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A service infrastructure for the representation, discovery, distribution and evaluation of agricultural production standards for automated compliance control

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ABSTRACT

Modern agricultural production is governed by a variety of production standards that restrict and guide farming practices. Controlling the compliance of farms to these standards is currently a considerable and expensive manual effort for several stakeholders of agriculture; an effort that could be alleviated with suitable information technology.

This article identifies the requirements and proposes a design for a service infrastructure that transfers the production standards in a computer encoded and machine interpretable format between the stakeholders of modern agricultural production. These encoded production standards can then have an immediate benefit for farmers and providers of Farm Management Information Systems (FMIS), ultimately enabling automated compliance control with existing farm data. The functionality of the infrastructure is demonstrated with a precision fertilisation case, where compliance to several fertilisation restrictions is controlled and confirmed automatically.

The proposed REST-based service infrastructure was found sufficient in fulfilling the identified requirements. Automated compliance control for a fair proportion of production standards, despite several technical challenges, can be reasonably achieved with existing technologies as a lightweight infrastructure of REST-based Web services.

1. Introduction

Agricultural production standards, e.g. the European cross compliance, are an effort to protect the environment from agricultural activities (Louwagie et al., 2011). The European cross compliance imposes restrictions on farming practices and ties the payout of vital farming subsidies to adherence of these restrictions, thus cross compliance carries considerable financial consequences for farmers (de Graaff et al., 2011). The European cross compliance is also the most widely studied of the many production standards and has been found to have a positive environmental impact on nitrogen fluxes (Follador et al., 2011), however, the policy has been met with a degree of rejection by several farmers (Davies and Hodge, 2006). Currently, controlling and monitoring cross compliance alone is estimated to require more than two days worth of administrative work for each individual farm being monitored (Varela-Ortega and Calatrava, 2004). Considering the over 10 million farms in Europe (European Union, 2011), controlling compliance to all production standards amounts to a substantial and expensive manual effort. This is in addition to the work imposed on farmers to demonstrate their compliance in the form of collecting documentation and otherwise assisting in the controlling process.

Implementation of compliance control involves several stakeholders of modern agriculture and in practice, consists of printed manuals, printed checklists and manual labour. This article considers compliance control as a challenge of information technology. With the emerging precision, or information intensive agriculture, large quantities of data on farming activities become available that can be used as input for automated compliance control. Agricultural production standards already have a part in FMIS (Farm Management Information Systems), albeit as hard-coded values, supporting other FMIS features such as operational planning. This hard-coding is unsuitable considering the dynamic nature of agricultural production standards, i.e. revisions are published every now and then that supercede previous standards. However, information technology could be used to better distribute and present these production standards to farmers and beyond replacing the hard-coded limits in FMIS, ultimately used to automate parts of the compliance control process. The potential of this scheme is recognised by Nash et al. (2011), who also extensively cover the criteria and limitations of any encoding of production standards. Furthermore, agricultural production standards already affect existing information systems, such as systems for decision support,

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production optimisation or operational planning. Thus, having the encoded content of the production standards readily available would have potential benefits for all these systems. The handling of agricultural production standards also requires great flexibility in the globalising economy, as agricultural products can be sold to international markets where these production standards can differ. Moreover, when different production standards affect separate fields, farmers are forced to mind and adhere to several, possibly mutually contradicting production standards at the same time.

1.1. Research objectives

Automated compliance control is a complex problem that affects several stakeholders of modern agriculture. Proper automation requires technical solutions to cover the long, and currently largely manual, workflow of compliance control. Thus, elements required to cover the workflow, and hence also the research objectives, can be summarised as follows: A computer readable encoding for agricultural production standards; discovery and distribution of these to FMIS through a Web service infrastructure; and automated compliance control by evaluating the encoded production standards and farm data. Certain availability of farm data is assumed to precede the workflow of automated compliance control and this data is further assumed to reside within, or be accessible to, the FMIS. The acquisition of this data is beyond the scope of this article, though the majority of the relevant data is recorded during normal farming operations by mobile farm equipment (Steinberger et al., 2009).

This article presents a design for a service infrastructure that achieves these objectives, by fulfilling the requirements of the associated stakeholders of modern agricultural production. This infrastructure is then evaluated with the workflow of a precision fertilisation case, where compliance control is performed both before and after a precise fertilisation operation.

2. Related research

Little research exists for automating compliance control or the formal representation of agricultural production standards. However, compliance control and its socioeconomic effects on farmers as well as its effectiveness in environmental protection has been widely studied. Parallels of the research problem can also be found in other fields of research where similar rules are encoded, distributed or utilised (Gordon et al., 2009; Gao et al., 2008; Marques et al., 2001). In particular, logical rules and their practical limits have been widely studied in computer science, though the expression and evaluation of rules with spatial elements is still an active area of research.

The complexity, cost and considerable manual labour of compliance control for the European cross compliance has been established in research (Varela-Ortega and Calatrava, 2004). Since non-compliance carries a considerable economic penalty, the control systems have to be implemented with great care (Davies and Hodge, 2006). Moreover, it would be naïve to assume that subjects of compliance control would actively promote their own non-compliance.

Automated compliance control was directly addressed in the EU project FutureFarm[1] (2008–2011) whereon this article is based. The project studied the requirements and benefits of automated compliance control, and produced several technical documents that specified the encoding of agricultural production standards, data access and service interfaces. Additionally, a service was designed and implemented that handled the actual evaluation of compliance. Use of these services was demonstrated by two project partners at the GeoFarmatics 2010 conference in Cologne, Germany. Some of these results have been published beyond the project deliverables and are summarised in Sørensen et al. (2010a), Nash et al. (2011) and Sørensen et al. (2011). Another EU project, cross compliance assessment tool (CCAT) (Elbersen et al., 2010), produced a tool for assessing the effects of cross compliance (Bouma et al., 2010). This tool is used to assess the costs and effects of cross compliance but the process of compliance control itself was not addressed.

Compliance control inherently affects the FMIS, which is the central system in the process. This imposes certain functional requirements on the FMIS; a conceptual model of a modern FMIS markedly suitable for automated compliance control is given by Sørensen et al. (2010a). Future FMIS are also expected to utilise the Internet, either in the form of a Web application or as a collection of Web services (Murakami et al., 2007, 2010,). Many of the long-term goals of production standards and compliance control, e.g. sustainability or ecology, are in line with those of precision agriculture (McBratney et al., 2005). Precision agriculture is also an important factor for most applications of automated compliance control, as the spatial data collected during field operations is often essential for determining compliance. Several information flows within the FMIS are also involved as data must be collected from mobile farm equipment, as well as from various Web services.

Automated compliance control requires agricultural production standards computer encoded as logical rules. While logical rules have been widely studied, interchangeable rule formats (Boley et al., 2007) are still being developed. Likewise, spatial reasoning for semantic Web (Hoekstra et al., 2009) is still an active field of research. Computer encoded rules and rule interchange have yet had little applications in agriculture, though they have been applied for integrating business processes by Milanovic et al. (2007) and in the legal domain by Gordon et al. (2009).

3. Requirements of the infrastructure

To achieve the research objectives stated in Section 1.1, a technical service infrastructure is required. The requirements of this infrastructure must be derived from the interests and requirements of the identified stakeholders for the infrastructure. These requirements are then the foundation for the requirements of the individual components of the infrastructure. In addition to the requirements from the stakeholders, the infrastructure has the implicit technical requirements of effective information interchange, openness and overall simplicity of design. Though implicit, these requirements can with reason be considered fundamental to modern information systems of quality.

3.1. Stakeholders

For compliance control, the list of stakeholders with direct interests or concerns is similar, though slightly shorter than that of a complete FMIS (Nikkilä et al., 2010). The foremost stakeholders are the farmers tasked with demonstrating compliance and standards publishers who also control compliance. Additional stakeholders arise from the need to set up and maintain the infrastructure as well as the need to interface with the infrastructure through FMIS. Tertiary stakeholders, though not considered here, would cover those with an indirect interest in compliance control; such as the general public who desire safe agricultural products and ultimately pay the costs of compliance control through taxes and prices of agricultural products.

3.1.1. Farmers

Farmer are concerned with demonstrating compliance to several different production standards. For this, farmers are required

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