# Specialist SDIs to Support Business Processes

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## SUMMARY

*The majority of Spatial Data Infrastructure (SDI) initiatives have focussed on the provision of generic geospatial data to serve a broad range of users. Whilst the resulting SDIs are invaluable in increasing the availability and utility of geodata in existing and potential markets, their generic nature means that it is unlikely that they will have all the components required to fulfil specific needs. This paper discusses the creation of SDIs to support specified business processes, using an example of a business process from precision farming. These specialist SDIs both draw on and contribute to existing general-purpose SDIs.*

**KEYWORDS:** Spatial Data Infrastructures, Business Processes, Workflows, Precision Farming

## INTRODUCTION

There are currently many worldwide initiatives to produce Spatial Data Infrastructures (SDIs) providing access to geospatial data and services through interfaces implementing ISO/TC211 and/or OGC standards. These initiatives are taking place at many levels, such as international (e.g. INSPIRE), national (e.g. GDI-DE), regional (e.g. GDI-GeoMV) and local (e.g. GDI-West Mecklenburg). Whilst the resulting SDIs increase the accessibility of geospatial data, the initiatives are largely concerned with the delivery of general-purpose geospatial data (e.g. base data such as topographic mapping and satellite imagery or administrative data such as boundaries and census data) rather than focussing on meeting the demands posed by specific use-cases. This paper considers a use-case where a user (exemplified here by a practitioner of Precision Farming (PF)) wishes to use an SDI to support their business processes. The geospatial data demands of PF will first be introduced, focussing on the nature of the data and operations that must be available for the given workflow. The components of an SDI which would be required in order to support this workflow will then be considered, and the integration of components of existing general-purpose SDIs into specialist SDIs will be discussed. Based on these findings, recommendations for the future development of SDIs to assist in supporting business processes will be made.

## PRECISION FARMING AND GEOSPATIAL DATA

Precision Farming (or Precision Agriculture) is the consideration of small-scale differences in agriculture, allowing an increase in the economic and ecological efficiency through an integrated management of crop production (Jarfe & Werner, 2000). These differences may be spatial and/or temporal variations in a range of factors affecting the development of the crop, and the key to the successful use of PF is the collection and analysis of spatially and temporally referenced data upon which the necessary management decisions can be based. The cycle of geospatial data in PF is illustrated in Figure 1 - it can be seen from this simple representation that PF is both a consumer and a producer of geospatial data, and that GIS-based management and analysis of this data plays a central role in the PF system.

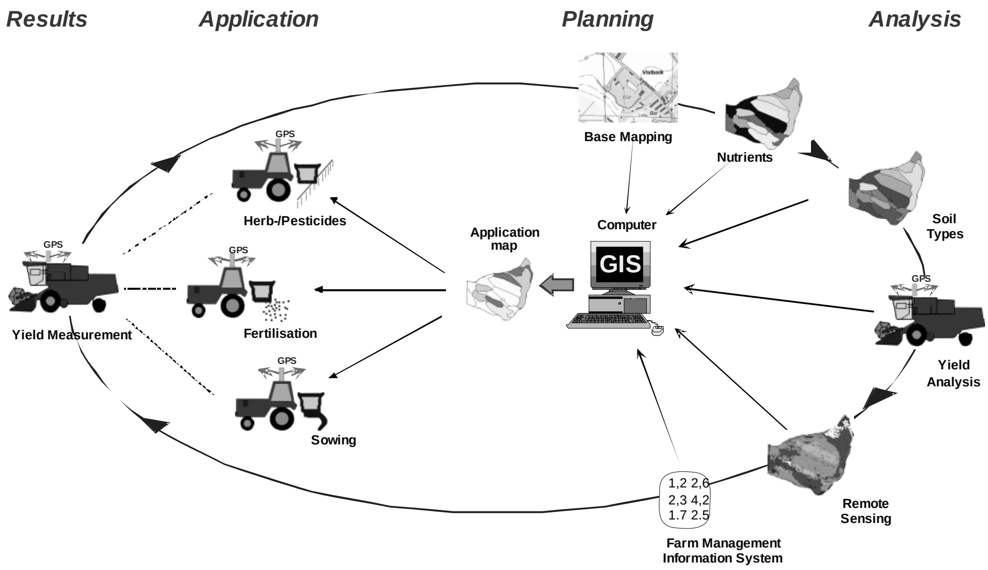


***Figure 1:*** The PF Data Cycle (after Korduan et al., 2000)

What makes PF a particularly interesting example for the use of geospatial data and SDIs is that there are many actors involved in the PF chain, including the farmer themselves, specialist consultants (e.g. for soil testing or nutrient management recommendations), contractors (e.g. providing machinery and workers for planting/fertilising/harvest), suppliers of data (e.g. topographic maps from government agencies) and products (e.g. seed from specialist suppliers), and consumers/companies/agencies requiring access to records for quality control or cross-compliance checking (e.g. the EU Integrated Administration and Control System). Another relevant facet is that the key player in the PF system, the farmer, is likely to have limited interest and/or skills in geospatial data management and analysis (Kitchen et al., 2002). Indeed, the complexity of PF software and the high time and cost requirements for data management are often cited as one of the main barriers to the more widespread adoption of PF (e.g. Fountas et al., 2005, McBratney et al., 2005, Werner & Jarfe, 2000). One aspect of this complexity is the variety of coordinate systems and data transfer formats likely to be encountered. The ease with which geospatial data can be discovered, queried, transformed, transferred and even analysed through an SDI are therefore likely to mean that SDIs have an important role to play in the reduction of complexity in data management for PF.

# SDI USE-CASES IN PRECISION FARMING

In order to build a specialist SDI it is first necessary to identify the use-cases for the SDI and the actors involved in these use-cases. The required data, actors and interfaces to support these use-cases can then be specified and the SDI collaboratively implemented. Soil testing is an example from PF of such a use-case, where a variety of geospatial datasets must be drawn upon in order to plan, carry out and analyse the tests. The aim of the soil testing is to determine the soil type and current nutrient contents in order to plan the management of the crop. The result of the actual testing is the current values (e.g. pH, mineral content, etc.) for a set of defined points or grid cells, which will then be processed (e.g. through interpolation) into a series of space-filling soil and nutrient maps. Although many different variations on the basic workflow are possible, here we assume that the *Farmer* plans the testing and passes the plan in the form of a contract to the *Soil-testing Consultant* who collects and analyses the samples before returning the georeferenced results to the *Farmer* who uses their software to convert the results into a set of maps. The typical current workflow involves the production and transfer of hardcopy maps and results, which will then normally be re-entered into a computer system by the receiver. Soil testing is only one potential PF use-case in which an SDI is involved, but illustrates many of the requirements of a specialist SDI well. Figure 2 shows how the use case "soil testing" forms part of the more general use-case "plan fertilisation" – planning of other measures such as sowing and herbicide application will also draw upon soil testing in a similar manner.

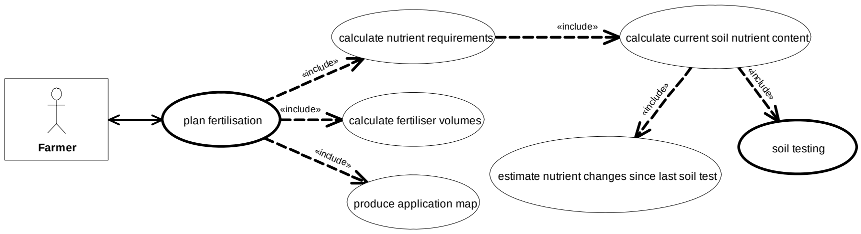


***Figure 2:*** The use-case "soil testing" forms a part of the more general use case "plan fertilisation"

A closer analysis of the use case "soil testing" allows the identification of three distinct parts; the soil testing must be planned, the samples must be collected and physically analysed and the results of the physical analysis must then be further processed to produce the desired soil and nutrient maps. Additional use-cases for a potential specialist SDI can also be identified in order to contract the soil-testing consultant (including indicating the desired sampling locations) and to retrieve the results of the physical analysis. These use-cases and the actors potentially involved in each of them are illustrated in Figure 3. From this diagram it can also be seen that there are two actors (*Geological Survey Agency* and *Topographic Mapping Agency*) whose roles in all use-cases in which they are involved consist simply of delivery of maps (providers of data). The remaining two actors, *Farmer* and *Soil-testing Consultant* have a variety of roles in the use-cases, both providing and receiving data.

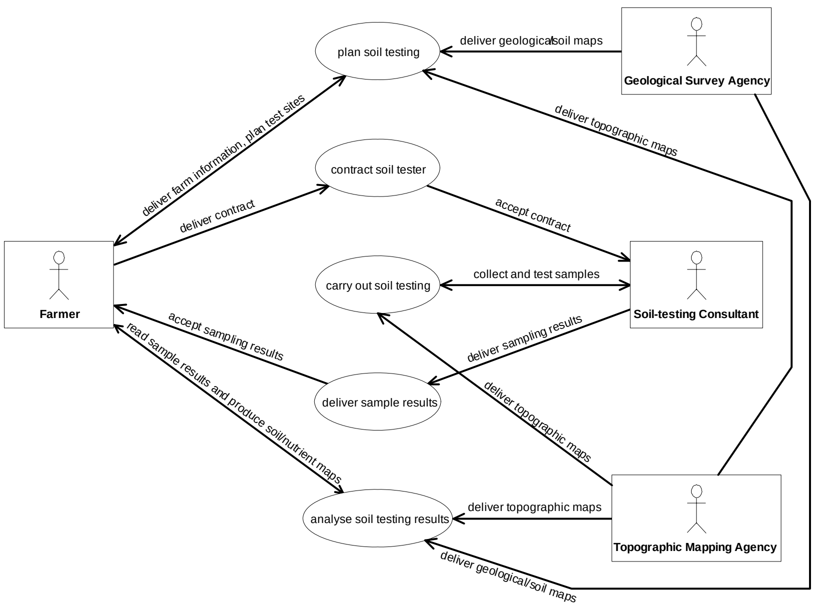


***Figure 3:*** Use-cases, actors and roles in the scenario "soil testing"

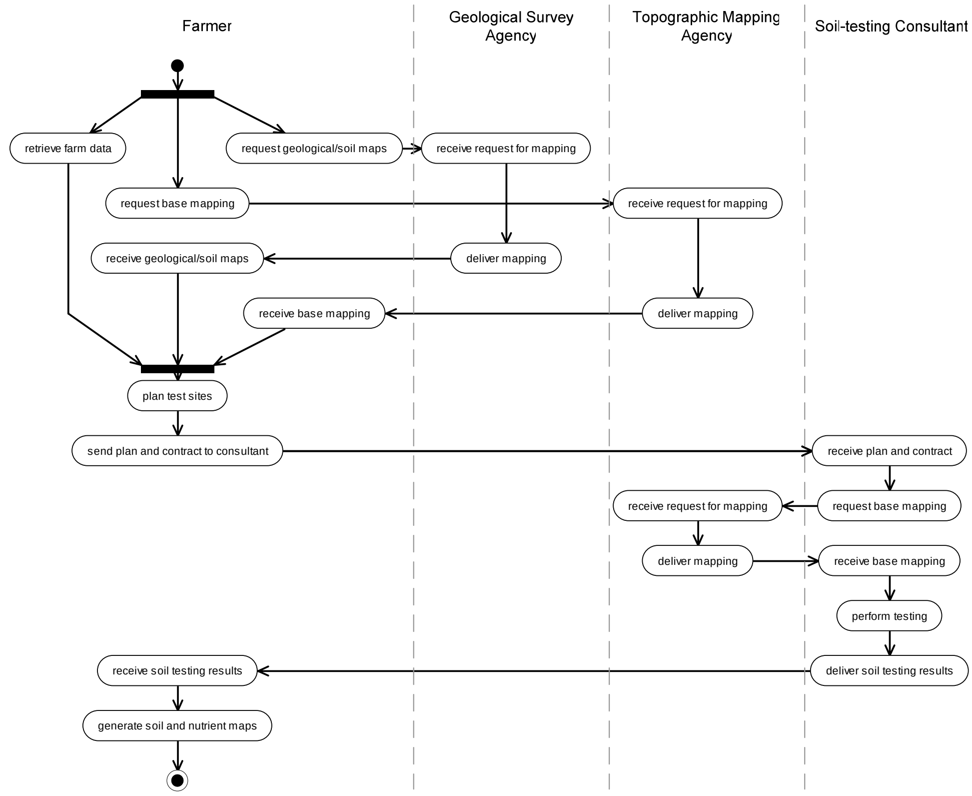


***Figure 4:*** Activities in the use case "soil testing"

Considering the activities involved in this scenario, illustrated in Figure 4, it can be seen that there are a number of points where data transfer (requests and responses) occur. In the majority of these transfers, geospatial data is being transferred, either in the form of mapping or in the form of testing locations and times. For the mapping, a straightforward raster image would normally suffice (e.g. scanned topographic mapping for use as a backdrop during other operations), but for the transfer of, for example, test results, the spatial data (i.e. locations of the sample points) and the attribute data (i.e. the results of the analysis) must be combined for a sensible transfer and interpretation of the data. A transfer method allowing more than a visualisation of the data is therefore necessary for these items. It is also to be noted that the communication with the *Topographic Mapping Agency* and *Geological Survey Agency* are likely to be largely synchronous (i.e. the response immediately following the request), whereas the communication between *Farmer* and *Soil-testing Consultant* is largely asynchronous, in that the results are returned at some time after the contract and plans have been delivered (although in practice this is likely to be implemented as a request/response for the contract and a second request/response for the results). Another point to note is that the delivery of contract and plan to the *Soil-testing Consultant* is the only request where considerable geospatial content is included (e.g. locations of sampling points, boundaries of sampling areas, etc.), whereas the geospatial content of the other requests is likely to be limited to a simple bounding box indicating the area of interest. In contrast, all responses are composed of mainly geospatial data.

# COMPONENTS OF AN SDI FOR PRECISION FARMING

As discussed in the previous section, much of the geospatial data transfer for PF, particularly from 'external' agencies such as suppliers of base mapping could be satisfactorily accomplished using simple raster images generated from the data. The OGC- and ISO TC211-specified Web Map Service interface (ISO/TC211, 2005), which forms the basic component of many current SDI initiatives is ideally suited for this function. All that is required is for the farmer's software to implement WMS client functionality (and, naturally, for the farmer to have a suitable internet connection) and these existing data sources will be able to be used. For the transfer between farmer and consultant, the OGC Web Feature Service interface (Vretanos, 2005) describes a suitable interface allowing query and insert/update capability on vector-based spatial and attribute data (e.g. in GML (Cox et al., 2004)). However, the WFS specification only describes the operations of the interface – the schema to be used is not specified, and unless agreed upon between all parties then semantic incompatibilities or even technical incompatibilities are likely to occur. An application schema (or community schema) for the specific domain of interest (here PF) must therefore be defined and used by all parties, defining the ontology, semantics and encoding of the relevant features. For the case of PF, agroXML (KTBL, 2005) is currently being developed as a standardised XML-based transfer format based on ebXML (Eisenberg & Nickull, 2001) and UBL (Meadows & Seaburg, 2004). Discussions are currently ongoing as to the possibility of integrating agroXML into a GML application schema, allowing compatibility with WFSs, although this may preclude compatibility with the existing base-schemas (Korduan & Nash, 2005). Similarly, for transfer of attributes for raster-based geospatial data, the OGC Web Coverage Service (Evans, 2003) could be used, with a similar qualification regarding the need to agree on ontology and semantics as well as transfer formats and interfaces.

In order to limit the required complexity for the farmer, as well as to alleviate fears about external storage of (or access to) data (reported by Fountas et al., 2005), it may be preferable to limit the required software for the farmer to client-software capable of accessing data from and uploading data to external services. This would imply that any actors receiving data from farmers (such as consultants or contractors) must be running servers capable of receiving uploaded data (e.g. the OGC Web Feature Service in 'transactional' mode). Additionally, in order to further reduce the complexity of the farmer's software, remote processing servers (e.g. implementing the emerging WPS interface (Schut & Whiteside, 2005)) may form an important role in future SDIs for PF. Given that PF is an evolving field where new models of, for example, plant growth are constantly being developed, this would also allow farmers access to the 'latest and greatest' models and analysis without having to alter their software. However, such services are not yet fully defined and are certainly not widely implemented and so currently it is to be assumed that the client software will run the analyses locally.

An additional important component of an SDI for PF is the provision of suitable comprehensive metadata and metadata services to enable farmers (or farmers' software) to efficiently discover and use available geospatial data services. A suitable metadata profile (e.g. of the CSDGM standard as implemented by Korduan (2004) or of the ISO19115 standard as proposed by Backes et al. (2003)) coupled with a suitable search mechanism (e.g. OGC Catalogue Services (Nebert & Whiteside, 2005) or standard search-engine based (e.g. Ramsey (2004) presents a method for discovery of OGC services via Google)).

The final important components of an SDI for PF (visualised in Figure 5) are suitable security/authorisation and e-business/payment mechanisms, which are likely to be important factors both for commercial/governmental data suppliers and for the PF-specific actors (e.g. for a soil-testing consultant to ensure that each farmer may only access their own soil testing results). These components are, however, still at a very rudimentary stage and in the majority of SDIs the data and services are freely accessible (subject to intellectual property rights rather than enforced security and payment mechanisms). The possibilities for successful business models for SDI service providers are, therefore, although thoroughly analysed (e.g. by Wagner, 2003), still limited in terms of implementation. It is therefore assumed that until standards in this area are agreed, standard authentication and access methods based on web server and browser technology (e.g. based on IP matching) and non 'e-business' payment methods (e.g. based on an annual contact for access to a service) would be implemented where required.

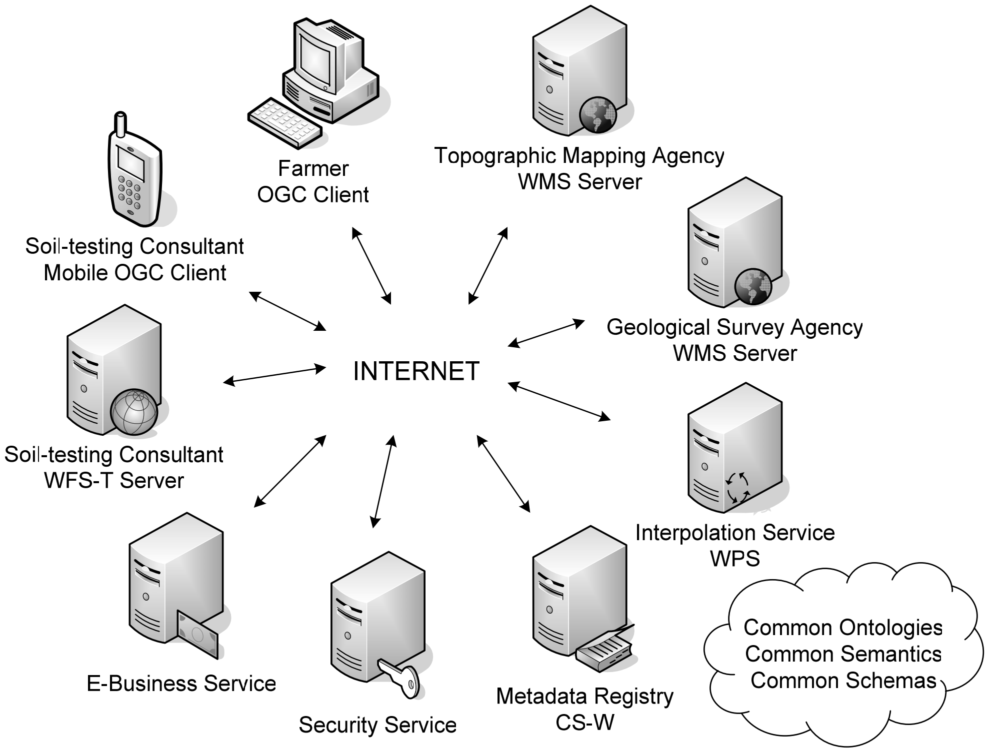


***Figure 5:*** Components of an SDI to support the PF business process "soil testing"

## RELATIONSHIPS BETWEEN A SPECIALIST SDI AND OTHER SDI INITIATIVES

As already discussed, a specialist SDI does not exist in isolation – it will both draw on and contribute to the "SDI Hierarchy" (Williamson et al., 2005), as illustrated in Figure 6. The supply of topographic or geological mapping, as required for the use-case which has been discussed in this paper, as well as the supply of other general datasets which may be of interest for users of a specialist SDI, such as climatic data or satellite imagery, are already constituent parts of many SDI initiatives and these services are therefore available to be used as part of a specialist SDI. In order to bind such services into the specialist SDI, all that should be required is for the metadata from the general services to be comprehensive enough that they can be discovered based on the context required from the specialist SDI (e.g. topographic mapping may be searched for using keywords such as "base mapping" in the context of an SDI for PF), or for a service provider to a specific sector to supplement the existing metadata with domain-specific extensions (i.e. a portal for a specialist SDI would supply 'domain-enhanced' metadata). Subject to access restrictions, services from one specialist SDI may be able to be incorporated into other specialist SDIs, e.g. an SDI for e-government may have overlap with an SDI for PF, both in order to allow farmers to access administrative information (such as the boundaries of their land) and to allow the farmers to share information for e-government (e.g. for calculating subsidy payments). Whether the services implemented as part of a specialist SDI may contribute to a more general SDI is debatable – by their nature they are likely to handle data of interest to a limited group of users, but the use of standardised interfaces, formats and protocols means that subject to demand and access restrictions, there is no technical reason why this may not be realised.

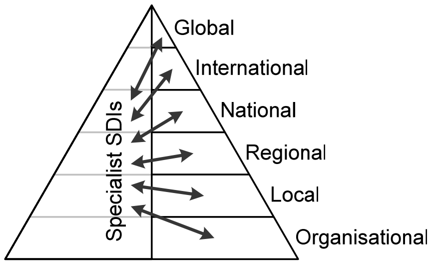


***Figure 6:*** The contribution of specialist SDIs to the SDI Hierarchy (after Williamson et al., 2005)

## FUTURE DEVELOPMENT OF SPECIALIST SPATIAL DATA INFRASTRUCTURES

The majority of SDI initiatives to date have been general SDIs serving data (or more usually, visualisations of the data through a WMS interface) to a broad and often undefined target audience. In contrast, a specialist SDI will have a clear user base and the services offered will be selected to fulfil a defined set of requirements such as simplifying or automating parts of a business process. The generalist nature of the services specified by the OGC and ISO/TC211 means that as well as being used for generic data, they may also be used to construct such specialist infrastructures. The use of common standards means that services from other SDIs may be linked into specialist SDIs, either on a static basis where a particular service is required to fulfil a particular use-case, or dynamically when one of a range of services will suffice and the end-user can make a choice, based perhaps on access costs or other preferences, as to which service should be used in that particular instance. In order for the user, who may well not be a geospatial data specialist to do this, the workflow needs to be defined in advance and the suitable services identified, or in a more dynamic environment, a metadata query defined that will reliably return appropriate services from a catalogue. Although this workflow may be defined in the client software, a better solution may be to provide a workflow service as part of the specialist SDI. Whilst this could perhaps be defined as a processing service, the fact that the user may be required to provide input during the workflow (e.g. to choose which services to dynamically chain) means that a more specialised service is likely to be required. Standards for such services are currently still in development, but such advanced services are likely to play an important role in specialist SDIs.

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