PROJECT PLAN FOR INTEGRATED MAPPING AND INFORMATION SYSTEMS IN THE SOUTH AFRICAN SUGAR INDUSTRY

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Abstract

There are a number of current initiatives in the South African sugar industry investigating and implementing mapping programmes and information systems These independent initiatives have raised concern over the lack of industry standards and frameworks necessary to consolidate the mapping and sugar industry information for the benefit of the whole sugar industry.

To address these issues the South African Sugar Association Experiment Station appointed private consultants to undertake a study of the mapping initiatives, information systems and information requirements, common to all stakeholders in the sugar industry. The results and recommendations from six project reports for the industrial study, completed in December 2001 are summarized.

Keywords: GIS, User Requirement Analysis (URA), mapping, integrated databases

Introduction

There are a number of current initiatives in the South African sugar industry investigating and implementing mapping and information systems such as the LIMS (Laboratory Information Management System). These independent initiatives have raised concern over the lack of industry standards and frameworks that are necessary to consolidate the mapping and industry information for the benefit of the sugar industry as a whole. To address this issue the South African Sugar Association (SASA), Experiment Station (SASEX) appointed private consultants to undertake a study of the mapping initiatives and undertake a user requirement analysis (URA) of industrial and map data common to all stakeholders in the sugar industry by December 2000.

The scope of a URA included all South African Sugar industry stakeholders comprising of 15 Mill Group Boards, 3 milling companies, large-scale and small-scale grower representatives, various divisions of SASA and SASEX as well private contractors associated with the industry. Relevant standards and documentation were obtained from a variety of independent sources including the timber industry, mapping and surveying consultants.

The information system development methodology employed by the consultants closely followed the 'Generic' GIS development methodology described by Reeve and Petch (1999). This generic development methodology otherwise known as the 'waterfall' model consists of five stages namely *Initial awareness, Building the business case, Detailed analysis and design, Implementation* and finally *Maintenance and review.*

The mandate of the consultants was to model data flows and information requirements within the sugar industry using Computer Aided Software Engineering (CASE) tools through a URA of the various stakeholders. Investigations included analysis of industrial databases, information flows as well as cost benefit analysis and implementation strategies for an integrated information management system. Implementation, maintenance and review of an integrated mapping and information system were not part of the project brief.

The key goals of this project were to:

- Review and document the current status of mapping and data collection, storage and its usage in the sugar industry
- Assess industry user requirements (miller, grower and SASA) for mapping and information systems
- Identify alternative methods for map and data capture, integration, maintenance and management at industry level
- Propose a functional and conceptual design of a mapping and information system for the sugar industry
- Formulate several industrial implementation strategies.

Gers and Erasmus (2001) summarized the status of mapping and information systems and documented key industrial concerns obtained from user a requirement analysis of the various industrial stakeholders. This paper reviews the status of the sugar industry's mapping and information requirements, the conceptual design of the proposed integrated mapping and information system and its implementation strategy. Readers requiring more details about the project are strongly advised to refer to the extensive suite of project documentation (see list of Sources).

The South African sugar industry

The South African Sugar Industry is essentially a partnership between millers and growers. This partnership has the following overlapping key business objectives namely:

- To optimise sugar production and gross revenue
- To optimise sugar extraction and sugar quality.

These key business objectives can be translated into the following business processes:

- Yield estimating
- Harvest planning
- Length management of the crushing season (Local Area Agreements or Cane Delivery Agreements).

Despite the simple partnership between millers and growers, the complex South African sugar industry has many important role-players that interact with each other namely, the Milling Companies which are represented by the South African Sugar Millers Association Limited (SASMAL). Large-scale and small-scale growers are represented by Local Grower Councils and by the South African Cane Growers Association (SACGA). Each mill has a Mill Group Board (MGB) that comprises of both miller and grower representatives who negotiate the Local Area Agreements (LAAs) or Cane Delivery Agreements. The South African Sugar Association (SASA) and the South African Sugar Association Experiment Station (SASEX) are service providers to both miller and grower stakeholders.

Review of information and mapping requirements

The sugar industry has an extremely wide range of user groups with regard to their size, available resources, (spatial and non-spatial) information requirements as well as their computing experience. The range varies from well resourced groups who are highly specialised and experienced in computing, spatial and or non-spatial information management, to those with no computing or information expertise and which have few financial resources.

General information requirements

Generally the large-scale and small-scale growers, researchers and extension officers have the largest spatial information requirement, although all users identified some benefit from having access to current and accurate spatial information. The most common requirement is field-level spatial information. This implies that map information must reflect the boundaries of individual cane fields.

There is also a wide range of spatial data requirements. The growers need detailed information about their farms and fields at a fairly level of high accuracy. The mills only need to know the total area under cane for their mill area. However, the accuracy of the total area under cane is entirely dependant on the accuracy of the field-level mapping undertaken on each farm.

The study concluded that the *primary requirement* of all sugar industry stakeholders is access to accurate and current information (spatial and non-spatial) to help them plan and execute their daily operations. Access to a history of the information is also a requirement. The fulfilment of this primary requirement must be done as cost-effectively as possible and should not add significantly to the overall costs of producing sugar. Most of the users and stakeholders are extremely mindful of this fundamental constraint.

Non-spatial information requirements
The primary requirement of access to accurate and current non-spatial information is currently being addressed by the implementation of LIMS (Laboratory Information Management System) that is currently being rolled out across the industry in a phased manner. This LIMS system is essentially an enterprise relational database, which stores all industrial cane delivery, grower, farm, field and other non-spatial information for a minimum period of five years.

To date information problems have been experienced in the industry which include:

- Poor access to information by relevant parties
- Inability to validate poor quality data
- Data storage has been limited and inefficient, resulting in "lost data" and duplicated data
- Data storage has been fragmented resulting in some inconsistent data inputs
- Large number of role players
- Diverse nature of the role players & their information requirements
- Need for confidentiality of certain data sets.

Spatial information requirements
Currently each individual stakeholder group collects, captures and manages their own spatial data. The mapping initiatives within the industry are largely governed by the legal requirements of the Local Area Agreements (LAAs) that stipulate that the Mill Group Board is responsible for the development, maintenance and operation of a mapping or cartographic programme for their cane supply area. The level of accuracy required from these mapping programmes is less than 1% error for the total measured cane area.

To date, these mapping programmes have been undertaken in the absence of any recognised and approved industry mapping standards. Approximately 55% of the total area under cane has recently been mapped. However, only about 18% of this has been mapped to the field-level whilst the remainder has been mapped to block-level as of June 2001.

Fortunately, it appears that a large percentage of the mapping has been done according to various independent standards and methodologies that may differ from one another but are each reliable in their own right. The absence of a single mapping standard, however, has introduced a number of information related problems from an industry perspective. These problems include:

- Inability to integrate information across the industry
- Varying levels of accuracy
- Varying levels of detail
- Difficulty in maintaining block mapping
- Difficulty in validating quality (quality control).

Proposed integrated mapping and information system

The recommended information strategy

Strategically three groups of spatial or mapped data were identified. The first of the three data groups is spatial data of primary importance. These data form the core map data required by the sugar industry. They are regarded as essential information and would include information such as field and farm boundaries. The second spatial data group is the data that are required by the industry but not deemed essential and would include road centrelines, soils, dams, rivers, topography (slope/aspect) and climate. The third level of data are the non-spatial or attribute data. There are data that are generated by the farming operations, much of which are currently being stored or is planned to be stored in the LIMS database.

The objectives of a spatial information strategy for the sugar industry is to ensure that all required spatial information is collected, captured, validated, stored and managed as efficiently as possible. The information should be standardised, easily accessible to any authorised user and utilised to improve the business of the industry as a whole. The proposed conceptual design of the integrated information system is illustrated in Figure 1.

The recommended integrated information system will consist of the Sugar Industry Data Warehouse, a data server, an application server and a web server (Figure1). (The Sugar Industry Data Warehouse is a repository in which related spatial and non-spatial data of primary and secondary importance and field delivery data are stored.) Information needs to be standardised and integrated, but not necessarily centralised. The warehouse may be physically distributed, but should be accessible as a whole via the World Wide Web, Local Area Networks (LANs) or Wide Area Networks) WANs. The different sugar industry role players would update the Sugar Industry Data Warehouse with relevant information.

Recommended strategy for implementation

The objective of the recommended implementation strategy is to prioritise implementation phases that offer the most benefit to the whole industry at minimum cost. Later more difficult/costly phases will be built on the earlier successes.

The recommended phases are prioritised and summarised in Table 1. The first step of implementation would be to implement an approved set of industry-wide spatial data standards namely the Sugar Industry Mapping Standard. The focus should be on the spatial data features of primary importance.

The second step would be to map all outstanding unmapped cane areas in accordance with the Sugar Industry Mapping Standard. For large areas/farms it is believed that an aerial photography-annotation-capture-validation method is the most appropriate.

For small-growers who are geographically dispersed, GPS mapping is recommended. Here again it is essential that the correct accuracy is guaranteed and that GPS mapping is done strictly in accordance with the Sugar Industry Mapping Standard.

The third implementation step involves standardising the data from cane areas already mapped. As determined during the requirements analysis, 18% of the area under sugar cane has already being mapped to the recommended field-level. For these areas, the data produced by the mapping programmes will have to be converted to the Sugar Industry Standard and loaded into the operational database. This should not be a difficult process if the data were mapped, captured, and validated to some form of local standard.

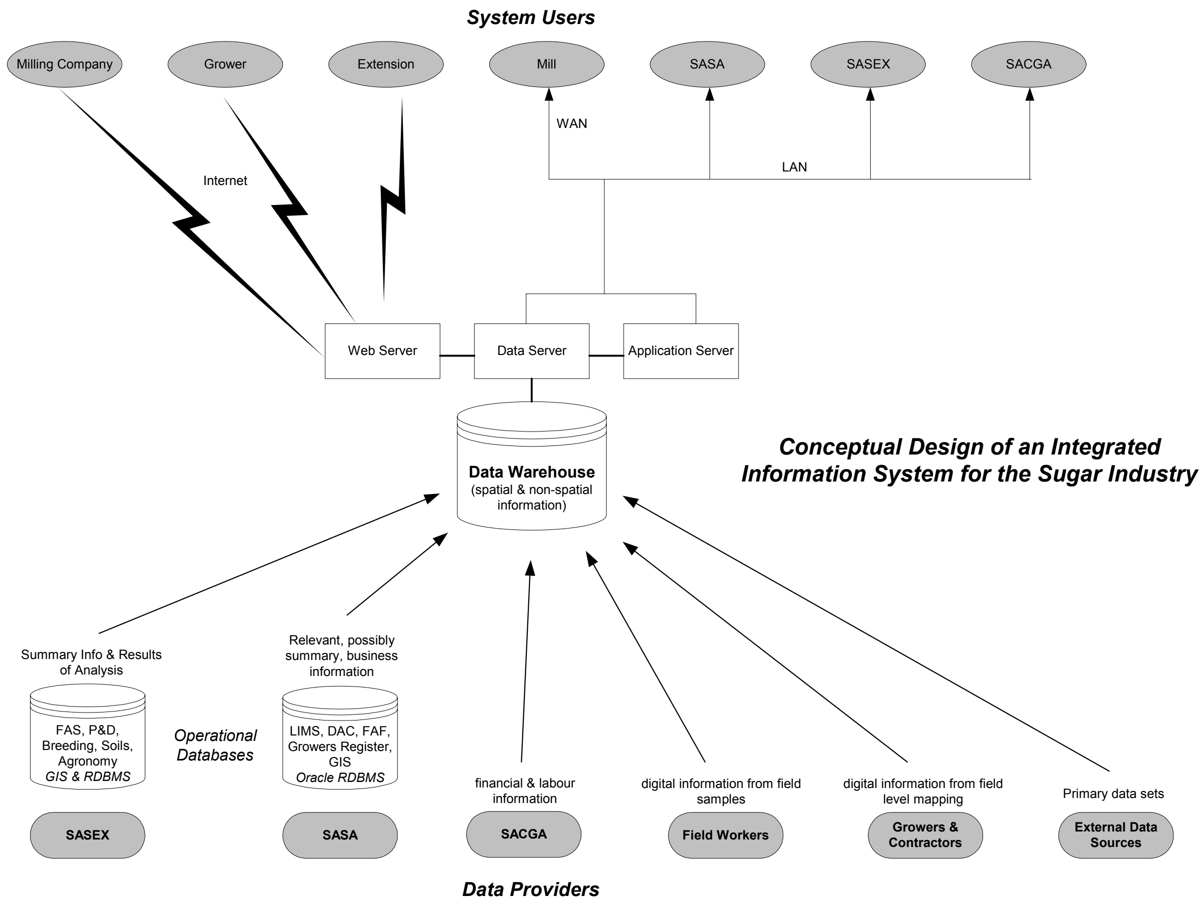

Figure 1. Conceptual design of the proposed integrated information system for the sugar industry

The fourth implementation step involves spatially enabling the Industry Data Warehouse, LIMS. The sugar industry is in the process of developing a large industry-wide data warehouse. Currently the warehouse does not cater for spatial information. Following discussions with the LIMS development team, it is recommended that a pilot project be undertaken to test the concept of spatially enabling LIMS.

The fifth implementation step is the establishment of Regional Spatial Information Service Centres. During the requirements analysis phase of this project it became apparent that there were some users that are very advanced in the use of computers and spatial information systems and have enough resources to develop and maintain their own systems. However, the majority of users are not in this category and the establishment of a regional spatial information service centre in each MGB area was proposed. These centres would fall under the management of the MGB and would be responsible for the following services:

- Planning and implementation of all mapping and map updating programmes
- Implementation and maintenance of an operational spatial database
- Information dissemination and updating of the Industry Data Warehouse
- Map production services
- Spatial analysis services
- Spatial reporting.

It is envisaged that these centres will provide a valuable service to all users in their regions including the millers, growers, researchers and extension officers. In fact, they will play a key role in providing information to the entire industry by updating LIMS with the latest field performance and boundary information on a regular basis.

The sixth implementation step will develop spatial data maintenance systems for the sugar industry. Once the MGBs have their spatial data mapped, captured, validated, stored and managed, it is highly recommended that a system be developed that will allow for the efficient ongoing maintenance of the spatial data. This system must be simple to use and must enforce data maintenance according to the Sugar Industry Mapping Standard. The users of this system would be the growers who are based on the land and are best placed to report changes in field boundaries, field numbers and other spatial features. It is recommended that a project be undertaken to determine the requirements of such a system once the operational spatial database has been designed and implemented.

The seventh implementation step is the research and development of models to improve sugar industry operations. Once the Sugar Industry Data Warehouse is completed, it is recommended that SASEX be encouraged to develop additional models that could be run against the spatially enabled data warehouse creating derived datasets that could improve the industry's operations as a whole.

The final implementation step is to develop the spatial information and GIS capacity of SASEX further. There is a strategic need to increase the expertise and resources at the current SASEX GIS section of the Agricultural Engineering Department. This will enable the following to be achieved at the industry level:

- Provide custodianship and ongoing maintenance of the Sugar Industry Mapping Standards and contracts
- Consolidate and maintain the industry spatial database which would be housed in the industry data warehouse
- Source and load valuable external spatial data sets
- Provide first-line support for the regional operational database facilities
- Develop industry value-adding applications
- Undertake spatial analysis and provide information services at the industry level.

Benefits of implementing a spatial information system

The benefits of implementing a spatial information system can be subdivided into those benefits that can be quantified to some extent (tangible benefits) and those that can be identified but are difficult to quantify (intangible benefits).

Tangible benefits include reduction in operational costs. Experience has shown that by mapping farmed areas more accurately, there is an actual decrease in field area, as compared to the original reported area. These results have been experienced by many of the forest industry companies, who found that after accurately mapping their areas under forests there was a general reduction in actual afforested areas of between 8-20%, when compared to the original reported areas. Furthermore the greater accuracy of area statistics gave financial managers a more reliable method of auditing the costs attached to work areas.

Cost benefit analysis

For the purpose of this cost benefit exercise, it was assumed that the reported cane areas decreased by 8% due to accurate field-level mapping that excluded roads, infield breaks and other non-cane areas. Using the average per hectare analysis reports provided by the SACGA, it was found that two costs were fixed per hectare, namely fertiliser and chemicals. Using the cost information and the above assumptions, calculations were made to try to estimate the magnitude of potential savings that could be made annually on a per hectare basis (Table 2a).

Table 2a. Potential annual operational costs and cost savings per hectare from accurate field-level mapping and block level mapping for coastal, irrigated and Midlands farms.

	Coastal farm		**Irrigated farm**		**Midlands farm**	
Farm activity	**Cost (R/ha)**	**Potential saving (R/ha)**	**Cost (R/ha)**	**Potential saving (R/ha)**	**Cost (R/ha)**	**Potential saving (R/ha)**
Fertilising	491	39	1027	82	489	39
Chemicals	239	16	306	25	219	18

Table 2b. Typical costs associated with block level mapping and field level mapping for Coastal, Irrigated and Midlands farms.

Mapping accuracy	**Cost (R/ha)**
[Ψ]Aggregate or Bock Level Mapping	9.50
[β]Field Level Mapping	12.00

Ψ Aggregate level mapping involves the mapping of all panels that make up a field, separated by a shortest straight-line distance of less than 5.0 meters between them, as a single unit.

β Field level mapping involves the mapping of each and every panel that makes up a field, as individual units.

Table 2b indicates that there is potentially a direct cost benefit if the farms were mapped at a field-level. The potential cost savings are far higher than the marginal cost of field-level mapping as opposed to farm or block-level mapping. This marginal cost is currently approximately R2.50/ha. It is clear that by having access to more accurate field-level areas, the industry could experience significant operational cost savings.

Additional benefits of having accurate area under sugarcane data are improvements in yield estimates on a regional scale. Improved estimates of annual production will improve the accuracy in forecasting of the correct milling season. Calculations made by the SACGA indicate that in some cases R800 000 per mill area could be lost for each week that the length of milling season (LOMS) is estimated incorrectly.

The regional spatial information centres would ensure that the spatial data would be properly maintained and that the local users of information would be given the necessary service and support to realise the full benefits of having easy access to accurate and current spatial information. These facilities would have the necessary tools to maintain, analyse, manipulate and output the data for efficient service delivery. Regular maintenance of the spatial database could also translate into a cost saving by lengthening the period between re-mapping or, ideally, even eliminate the need to re-map existing cane areas.

Intangible benefits of accurate current information include being able to make more informed or better decisions and saving time.

The efficient collection and management of spatial information has consistently reported time/cost savings. These time/cost savings can translate to an improved efficiency of between 10% and 80%, depending on the specific task.

Conclusion

The timing of the industrial study was appropriate given heightened interest in mapping and information management within the South African sugar industry. This interest has largely been driven by the industrial business requirements for more accurate and timeous spatial and non-spatial information for a host of reasons including:

- Improving grower estimates of areas under sugar cane
- Forecasting crop yields
- Increasing international export of sugar
- Administering Local Area Agreements
- Determining the length of the milling season more accurately
- Improving cane cultivation and harvest scheduling and transport logistics
- Agronomic improvements.

The use of LIMS for integrating mapping, field delivery and performance information is opportune given the large capital outlay involved in establishing the system at each mill. Furthermore the Enterprise relational database underlying LIMS can totally integrate and efficiently managed cane delivery and field boundary (spatial) information in a single repository.

A document on '*Recommended Standards for Differential Global Positioning System and Digital Orthophotograph mapping in the South African Sugar Industry'* (Gers, 2002) has been prepared that addresses the mapping and information standards required by the industry. Initiation of a pilot project aimed at spatially enabling the LIMS is currently being considered by the SASA Information System Department.

As global markets continue to place mounting pressure on the cost competitiveness of South African produced sugar, innovative and sustainable cost saving mechanisms are continuously required. The South African sugar industry finds itself in a fortunate position in terms of the recent information technology developments, especially when compared with other developing countries. Substantial gains stand to be made through improved management and distribution of accurate information, of which spatial information forms but one small component. The synergies of integrated information systems must be realized to improve the management of the diverse facets in sugar production. This will ultimately lead to more cost competitive sugar production in South Africa.

REFERENCES

Gers, C and Erasmus, D (2001). Review of mapping, Geographic Information Systems and key concerns in the South African sugar industry. *Proc S Afr Sug Technol Ass* 75: 34-37.

Gers, C (2002). Recommended Standards for Differential Global Positioning System and Digital Orthophotograph mapping in the South African Sugar Industry. South African Sugar Association Experiment Station, First Edition (in press).

Reeve, DE and Petch, JR (1999). GIS for beginners: GIS Organizations and People A Socio-technical approach, Taylor and Francis, First Edition, pp 45-149.

Sources

Erasmus D, Thompson J, Zwarts A, Hine S and Gers C (2001). Development of a Project Plan for an Integrated Mapping and Information System in the South African Sugar Industry - Document 1: User Requirements. South African Sugar Association Experiment Station and Geographic Information Systems Pty (Ltd), Durban, 30 pp.

Erasmus D, Thompson J, Zwarts A and Hine S (2001). Development of a Project Plan for an Integrated Mapping and Information System in the South African Sugar Industry - Document 2: Integrated Information Strategy. South African Sugar Association Experiment Station and Geographic Information Systems Pty (Ltd), Durban, 24 pp.

Erasmus D, Thompson J, Zwarts A and Hine S (2001). Development of a Project Plan for an Integrated Mapping and Information System in the South African Sugar Industry - Document 3: Conceptual Database Design. South African Sugar Association Experiment Station and Geographic Information Systems Pty (Ltd), Durban, 26 pp.

Erasmus D, Thompson J, Zwarts A and Hine S (2001). Development of a Project Plan for an Integrated Mapping and Information System in the South African Sugar Industry - Document 4: Spatial Information Standards. South African Sugar Association Experiment Station and Geographic Information Systems Pty (Ltd), Durban, 64 pp.

Erasmus D, Thompson J, Zwarts A and Hine S (2001). Development of a Project Plan for an Integrated Mapping and Information System in the South African Sugar Industry - Document 5: Final Summary and Recommendations. South African Sugar Association Experiment Station and Geographic Information Systems Pty (Ltd), Durban, 41 pp.

Erasmus D, Thompson J, Zwarts A and Hine S (2001). Development of a Project Plan for an Integrated Mapping and Information System in the South African Sugar Industry - Document 6: Executive Summary. South African Sugar Association Experiment Station and Geographic Information Systems Pty (Ltd), Durban, 16 pp.

Table 1. Summary of the recommended strategy for implementing an integrated information system for the sugar industry

Implementation Step	Priority	Timing	Cost	Responsibility	Benefits
Mapping Initiatives					
1. Adopt and Implement Sugar Industry Mapping Standard (SIMS) ▪ Review & agree standards presented ▪ Communicate with stakeholders	A	Short Term	Nil	SASEX (custody & Maintenance) MGB (implementation)	▪ Ability to standardise all future mapping & updating ▪ Ability to integrate all industry spatial information ▪ Ability to control quality of mapping & data capture ▪ Ability to develop an industry standard operational database ▪ Ability to develop & implement standard industry applications
2. Start mapping areas currently not mapped	A	Short Term	R12/ha	MGB (contractors)	▪ Obtain an accurate area under cane ▪ Improve yield estimates ▪ Satisfy LAA requirements
3. Start converting existing field-level mapping to conform with SIMS	A	Short Term	R5 – R10/ha	MGB (contractors)	▪ Ability to integrate all industry spatial information ▪ Ability to develop an industry standard operational database ▪ Ability to implement industry-wide applications
Database Development Issues					
4. Spatially enable industry data warehouse (LIMS)	A	Short Term	R250 000	SASA (consultants)	▪ Ability to store, maintain & serve spatial data for the entire industry ▪ Improve industry data security (backup & access rights) ▪ Improve information access ▪ Ability to implement value-adding industry applications
5. Establish regional spatial information centres	B	Medium Term	R60 000 each	MGB Service Providers	▪ Maintain the regional spatial operational databases ▪ Manage the regional map updating system ▪ Implement & ensure adherence to standards ▪ Provide a spatial information service to the regional users ▪ Update the Industry Data Warehouse regularly
6. Develop & implement a spatial information updating system	B	Medium Term	R100 000	SASEX (contractors)	▪ Ability to update operational spatial database efficiently ▪ Reduce costs of regular re-flying & re-mapping ▪ Reduce costs of data maintenance
7. Research & develop models to improve sugar industry operations	B/C	Medium to Long Term	?	SASA SASEX	▪ Leverage decision making (speed, accuracy & quality) ▪ Disseminate valuable derived data to the industry ▪ Encapsulate and apply industry knowledge
Industry Spatial Information Expertise & Capacity					
8. Further enhance industry spatial information expertise and develop a GIS centre of excellence	B	Medium Term	?	SASEX	▪ Custodianship & maintenance of Industry Standards ▪ Enhance research programmes with spatial information element ▪ Develop spatial models ▪ Provide derived data for the industry ▪ Source & maintain valuable external spatial data