flows would emerge in this perspective around use of sensors, sensor networks, Big Data at plot, field, farm, village, region levels on large data clouds, advanced analytics, the Internet of Things etc. An emerging need in this perspective comprises more open data an requires Big Data repositories, trust centres for open data and information, cloud based Big Data and applications and greater bandwidth and speed for connectivity as common infrastructure.

Data privacy will be one from key aspects of future Big Data strategies. When private data will be managed on Big Data platforms, only a data owner will have the right to decide, who and under which conditions will have access to the data. To achieve the acceptation of platform by farmers, the data privacy needs to be guaranteed. For such a purpose we allocate specific task to data privacy. Data ownership and data privacy is a major issue with regard to data used and produced on the farm, and forest. Multiple sources of data need to be integrated in order to be useful, and ownership and control become major issues, quite apart from the technical challenge of allocating value in such complex scenarios. Data produced by farmers and forest owners needs to be suitably protected both for reasons of privacy and ownership. This task will combine legal, ethical and technical approaches to make data usage both possible and attractive to the relevant actors. The starting point for our approach will be to use semantic architectures for data provenance and trust to enable data to be appropriately tagged and associated privacy and restrictions to be allocated to data.

Social organization of farmers' decision-making

Social organization of farmers' decision-making follows analyses of farming structures in different countries and the way, how adoption of precision farming is running in these countries. In many regions Precision Farming was considered an actual, but not a topic of increasing interest. It was stated that political will and support of these technologies is not demonstrated yet and therefore their full potential is not exploited.

It was also recognized that agricultural technology firms and private consultants are considered as the main engine of Precision farming adoption. Interviewees pictured that typical Precision Farming farms are rather large in size and to be operated by relatively young and highly skilled farm managers. Important is role of consultants in site specific crop management, who could be consider as intermediates or partners facing high expectations and pressure. European farmers still prefer phone to e-mail, but web pages play an increasing role. Farm data is considered sensitive and farmers still prefer personal contact to their consultants.

The big problems for collaboration are non-compatible solutions. They have forced customers into purchasing only products of one provider. Compatibility problems have delayed the adoption of site specific crop management and can still be considered as a most important barrier towards investment. We therefore assume that when the technology of Precision Farming works trouble-free and economic benefits can be clearly demonstrated according to the kind of client (cooperative, farm, contractor etc.) the technology will develop and spread similar to smartphones and become common standard. Farmers are not searching for hyper-mechanization. Their premise is to register and administer what is useful and to report the inevitable. Precision Farming is adopted, when economic reasons such as high input prices or environmental regulations are in favour and/or certain barriers are removed. Introduction of site specific technology also happens by evolutionary replacement of old machines. New machinery is increasingly equipped with site specific on-board technologies. Integrative and easy to handle solutions are needed. The critical discussion on the possible ecological benefits of PF and its practicability should be deepened. (Charvat K. e., 2010)

The study provided by Ganicky at al. (Ganicky) solve question, when precision farming could be profitable. This question is difficult to answer by any published profitability review because there are:

- incompatible approaches to economic analyses;
- costs that are often overlooked, and
- benefits with ill-defined value.

To see what price a farmer has to pay to switch from traditional (conventional) to Precision Farming, let's analyse how effective are the investments to Precision Farming and which of them are unavoidable. Economically effective management of within-field variability means in other words that well trained farm manager does correct decisions based on complex information and these decisions are precisely implemented. High quality information is the basis for effective management. Therefore initial investments into information like boundary mapping, soil sampling and management zones identification, GIS mapping etc. is also unavoidable. These investments into information should be viewed as durable and their costs should be amortized as a fixed cost over a number of years. Implementing the decisions of farm management means in fact to operate the fields. All costs of this type are considered to be variable. These costs are unavoidable. To operate fields, appropriate Variable Rate Technologies (VRT) and other types of technology are required, like e.g. GPS-receiver, yield monitor, computer, GIS and other software, VRT application equipment etc. All this equipment represents durable capital investments. Furthermore, there are other fixed costs like depreciation, interest on investment, insurance costs associated with durable capital (like the abovementioned equipment). These investments are avoidable. The investments and fixed costs associated with purchasing VRT application farm equipment usually constitute substantial part of all investments and costs encountered by a farmer when adopting Precision Farming. In any case, effective use of PF management may require the development of the knowledge base, experience and accumulating information about fields and their productivity over several years. In all cases mentioned above a farmer may elect to custom hire the VRT equipment, yield monitor and other technology like GPS together with the consulting services from specialized companies. Such companies in general are better equipped with modern VRT machines, have highly qualified specialists and can offer full service (for example GPS field boundary mapping, soil sampling and management zone establishing, fertiliser recommendation, fertiliser prescription and VRT application). Such operating leases are offered on a variable cost basis - priced per hectare or per day of operation. For smaller farms, and in any case for a novice to PF management, this way of operating fields offers the optimal and at the same time the least expensive possibility. The model, which can reduce fixed cost for farmers and make PF profitable, is model based on outsourcing. Farmers buy services from service organisation, fixed cost are changed on variable cost. Technology on side of service organisation used for longer period and more effectively, so it reduces cost for the process.

Standardization

It is important to focus on standardisation for a wider adoption of precision farming. Standardisation importance will grow for interconnectivity of different levels of farming knowledge systems. It is important to support the development of machine-readable protocols, and standards to integrate management information systems with policy tools. Major priorities for future knowledge systems will be the integration and orchestration among services based on semantic integration of collaborative activities, including semantic compatibility for information and services, as well as ontologies for collaboration. (Charvat, Gnip, & Mayer) (Charvat K. , Gnip, Krocan, Spyros, & Mayer)

More information on standardisation within the Precision farming domain may be found in a separate paper. (Řezník, et al.)

Contribution of FATIMA and FOODIE towards precision farming

Fatima

The challenge for sustainable crop production is to achieve optimized yield (in quantity and quality) and farm income with a minimum of inputs (nutrients, water, energy, pesticides, herbicides, labor, money), while preserving and protecting the environment and social fabric. We focus here on nutrients and water, while maintaining an integrated perspective of all factors. FATIMA to this challenge is plant- and people-centered at the same time and both are linked.

"People-centered" means that we first set out to learn and understand how people (farmers, rural communities, agribusinesses) grow food and how people (consumers, land and water managers, decision makers, policy makers) act and react in the given governance structures. Only then can we co-create and co-develop (together with them) technological tools, socio-economic models, and policy instruments that can assist them in their tasks. Only this way leads to acceptance by and co-ownership with users and other actors, which is the basis for wide uptake of any technology.

"Plant-centered" means that we look at how the plant/crop grows at the center of a complex web of external drivers (like climate, weather, soil), inputs (nutrients, water, also energy, pesticides), internal growth factors (cultivar, variety, soil fertility), and outputs (yield quantity and quality), all of these spatially distributed and evolving with time. The accurate knowledge of the actual plant status in each moment and at each location is the key to drive optimum management and to apply more effectively and efficiently the knowledge that the scientific-technical basis puts in our hands.

The main target of FATIMA is to develop Earth observation (EO) and wireless sensor network (WSN) assisted pre-operational tools and services for effective and efficient precision farming and agri-environmental management. Methods are target on increasing nutrient efficiency means reducing external inorganic inputs, as well as water in the case of irrigated crops, while maintaining or increasing yield (both in quantity and quality). FATIMA focused on improvement of ground and surface water quality will be achieved by reducing inorganic inputs and saving water thus reducing diffuse pollution to a minimum and keeping recharge at stable levels. This direct (local) improvement will be potentiated by the non-local effect of reduction of the primary energy embedded in inorganic inputs and in water delivery. It supports reduction of soil contaminations with toxic compounds and heavy metals will equally be achieved by reducing inorganic inputs and by additionally following good practices on selecting "clean" source of these inputs (depending on where they are manufactured, they may contain more or less heavy metals). Important is also conservation of biodiversity and wildlife will depend on healthy ecosystems. Saving water in crop production will leave the necessary water for ecosystems maintenance; healthier soils will also protect biodiversity. Reduction of soil erosion and improvement of soil quality and structure will be achieved again by the reduction of inorganic inputs and by the measures derived from. E.g. Fine-tuned spatial and temporal coupling of N-cycles will help maintain soil physico-chemical properties; less contamination (in combination with soil remedial measures) will restore soil water retention capacity and reduce external nutrient and water needs. Spatial and temporal coupling of the N cycle means protection of the environment by drastically reducing i) nitrate leaching below the rooting depth and thus ground-water contamination, ii) greenhouse (nitrous oxide) emissions to the atmosphere, iii) disturbance of background values of soil chemical properties (nitrates, electrical conductivity, pH) that can otherwise increase oxidation of soil organic matter and offset soil fauna and microbial communities. Last goal is improving human health, through the reduced release of pollutants and GHGs, will again be achieved by reducing inorganic inputs. There is a double feedback in here: firstly the reduction of inorganic inputs directly reduces the contamination of the environment and the agricultural products; secondly, through the energy embedded in these inorganic inputs it leads to a reduction in primary energy (oil, gas) consumption and the pollutions and GHG emissions associated with primary energy production.

FOODIE

The FOODIE project focused on building an open and interoperable agricultural specialized platform hub on the cloud for the management of spatial and non-spatial data relevant for farming production; for discovery of spatial and non-spatial agriculture related data from heterogeneous sources; integration of existing and valuable European open datasets related to agriculture; data publication and data linking of external agriculture data sources contributed by different public and private stakeholders al lowing to provide specific and high-value applications and services for the support in the planning and decision-making processes of different stakeholders groups related to the agricultural and environmental domains. The **main idea** of FOODIE project is to:

- build an open and interoperable agricultural specialized platform hub on the cloud for the
- management of spatial and non-spatial data relevant for farming production
- discovery of spatial and non-spatial agriculture related data from heterogeneous sources
- integration of existing and valuable European open datasets related to agriculture
- data publication and data linking of external agriculture data sources contributed by different public and private stakeholders allowing to
- provide specific and high-value applications and services for the support in the planning and decision-making processes of different stakeholders groups related to the agricultural and environmental domains.

which is conceptualized in the following architecture diagram of FOODIE service platform (Figure 2). (Charvat, et al., 2014, May).

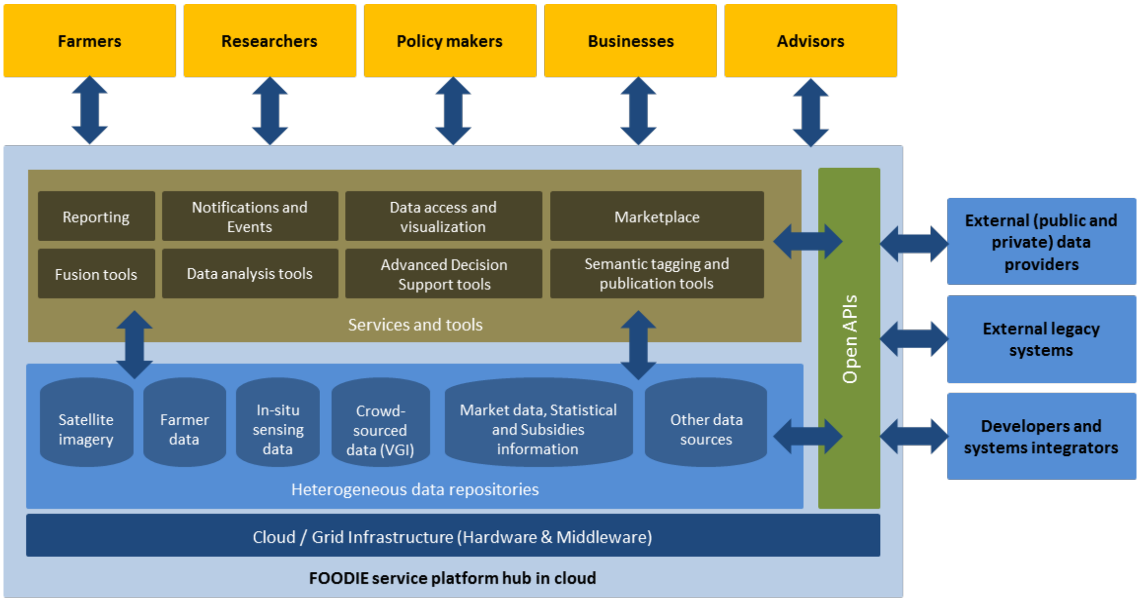


Fig 2. FOODIE service platform hub in cloud

Examples of potential new types of Precision Farming services

Tactical planning

Main research is currently focused on basic precision farming methods, which are typically related to operative decision on the field level. On other side it was documented, that right decision on the base of farm level and level of external (prices, cost, worldwide yield, subsidies) information has the main influence on profitability of farm. The experiences from previous years demonstrates that using precision farming methods a famer could increase his profitability approximately from 15 to 25 percent. The decision about optimal production mix and used methods of production could increase farmer’s profit from 100 to 300 percent. From this reason it is necessary to introduce new knowledge management and access to information on all levels, which has to support such decision.

Tactical planning was a concept introduced as part of COIN project (Krivanek, Charvat, Gnip, Vohnout, & Charvat) and it was focused on introducing new methods oriented on tactical planning for next seasons. This concept is till now not fully operational, because it requires access to large amount of data, which are now not available, but this could well demonstrate potential advantage of Big data approach. The main purpose of tactical planning is to recommend optimal production and land use for next seasons to maximize expected profit. The problem could be described such as a farmer has a number of parcels with different properties available for his production. It is possible to grow different kinds of products on these lands. On each of these lands it is possible to grow maximum one product using one of two methods. Due to many reasons, for example crop rotation and field localization, it is not possible to grow each of the products on each of the lands in next season. For formulation and solving the problem we need various input data. The factors affecting the profit could be:

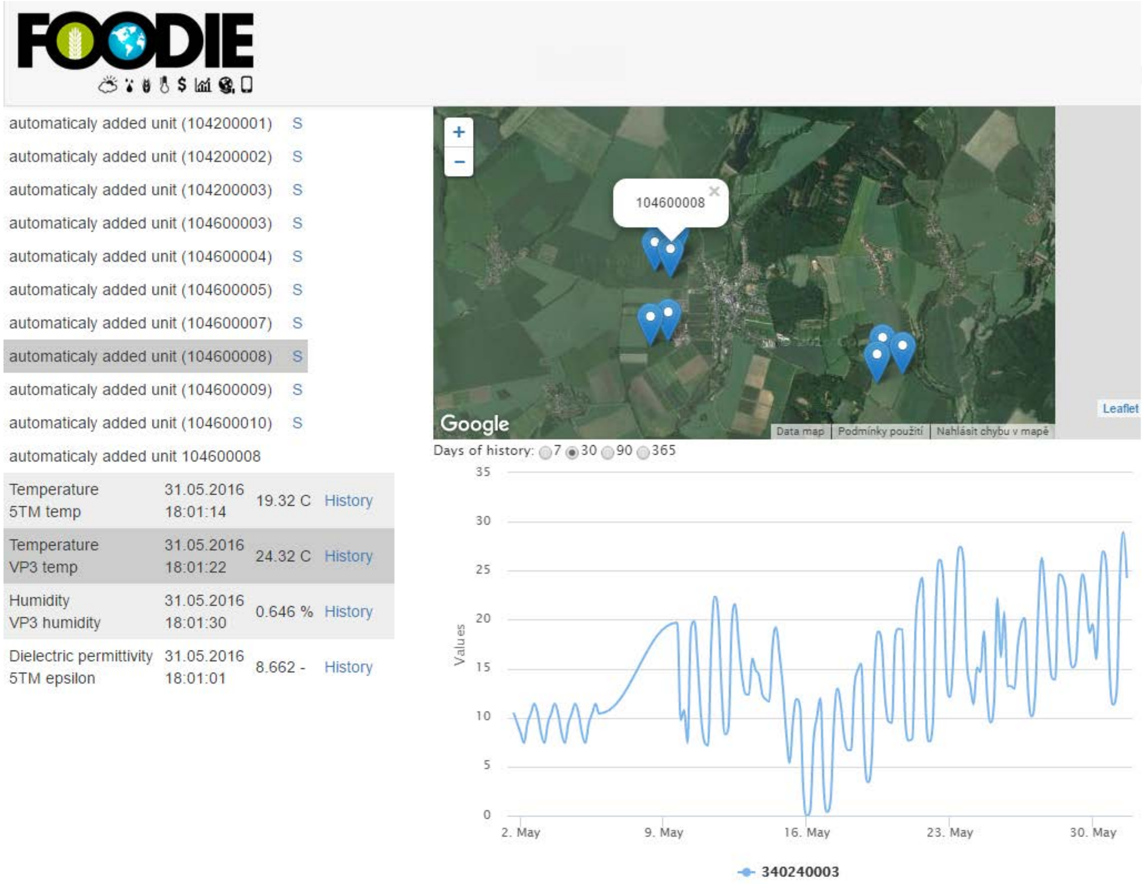
- prices at which the farmer will be able to sell his/her products,
- subsidies for plant production or different use of land,
- yields / hectare of particular crops,
- costs including several items:
    - The costs for growing different crop kinds depending on land properties and land area. A lot of items like seed, fertilizer, operating costs and labour costs can be included into these costs.
    - Fixed costs connected with each kind of crop.
    - Fixed costs of using variable fertilizer application, which have to be included, if farmer uses variable application on any of his lands.
    - Fixed costs of variable fertilizer application on particular lands.

The goal of this problem is to create recommendation saying which crop should be sowed on each land and which way of their growing should be chosen. The optimal production plan for the given input data is described by optimal solution of this problem. In terms of mathematical programming solving this problem means finding optimal values of all variables, which are used in this model. Especially in case of farmers, who were using precision agriculture in the past, it will be possible to estimate many data values with quite high accuracy. Most of the information will not exist in the farm information system in the form requested by the model. To get the values of some data it will be necessary to create procedures, which will calculate the values from available data.

Sensor Observations and Measurements

Importance of sensors in the field of Precision Farming is still growing. Utilization of sensors in PF can be divided into two basic groups. First group contains static in-situ sensors mainly used for observing agro-meteorological data in the fields. Another group can be called as mobile and contains sensors connected to agricultural machinery and used for tracking. Example of the utilization of mobile sensors will be described in next paragraph FarmTelemetry. Important issue for usability of sensor data in PF is data exchangeability between solutions or systems. There is difference between standardized and used protocols or formats.

Observing of agro meteorological phenomena on the level of individual farm provides more detailed information and accurate description of weather, water and soil conditions than results from observations on regional or more global level. Providing this kind of information to farmers continuously helps them to make substantiated decisions. Example of client for agro meteorological observations is shown on Figure 3. Continuous collecting of data produces large volume of measurements where it is necessary effective storing and proper analysing. There are two types of information from static in-situ sensors. First type is current state of conditions on the farm and on fields that can be constructed from last observed values or short-term series. Another type is seasonal state of conditions that demands on long term series of observations. Providing both types requires well designed data model on one side and suitable visualization methods on another side. Integration of data produced by in-situ sensors with machinery tracking data and LPIS block information during Foodie project provides complex analyses with high added value results.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Temperature 5TM temp	31.05.2016 18:01:14	19.32 C	History
Temperature VP3 temp	31.05.2016 18:01:22	24.32 C	History
Humidity VP3 humidity	31.05.2016 18:01:30	0.646 %	History
Dielectric permittivity 5TM epsilon	31.05.2016 18:01:01	8.662 -	History

Days of history: ○7 ●30 ○90 ○365

Fig 3. Client for agro-meteorological observations

Farm Telemetry

The Farm Telemetry system is focused on monitoring of activities and utilization of individual tractors. Data collected by sensor units on tractor allow possibility of analyses and obtaining overall overview for individual farmer’s fields (blocks). Application currently supports following tractor-oriented analyses:

- Cultivated blocks – provides list of all farmer’s blocks, where the selected tractor was working during the selected day. There is provided information for each of the blocks about spent time and about used passive machinery. Information about average fuel consumption (litres per hour) can be provided, if current settings of active unit supports reading this information.
- Utilization – provides information about time the tractor spent by working on farmer's blocks, by moving on other places and by standing in place during selected day. The sum of these times is always 24 hours.
- Activities log – provides detailed information about activities of the selected tractor during the selected day. The log contains start time and end time of each activity, location of the activity, used passive machinery and sum of fuel consumption during the activity. Level of detail of the log can be customized by user. User can adjust values of three attributes:
    - Minimal work time – if the sum of movement times on farmer’s block doesn’t reach at least this value during selected day, the movements on this block are considered as “other movements”, not work.

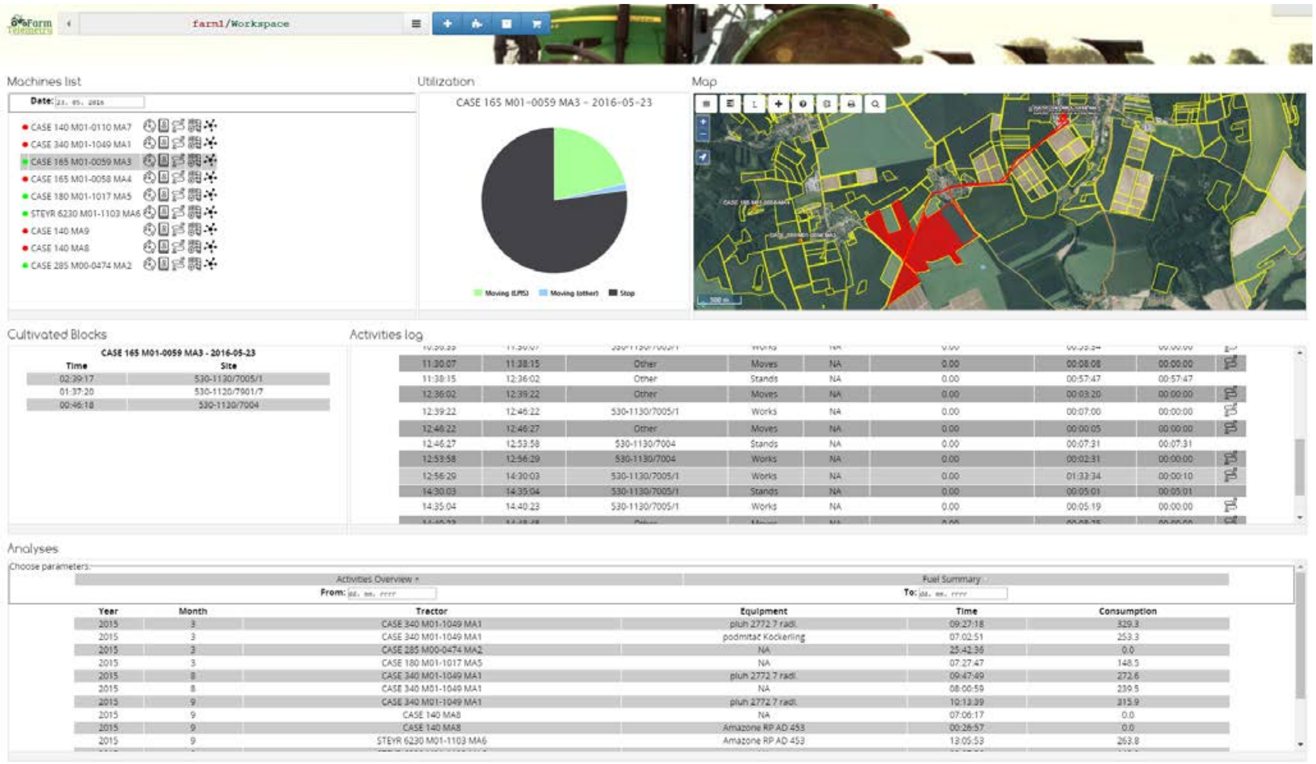
  - Minimal pause time – shorter stops aren’t listed explicitly in the log. They are only counted as sum of delays during movement or work.
  - Allowed outside field time – if the time outside field (for example during turning at the edge of the field) doesn’t reach at least this value, leaving the field (block) is not listed in the log.

- Overview of activities at field (block) – provides monthly overview for selected field. The overview shows information about sum of times each tractor has spent on the selected field including used passive machinery and sum of fuel consumption.

The field trials during season demonstrate that Farm Telemetry will deal with real Big data. This required optimization on the level of database structures and communication protocols. The main problem is that data from every farm has to be stored minimally for full season, to guarantee complex analysis of costs.

Measuring unit with connected sensors is mounted on active machinery. Current values of sensors are read in case of position change or every 2 seconds of running engine of machinery. If measuring unit is connected to the Internet, sequences of observed values are sent to the server. If the connection is not available, values are stored to the RAM on the unit.

Number and type of collected data depends on control units of specified active machinery (e.g. CANBUS) what values allow to be read (fuel consumption, engine load, speed etc.). From this reason each measuring unit is producing different number of values, but in most cases the basic set of values contains same phenomena. Example of analyses results can be seen in FarmTelemetry application client on Figure 4.



Date: 23. 05. 2016

- CASE 140 M01-0110 MA7
- CASE 340 M01-1049 MA1
- CASE 165 M01-0059 MA3
- CASE 165 M01-0058 MA4
- CASE 180 M01-1017 MA5
- STEYR 6230 M01-1103 MA6
- CASE 140 MA9
- CASE 140 MA8
- CASE 285 M00-0474 MA2

CASE 165 M01-0059 MA3 - 2016-05-23

CASE 165 M01-0059 MA3 - 2016-05-23

Time	Site
02:39:17	530-1130/7005/1
01:37:20	530-1120/7901/7
00:46:18	530-1130/7004

11:30:07	11:38:15	Other	Moves	NA	0.00	00:08:08	00:00:00
11:38:15	12:36:02	Other	Stands	NA	0.00	00:57:47	00:57:47
12:36:02	12:39:22	Other	Moves	NA	0.00	00:03:20	00:00:00
12:39:22	12:46:22	530-1130/7005/1	Works	NA	0.00	00:07:00	00:00:00
12:46:22	12:46:27	Other	Moves	NA	0.00	00:00:05	00:00:00
12:46:27	12:53:58	530-1130/7004	Stands	NA	0.00	00:07:31	00:07:31
12:53:58	12:56:29	530-1130/7004	Works	NA	0.00	00:02:31	00:00:00
12:56:29	14:30:03	530-1130/7005/1	Works	NA	0.00	01:33:34	00:00:10
14:30:03	14:35:04	530-1130/7005/1	Stands	NA	0.00	00:05:01	00:05:01
14:35:04	14:40:23	530-1130/7005/1	Works	NA	0.00	00:05:19	00:00:00

From: dd. mm. rrrr To: dd. mm. rrrr

Year	Month	Tractor	Equipment	Time	Consumption
2015	3	CASE 340 M01-1049 MA1	pluh 2772 7 radl.	09:27:18	329.3
2015	3	CASE 340 M01-1049 MA1	podmitač Kockerling	07:02:51	253.3
2015	3	CASE 285 M00-0474 MA2	NA	25:42:36	0.0
2015	3	CASE 180 M01-1017 MA5	NA	07:27:47	148.5
2015	8	CASE 340 M01-1049 MA1	pluh 2772 7 radl.	09:47:49	272.6
2015	8	CASE 340 M01-1049 MA1	NA	08:00:59	239.5
2015	9	CASE 340 M01-1049 MA1	pluh 2772 7 radl.	10:13:39	315.9
2015	9	CASE 140 MA8	NA	07:06:17	0.0
2015	9	CASE 140 MA8	Amazone RP AD 453	00:26:57	0.0
2015	9	STEYR 6230 M01-1103 MA6	Amazone RP AD 453	13:05:53	263.8

Fig 4. Farm Telemetry client with examples of analyses results

Delineation of management zones based on satellite remote sensing

Yield potential zones are areas with the same yield level within the fields. Yield is the integrator of landscape and climatic variability and therefore provide useful information for identifying management zones (Kleinjan, Clay, Carlson, & Clay, 2007). This presents a basic delineation of management zones for site specific crop management, which is usually based on yield maps over the past few years. Similar to the evaluation of yield variation from multiple yield data described by Blackmore et al. (Blackmore, Godwin, & Fountas, 2003), the aim is to identify high yielding (above the mean) and low yielding areas related as the percentage to the mean value of the field. Also the inter-year spatial variance of yield data is important for agronomists to distinguish between areas with stable or unstable yields. The presence of complete series of yield maps for all fields is rare, thus remote sensed data are analysed to determine in field variability of crops thru vegetation indices.

The estimation of yield potential zones from multi-temporal satellite data is established as the general model in FOODIE platform. As the main data source, ESPA repository of LANDSAT satellite images is used, which offers surface reflectance products, main vegetation indices (NDVI, EVI) and clouds identification by CFmask algorithm. A selection of scenes from recent 8 years is made for specific farm area to collect cloud-free data related to second half of vegetation period. Yield potential is calculated for separate scenes as the relation of each pixel to mean value of whole field. In last step all scenes are combined and median value of yield potential is calculated. After fully operation of Sentinel 2A/B satellites, calculation of yield potential will be enhanced by these vegetation products.

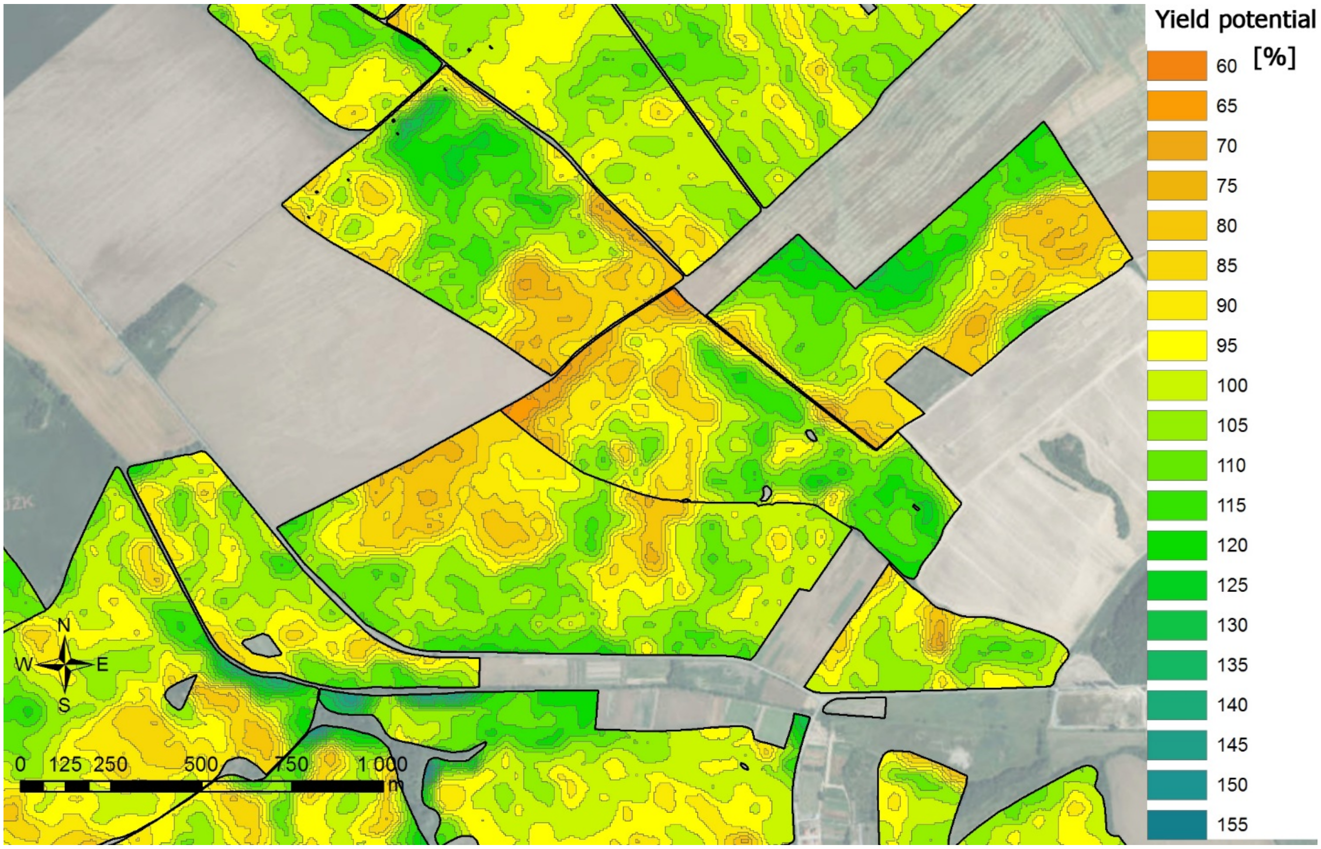


Fig 5. Map of yield potential delimitated from multi-temporal Landsat imagery

Conclusions

As visible as a red line throughout the whole paper, we are standing at the beginning of a new era for precision farming. Technological as well as personal shifts enable to obtain more data than ever before which is the real challenge of the Big data concept. The discussion is not about having floods of data, but even more about how to obtain more valuable information from such data flood than from poorer but clearer data sources.

Current approaches in precision agriculture have a common denominator, which is standardized and interoperable geospatial information. Geospatial information, i.e. knowing where something happened, is exactly the kind of information that stimulates all the current approaches, no matter whether it is variable rate application or an automated steering system. Only standardized and interoperable data are those that may be combined in space (from farm to farm) and time (from season to season).

Standardized and interoperable data are required for operative decisions, i.e. ad hoc management. Such requirement is even more important for the long-term visions. Economic and ecologically sound long-term decisions require integration of much more data sources than in the case of ad hoc management. Otherwise, obstacles of manual integration of large amounts of data exceed its benefits.

It is clear that not all the precision farming stakeholders may benefit from such progress. For instance, minimizing the environmental burden also means using less chemicals as incomes. This is certainly positive for a farmer and also the whole society, however negative for a producer and reseller(s) of such chemicals who are used for expanding precision farming market. Shift to the new era of precision farming comes at a price that is for some stakeholders bigger than for others.

An open issue lies in the area that affects Big Data in all its forms. Farmers in particular commonly distrust the companies aggregating data. Farmers are afraid that their sensitive data may be misused. Future efforts should, therefore, focus on the technological as well as the personal level in order to ensure that the FOODIE platform remains useful in daily life. In other words, the geospatial technology is ready to help minimise the environmental burden while maximising the economic benefits; the main obstacles now consist in insufficient policies and people.

Acknowledgements

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