Open data model approach for precision agriculture: integration of geographic information from LPIS to farmer's data

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Abstract

Any information system for precision agriculture is significantly dependent on its data model, i.e. how data is stored, managed and accessed. Most of these information systems deal with data in the proprietary structure that fits the most to the purposes of each organisation and/or individual. The data is commonly in a proprietary structure even if there is a standardized exchangeable format used by an information system.

The different groups of stakeholders involved in the agricultural activities have to manage many different and heterogeneous sources of information that need to be combined in order to make economically and environmentally sound decisions, which include (among others) the definition of policies (subsidies, standardisation and regulation, national strategies for rural development, climate change), development of sustainable agriculture, field records and profit analysis, crop management, pest detection, etc. If we would like to integrate data from several sources, we need to establish a unified data model that is capable to include the diversity of the underlying data models.

This paper deals with the issues related to the development of the open data model for the precision agriculture information systems. Any information system gains added value when it is based on the standards used within the particular domain. As such, the proposed open data model for precision agriculture addresses the international standardization approaches, European legislation as well as the needs of farmers. The open data model has been designed to be compliant with the requirements originating from the European directive 2007/2/EC (INSPIRE), with the ISO standards like ISO 19156:2011 – Geographic Information – Observations and measurements, principles used within the Land Parcel Identification Systems (LPIS) etc.

At the same time, the open data model is customizable and scalable. Its core is defined in a way enabling the import of LPIS- as well as INSPIRE- based data. Moreover, it supports the management of data originating from sensor measurements. From the thematic point of view, the open data model aims primarily at the content related to the precision agriculture. It means, that it incorporates information on crop species, soils properties, nutrient balance, applied fertilizers, pesticides including forms of their applications. On the other hand, information on atmospheric and meteorological conditions, transport networks for the fleet management and/or sensor measurements are supported as well.

The open data model for precision agriculture is being used within the European project Farm-Oriented Open Data in Europe (FOODIE). As such, the open data model for precision agriculture may also be understood as one of the founding stones for the

Foodie platform hub. The Foodie platform hub aims at enabling in an easy manner the (re)use of open data in the agricultural domain in order to create new applications that provide added value to different stakeholder groups.

Keywords: open data, precision agriculture, geographic information, land parcel identification system, farm management information system

Introduction

Any information system for precision agriculture is significantly dependent on its data model, i.e. how data is stored, managed and accessed. Most of these information systems deal with data in the proprietary structure that fits the most to the purposes of each organisation and/or individual. The data is commonly in a proprietary structure even if there is a standardized exchangeable format used by an information system.
The different groups of stakeholders involved in the agricultural activities have to manage many different and heterogeneous sources of information that need to be combined in order to make economically and environmentally sound decisions, which include (among others) the definition of policies (subsidies, standardisation and regulation, national strategies for rural development, climate change), development of sustainable agriculture, field records and profit analysis, crop management, pest detection, etc. When integrating data from several sources, it is needed to establish a unified data model that is capable to include the diversity of the underlying data models.
In this context, future agriculture knowledge management systems have to support not only direct profitability of agriculture or environment protection, but also activities of individuals and groups allowing effective collaboration among groups in agri-food industry, consumers, public administrations and wider stakeholders communities, especially in rural domain.
The European project called “Farm-Oriented Open Data in Europe” (FOODIE), funded between years 2014 and 2017 addresses the above mentioned issues. The main hypothesis for this paper is therefore stated: “It is possible to establish a unified data model for precision agriculture that respects the standards developed for the geographic information”. See http://www.foodie-project.eu for further information.
After presenting the state-of-the-art and methodology in this paper, the proposal on the unified data model for precision agriculture is discussed in detail. The second part of the paper contains the brief information on planned field tests that are intended to verify the proposed data model in practice. At the end, benefits, opportunities and future development are mentioned.

State-of-the-art

Request for data management in agriculture increases with the usage of Farm management Information Systems (FMIS) and adoption of precision farming techniques – site specific crop management. Is often argued that, in the cases of precision agriculture, physical inputs, such as fertilizers, pesticides, seeds and other, are substituted by information and knowledge, see Bongiovanni and Lowenberg-Deboer (2004). McBratney et al. (2005) identified the development of proper decision-support systems for implementing precision decisions as a major block in adoption of site specific farming. In the cases of data analyses and decision support programmes, it is recommended to focus on:

- the development of protocols and standards for the key data layers (yield maps and other);
- robust methods for data analysis, integration and delineation of management zones;
- innovative designs for the implementation of whole-of-field experimentation based;
- easy-to use software to facilitate the use and adoption of the above by farmers, their consultants and researchers.

An example of development of a model data-flows for decision support in precision agriculture is provided by Nash et al. (2009).

Communication and cooperation in adoption of precision agriculture depends on the farm size, as investigated by Kutter et al. (2011) from the farm survey made by qualitative experts in four European countries – Germany, Czech Republic, Denmark and Greece. Small farms were mainly connected to their local agricultural consultants, while large farms rely more on professional consulting. Services for strategic and tactic planning provided by consulting organization for farm enterprises, represented by the MJM Litovel, are the topic of the Czech pilot study in FOODIE project.

Several international and European initiatives may be identified that aim at facilitating the exchange and access to a wealth of heterogeneous data sets related to the environmental and agricultural domains. As the first should be taken into account the main European policies that are directly involved in the agriculture sector, such as Common Agricultural Policy or Water Framework Directive. In this sense, call for global data collection for agricultural monitoring is analysed by Sachs et al. (2010). Principles of common agricultural policy are provided by Donald et al. (2002). Influence of Water Framework Directive on agriculture is discussed by Bateman et al. (2006). See Řezník (2013) for information on Infrastructure for spatial data in Europe (INSPIRE) including the application schemas for agriculture and aquaculture. European nitrate directive and its influence on the farm performance was written by Ondersteijn (2002).

Methods

Information in systems for precision agriculture are traditionally autonomous. This stems, among others, from the security as well as historical reasons. As a result, it is talked about "isolated data islands for precision agriculture". The situation is slightly better when talking about subsidies for farmers. Since there is a common need for evidence, also a data model of such system is unified. Such systems are commonly called as "Land Parcel Identification Systems", with well-known abbreviation LPIS. On the other hand, 45 Land Parcel Identification Systems still may be identified in 28 European Member States. It is therefore clear that the unification of those systems and their data models has been achieved on the regional level in the cases of large and medium countries and on the national level in the case of small countries.

To deal with the "isolated data islands", the European Commission started the initiative called INSPIRE (INfrastructure for SPatial InfoRmation in Europe). This initiative was transformed in 2007 into the Directive of the European Commission and the Council

with designation 2007/2/EC. The Directive defines 34 themes covering a wide range from agriculture and aquaculture facilities, coordinate reference systems, cadastral parcels, transport networks, hydrography, land cover, orthoimagery, soil, human health and safety, natural risk zones, habitats and biotopes, energy resources, and others. Unification of data models for those 34 themes is one of the key aims of the INSPIRE Directive. Such unification includes interoperability and harmonization through explicit definitions of feature types, their aggregation into classes, attributes of feature types, domains of these attributes, etc. In other words, one general unified data model was developed for agriculture and aquaculture facilities. At the same time, there was also developed a methodology how to customize and extend the data models published under INSPIRE, see Řezník (2013).
In order to support the data interoperability, the FOODIE data model follows INSPIRE generic data models, in particular the INSPIRE data model for Agricultural and Aquaculture Facilities (AF), by extending and specializing them. Object-oriented modelling was used as a methodological basis for the data model development.

Figure 1. Example of a Plot according to the FOODIE data model.

Three levels of information are available within the FOODIE data model when the first two of them originate from INSPIRE:

(1) **Farm**, i.e. information about the whole area and all infrastructures included on it, under the control of an operator to perform agricultural or aqua-culture activities. Farm level is in INSPIRE called as "*Holding*". Since FOODIE data model respects the European legislation, it also adopts this designation. A *Holding* (farm) may be composed of one or more Sites.
(2) **Site**, i.e. the lower level than a *Holding* (farm), it is the geographical representation of land that constitutes a management unit. It includes all infrastructure, equipment and materials. A *Site* also corresponds to the LPIS concept on the level of so-called *Farmer's block*. A *Farmer's block* represents a continuous area of agricultural land with one type of crop culture used by one farmer in one farming regime (conventional or organic).

(3) **Plot,** i.e. a continuous area of agricultural land with one type of crop species, variety or crop management intensity (application of fertilizers, pesticides, etc.). A *Plot* is the elementary reference item in the data model and in precision agriculture correspond to the field management zones.

An example of a "Plot" is depicted in Figure 1, where each *Plot* has a unique identifier to distinguish a *Plot* from any other *Plot*. Note that a *Plot* does not imply any explicit relation to the cadastre. For instance, a *Plot* may be only a part of a cadastral parcel. In other words, a cadastral parcel may contain from zero to many (0..N) *Plots*.

In order to illustrate the application of the FOODIE data model let's imagine the following example:

A company named "FoodieAgroProfi, Inc." cultivates 4.000 hectares in the southern part of the Czech Republic. This whole area is, according to the FOODIE data model specification, called as *Holding*. Such *Holding* is composed of three types of *Sites*: arable land, grassland and vineyards. Vineyards are composed of 164 explicitly geometrically-defined *Sites* where the wine grapes grow. Arable lands are composed of 120 geometrically-defined *Sites* where wheat, spring-barley and oil-seed rape are produced. 120 geometrically-defined *Sites* are composed of 150 *Plots* according to the crop species. It means that one *Site* may contain more crop species defined in separate *Plots*. A *Plot* is therefore the elementary spatial unit within the FOODIE data model. Note that the geometrical definition of a *Plot* may vary in time, typically from year to year.

Regarding the initial import of data, it is possible to re-use the data already contained in an LPIS (Land Parcel Identification System). In that sense INSPIRE data model and LPIS concepts are complementary approaches for FOODIE data model[1]. Thus, for instance, LPIS data may be imported to FOODIE platform on the level of *Site* feature which is equal to LPIS *Farmer's block* level. A farmer may then add to the imported LPIS data the crop species or more detailed information (soil condition, use of fertilizers, crop protection, … - see *Plot* attributes in Figure 2) to obtain data ready for the *Plot* level.

FOODIE data model has been designed to be an open data model, thus allowing extending it through associations and/or attributes that further specialize the *Plot* feature. The aim of this extension is to provide modularity and enable any farmer/external service provider using FOODIE platform to extend the data model according to his/her needs.

FOODIE concepts and objectives are realized by means of the resulting service platform hub, which is demonstrated in three different pilots' scenarios across Europe, providing each of them a set of common and specific requirements:

- **Pilot 1: Precision Viticulture (Spain)** focuses on the appropriate management of the inherent variability of crops, an increase in economic benefits and a reduction of environmental impact.
- **Pilot 2: Open Data for Strategic and Tactical Planning (Czech Republic)** aims at improving future management of agricultural companies (farms) by introducing new tools and management methods, which follows the cost optimization path and reduction of environmental burden, improving the energy balance while maintaining the production level.

[1] Note that LPIS is mentioned in the INSPIRE Land Cover (LC) theme as a use case.

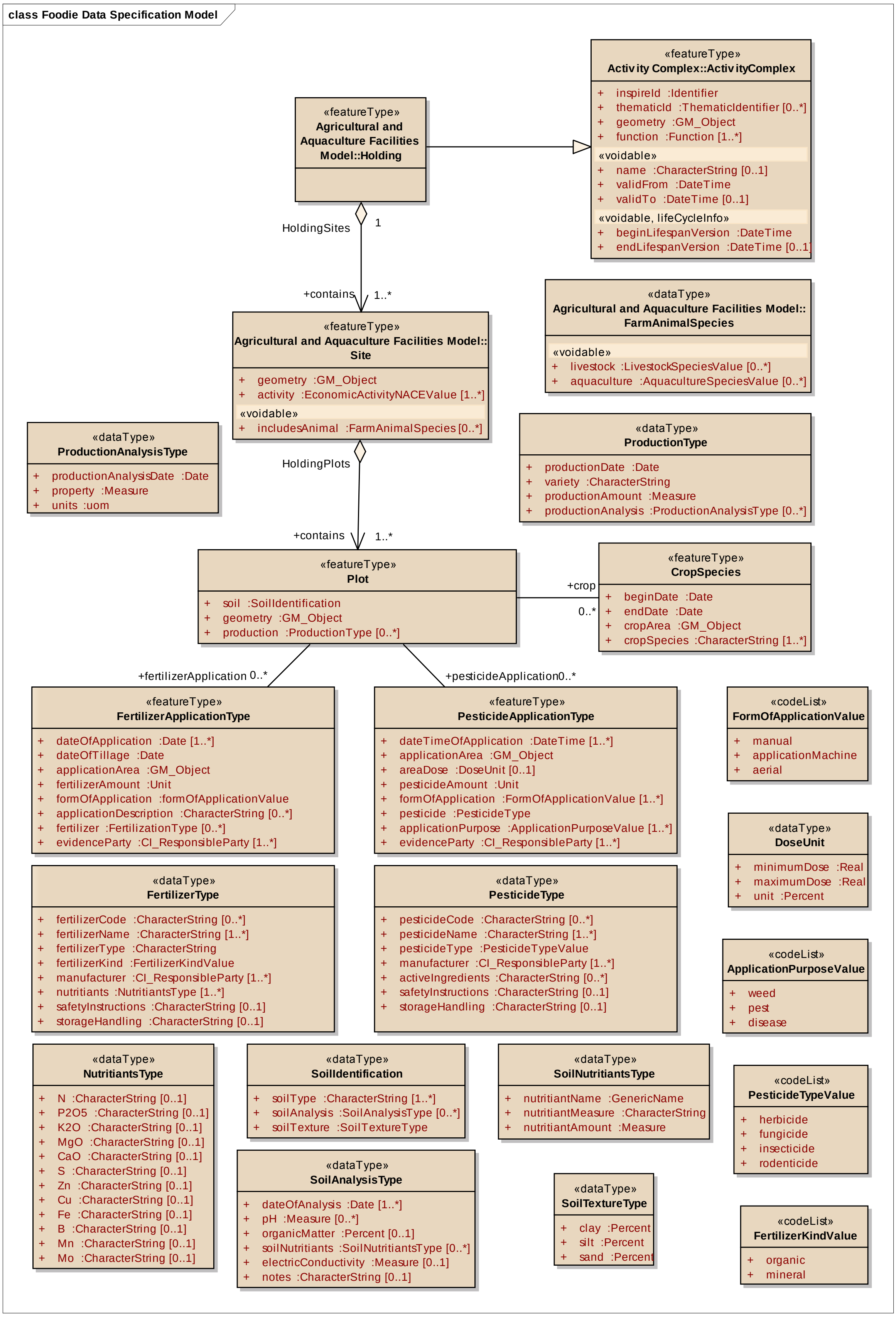

Figure 2. The second draft of the FOODIE application schema based on the Agricultural and Aquaculture Facilities Model application schema.

- **Pilot 3: Technology allows integration of logistics via service providers and farm management including traceability (Germany)**. This pilot focuses on integrating the German machinery cooperatives systems with existing farm management and logistic systems as well as to develop and enlarge existing cooperation and business models with the different chain partners to create win-win situations for all of them with the help of IT solutions.

Results

The UML class diagram presented in Figure 2 depicts the second version of the FOODIE data model. As such it may also be re-used for an LPIS in any Member State of the European Union. To sum up, following information is supported to be stored in the FOODIE data model:

(1) on the level of *Holding* (farm),
   a. general identification information, e.g. identifier and name of the farm, function, date of creation etc.,

(2) on the level of *Site*
   a. information on livestock species (if applicable),
   b. information on aquaculture species (if applicable),
   c. economical classification of activities,

(3) On the level of *Plot*
   a. description of soil, i.e. soil type and soil texture including the information on soil analysis like date, measured pH, organic matter, electric conductivity etc.,
   b. information on production (crop species, vegetation period, variety, yield etc.) including the production analysis allowing to add any property (e.g. content of proteins, sugar, percentage of any nutrients etc.),
   c. description of fertilizers, e.g. code, name, type, nutrients, manufacturer, safety instructions, storage handling etc.,
   d. application of fertilizers, e.g. date and time of application, date of tillage, application area, amount of used fertilizers, description of application, evidence party etc.,
   e. description of pesticides, e.g. code, name, pesticide type (herbicide, fungicide, insecticide, …), active ingredients, safety instructions, storage handling etc.,
   f. application of pesticides, e.g. date and time of application, application area, amount of used pesticides, form of application, application purpose, evidence party etc.

Discussion and conclusions

The working hypothesis was confirmed, i.e. it is possible to establish a unified data model for precision agriculture that respects the standards developed for the geographic information. When applying the developed FOODIE data model to FMIS, it is feasible to share the information independently between heterogeneous systems for precision agriculture. Moreover, the following work will be related to the semantic descriptions in order to ensure common understanding of the exchanged information. The system will be available in March 2017. The project consortium initiated the communication with the Joint Research centre of the European Commission to recommend the developed data model as the founding stone for the data exchange between FMIS.

One of the main open issues lies in the area that affects all FMIS. Farmers usually distrust the companies aggregating data. Farmers afraid, that their sensitive detailed data may be misused. Future development would therefore be on the technological level as well as on the personal level to ensure the usefulness of the Foodie platform in daily life.

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References

Bateman, I. J., Brouwer, R., Davies, H., Day, B. H., Deflandre, A., Falco, S. D., Kerry T. R. *Analysing the Agricultural Costs and Non-market Benefits of Implementing the Water Framework Directive*. Journal of agricultural economics, 2006, Vol. 57, No. 2, pp. 221-237.

Bongiovanni, R., Lowenberg-Deboer, J. *Precision Agriculture and Sustainability*. In Precision Agriculture, 2004, Vol. 5, No. 4, pp. 359-387.

Donald, P. F., Pisano, G., Rayment, M. D., & Pain, D. J. *The Common Agricultural Policy, EU enlargement and the conservation of Europe's farmland birds*. Agriculture, Ecosystems & Environment, 2002, Vol. 89, No. 3, pp. 167-182.

Kutter, T., Tiemann, S., Siebert, R., Fountas, S. *The role of communication and co-operation in the adoption of precision farming*. In Precision Agriculture, 2011, Vol. 12, No. 1, pp. 2-17.

McBratney, A., Whelan, B., Ancev, T., Bouma, J. *Future directions of precision agriculture*. In Precision Agriculture, 2005, Vol. 6, No. 1, pp. 7-23.

Nash, E., Dreger, F., Schwarz, J., Bill, R., & Werner, A. (2009). Development of a model of data-flows for precision agriculture based on a collaborative research project. Computers and Electronics in Agriculture, 66(1), 25-37.

Ondersteijn, C. J. M., Beldman, A. C. G., Daatselaar, C. H. G., Giesen, G. W. J., & Huirne, R. B. M. *The Dutch Mineral Accounting System and the European Nitrate Directive: implications for N and P management and farm performance*. Agriculture, ecosystems & environment, 2002, Vol. 92, No. 2, pp. 283-296.

Řezník, T. *Geographic information in the age of the INSPIRE Directive: discovery, download and use for geographical information research*. In Geografie, 2013, Vol. 118, No. 1, pp. 77-93.

Sachs, J., Remans, R., Smukler, S., Winowiecki, L., Andelman, S. J., Cassman, K. G., Castle, D., DeFries, R., Denning, G., Fanzo, J., Jackson, L. E., Leemans, R., Lehmann, J., Milder, J. C., Naeem, S., Nziguheba, G., Palm, C. A., Pingali, P. L., Reganold, J. P., Richter, D. D. Scherr, S. J., Sircely, J., Sullivan, C., Tomich, T. P., Sanchez, P. A. *Monitoring the world's agriculture*. Nature, 2010, Vol. 466, No. 7306, pp. 558 – 560.