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# DESIGNING AN ENVIRONMENTAL INFORMATION MANAGEMENT SYSTEM (EIMS): THE CASE OF WEB MAPPING PORTAL FOR FARMERS

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***Abstract***

*Today concerns for environmental sustainability practices are getting lots of attention due to the regulatory requirements, market pressure and natural resources deterioration. While many businesses have responded these demands by incorporating sustainable thinking into their strategies, in the same vein, researchers have attempted to provide different ground in understanding environmental sustainability best practices. IS researchers is no exception due to the growing recognition that the ICT and IS as being part of the solution to the environmental sustainability problem. This study, therefore, addresses this call by presenting the results of longitudinal and in-depth investigation of an IS design for supporting environmental information management and referred as Environmental Information Management System (EIMS). To better understand how a new EIMS can be designed, it then considers the design of a new Web Mapping Portal to assist farmers in land management and monitoring as a fruitful empirical context of investigation. Overall, the findings of this study show the value of IS scholars going beyond the dominant research on IS designed for supporting business (e.g. ERP, SCM and ERP) into more emerging research stream by addressing research question on how can IS be designed to address the complex problem in environmental sustainability.*

*Keywords*: *Design, Environmental, Information Systems, spatial web-based*

## INTRODUCTION

Many governments worldwide are faced with the challenge of how to manage and monitor the impact which organisations and society at large have at natural resources **[**1**] [**2**]**. Governments in countries such as Australia, USA and the UK have their Environment Protection Programs **[**3**] [**4**] [**5**]** which give them responsibilities and powers to reduce air, water soil pollution and deterioration. This entails, for instance, controlling or regulating the use of natural resources, preserving high-value species and protecting ecosystems on public and privately owned land **[**1**] [**6**]**.

In one Australian State, which is the focus of this research, apparently only about one third of the total land is government owned in which they can directly control environmental protection activities. Another two thirds are privately owned and primarily used for agriculture whereby activities such as fertilising and grassing by landholders can have adverse impacts on the land. Therefore, to help manage and reduce the negative effects of farming activities on this land, the government needs to work in co-operation with landholders (farmers). This includes collecting and monitoring the environmental information at the farm level (e.g. vegetation, waterways and soil type) and then used the information for developing suitable natural resources protection programs or funding support schemes at regional or state-wide level.

One of the challenges, however, for the government in this approach is how to collect voluminous data from a large number of farmers, who may less enthusiastic in environmental management initiatives. In addition, since the monitoring process involves paperwork, manual data processing and carries out on a regular basis over an extended period time, the data collection process is often considered as being tedious, labour intensive and time-consuming. Further, in the decision making process, the government may requires farmers to collect and measures all forms of environmental information at their paddocks which implies the data collection process requires proper technical and scientific standards. Thus, with the absence of computer-based tool, the other challenge for government was how to make the on-farm environmental data collection process is burden free for farmers but at the same time the information collected by farmers meeting the environmental information compliances or government needs.

To address the challenges, the government is trying to design computer-based system capable to support mainly farmers in the environmental data collection at farm level. In addition, the tool should enable the government that is facing the challenge of preserving the land, to oversee the information collected by farmers to support the regional or state-wide environmental information management, decision making process and support programs creations. Against these backdrops, this study aims to investigate how an Australian State government's attempt to design a new Environmental Information Management System (EIMS) that enables farmers monitor environmental information at their paddock and then exchange the information with related parties or government agencies they wish.

## ENVIRONMENTAL INFORMATION MANAGEMENT SYSTEM (EIMS)

An Environmental Information Management System (EIMS) is a subset of Information Systems (IS). There are various definitions of EIMS in the literature **[**7**] [**8**] [**9**]** , but this study refers this as computer-based IS which enables organisations to collect, manage and report information about the environmental impacts resulting from their operations. This study is specifically concerned with EIMS designed for farmers so that they can use it to collect and monitor their environmental data at farm level and then communicate it with other parties requiring the information electronically.

This study argues that EIMS designed for farmers is an interesting context to study in their own right, because it deals with the complex processes of the collecting, managing, storing and disseminating of contestable on-farm environmental information. In addition, the nature of environmental information collected and exchanged within EIMS is different with information managed by common IS applications (e.g. ERP, SCM and ERP) which is well understood.

There are also, however, some characteristics that make an EIMS for farmers is an interesting empirical context to study. Firstly, the EIMS is designed and developed for use by a large number of farmers who are majority Small Medium sized Enterprise (SME), heterogeneous in term of different farm businesses (e.g. wool, grain and beef) and have competing or even conflicting needs on what on-farm environmental information they wish to collect, store and share. Secondly, since most of farmers are SMEs, which have been acknowledged to face considerable barriers, including limited time, personnel, fund and other resources, it becomes critical to develop a new EIMS which can overcome such constraints which may hinders farmers to undertake environmental data collection over long period of time.

Finally, the lack of IT expertise, low interest and knowledge in environmental sustainability practices among SME farmers makes it important to understand how to design EIMS which is easy, practical and useful for such intended users who are majority not conversant with the potential benefits of undertaking on-farm information collection electronically. The next section discussed the review on the past research related to understand how the existing IS had been designed for use by SMEs particularly in agriculture context (farmer).

## PAST STUDIES ON EIMS

Recently, there has been growing concern among researchers to explore the connection between IS and the environmental sustainability [10] [11]. This is because the increasing demands prompting organizations or businesses at various sectors to demonstrate their environmental credentials. For the last decade, researchers have responded and suggested that there is a need for more studies to understand how IS artefacts can be designed with aim of supporting environmental sustainability practices. Examples included design and development IS to support energy monitoring [12] [13] [14], conduct Life Cycle Assessment (LCA) of production process [15] and underpin the implementation of waste management [16] [17].

Especially in agriculture sector, with an ever increasing demand on farm productivity growth, there has been also significant pressures placed on environmental sustainability practices. This is due to the recognition that on-farm activities also have negative impacts on environment as the results of, for instance, land use, widespread fertiliser and pesticides use [18] [19]. Review from the literature indicated that there has been a significant body of research attempted to develop IS to address such negative effects from farming activities and support environmental sustainability practices in the agriculture context.

Researchers, in this area, have come across with the design and development of various IS artefacts that allow the increased agricultural productivity to be achieved while maintaining environment. For example, a lot of researchers have focused on their work in designing and developing simulation and modelling systems which enable best scenarios concerning reducing negative effect natural resources from the farming to be tested [20] [21] [22]. Other studies have reported the development of IS for monitoring environment, which can be applied not just for modelling, but beyond that also for the actual sustainability assessment in agriculture [23] [24] [25].

Further results from literature review reveal there is a great deal attention describing the design of IS in agriculture context to assist farmers especially in sustainable farming practices [26] [27] [28]. Generally researchers argue that environmental-related activities are not of interest to many farmers. Another plausible explanation is that, farmers often have low motivation to carry out on-farm environmental sustainability practices due to their limited resources, lack of knowledge and absence of incentives. It was therefore anticipated that if farmers were provided with useful tools, they would be motivated and able to incorporate sustainable thinking in their farming activities. Within this wealth literature, however, much of IS in agriculture have been designed as Decision Support System (DSS) [e.g. [29] [30] [31]]. The key limitation of DSS is that the system is designed mainly for supporting decision making process in farm management (e.g. crop selection). Another key observation is that, while there has been a large number of DSS intended for farmers, however many of which have been reported failed to achieve the adequate level of acceptance when it comes to the adoption. One of the most repeatedly reasons which may contribute to the failure is farmers feel that the

DSSs are generally mismatch with their needs, too complex and uneasy to use **[**32**]** **[**33**]** **[**34**]**.

All the above evidences highlight that, while, previous studies have enhanced our understanding of how to design the IS for assisting decision making of farmers to improve farm productivity and at the same reduce environmental deteriorations. However, as the systems are majority DSSs, there is little insight into the design of IS to assist farmers in on-farm environmental information monitoring and exchanging with related parties, known as EIMS. In addition, given the persistent negativity, let alone the slow uptake, in the adoption stage, discussed above, it is often difficult to extract the knowledge from the literature revealing how to design IS which is practical, useful with ease of use and matched with farmers needs.

A limited, but growing, number of exceptions found in the literature [e.g. **[**18**]** **[**23**]** **[**24**]**], which investigated key issues for successful IS designed for farmers. However, to the best of our knowledge, there is no empirical work which reported the design process of successful EIMS for farmers from initial to the implementation stage. This paucity also means there is a need for more empirical research in this area from which this study can address in order to make contribution to the current body of knowledge. The following sections, therefore, presented the findings of the case study of Web Mapping Portal design project which offer a rich fertile ground to understand the process of designing successful EIMS for famers.

## EIMS: THE CASE OF WEB MAPPING PORTAL DESIGNED FOR FARMERS

Web Mapping Portal (WMP, pseudonym) design was initiated by an Australian State Government as part of Sustainable Agriculture project. As introduced earlier, this project was timely, given the reality that two thirds of the land was privately managed and majority for farming purpose. Rather than just enforcing regulations, in this project, the government tried to work directly with farmers to improve their productivity while reducing the adverse impacts of farming activities (e.g. land conversion, use of pesticides and fertilisers) on the environment.

This ‘soft approach' in particular necessitated the government to provide system which would enable farmers to monitor and link their farming activities electronically along with the impacts on the environment (e.g. waterways, soil and native vegetation). By using this system, farmers would then have a new way, not just, to record and measure accurately what production and farming activities were being done at their paddocks, but also, to share the information regarding what environmental improvement they had made to related parties. Later, the accumulation of information collected at farm level, by farmers, across the state could then provide government, as the owner, with empirical data to start planning suitable environmental support programs and investment at both regional and state-wide level efficiently.

The analysis from the case study suggested that to achieve those deliverable objectives, the WMP design project was undertaken into three stages including: developing conceptual design, prototyping and evaluation. The following sections discussed in more detail each of the WMP design phase.

## STAGE I: DEVELOPING CONCEPTUAL DESIGN

Following the decision to develop WMP, the government established a steering committee consisted of managerial staffs from related government agencies to help oversee the project. In addition, the government also formed a reference group and established at the outset of the committee. The group involved some farmers, government field staffs who worked with farmers, technical experts in the area of environmental management, agriculture and spatial technology. With such experts and knowledgeable members, the group was responsible to provide technical input for WMP conceptual design development. The other role was to help with needs identification from farmers' point of views, provide appropriate options and solutions for the WMP design.

Some activities were also done including series of discussions, brainstorming among the committee and reference group members to define broad principles for WMP and how it might look like. During the discussions, some existing farm management packages were also reviewed to complement the initial idea of

WMP conceptual design. Some major conclusions of the discussions and observations, for instance, suggested that the existing packages were:

a. Relatively expensive for farmers
b. Targeted to limited user groups (e.g. farmers, scientists or policy-makers)
c. Too difficult and farmers need supports in using the packages.
d. Little or no opportunity for two-way information sharing

Based on the results outlined above the steering committee and reference group were then able to produce principles on how WMP should be designed as discussed in the following.

First, it was decided that the WMP was to be a spatial web-based computer system which would offer farmers more interactive access to real time aerial photography of their paddocks. This was based on the recognition that delivery of on-farm monitoring would result in more informed actual land use and better decision will be made with good spatial information. Also, there was a great deal of environmental data collected from the paddocks, providing farmers with more useful and understandable information to assist them in better farm management and outcomes while preserving environmental 'best practice'. With the help of spatial technology, the multiple elements of on-farm environmental monitoring, most of would be greatly enhanced and achieved. Further, as the use of spatial technology was relatively new and still infancy when the project started, WMP would be a unique monitoring tool designed for farmers which has no comparable than the existing monitoring packages.

Second, the committee recommended that the WMP should be designed as affordable as possible or even made it publicly available for farmers. This was critical, given the observations indicated that farmers often felt that buying commercial packages particularly with quality aerial photography for farm planning was relatively expensive. Therefore, the WMP should be designed as a free spatial web-mapping that would offers more incentives for farmers and ultimately lead to greater uptake.

Third, the broad design principle was that the WMP must be easy and practical for use by farmers. As identified earlier, on-farm environmental monitoring activities were seen by farmers as adding another administrative burden on top of working in their fields, because it was considered labour-intensive, time-consuming and tedious. In addition, it was found that much of the existing monitoring packages had not been designed for ease of use, especially for farmers with limited computer skills. Therefore, it was important to design the WMP for farmers to make on-farm environmental monitoring burden free, more interactive and simple.

Finally, the WMP would be also be designed to assist farmers with various activities which had no direct environmental monitoring goals, but related to farm production activities which may still have environmental implications. These related to farm production such as feeding operations, fertilising and pesticide application. Another non environmental monitoring activity to be included in the WMP design was Property Management Planning (PLP), which would allow farmers (via the internet) to access a variety of spatial datasets, aerial photos and satellite imagery of their property, so that they could manipulate the data to illustrate property layout, assets, and current and future management activities. In this PLP, farmers could also set farm production targets and develop action plans that did not relate to environmental issues, and monitor the impact and achievement of these targets spatially. There was also the intention that the WMP would incorporate some provision for farm production record keeping.

In addition to defining conceptual design, the committee and the reference group identify the user groups that would interact with the systems and their information needs as well as their roles in the farm activities and environmental management. Table 1 summarises the proposed user groups for the WMP.

## STAGE II: PROTOTYPING

Having sufficient information for developing conceptual design, the steering committee then contracted a spatial technology vendor to involve in the WMP design project. The vendor would be responsible to provide technical expertise and support around the development of the WMP artefact.

Table 1. WMP proposed user groups

| Users | Interest |
|---|---|
| Catchment Officer | Record, manage and produce natural resources management plan (e.g. land, water and biodiversity) at regional and state-wide level and then monitor on-ground progress towards the targets. |
| Extension Officer | Record, manage and produce sub-regional natural resource management and then monitor activities undertaken plan (ie. farms visited, extension and on-ground supports). |
| Land holder or Farmer | Create farm targets, priorities, properties planning (e.g. fencing, buildings and dams) and proposed farming activities on a paddock basis. Record, monitor and report whole farm activities and assess the outcomes on a paddock basis. |

To start the development, the vendor ran a series of workshops with various groups of people including farmers, catchment and field staffs to find out from them what they wanted WMP to do. The workshops were also aimed at confirming the design principles proposed in the previous stage.

After these series of workshops, a document of detail technical specification was produced based on the information from the attendees. It recorded information about the main users and the relationships. A number of Use Cases (UC) was used to describe those relationships, workflow, who involved and what happened before and after the steps. Figure 1 illustrated relationship between system users and use cases, where a use case is an activity performed by the user.

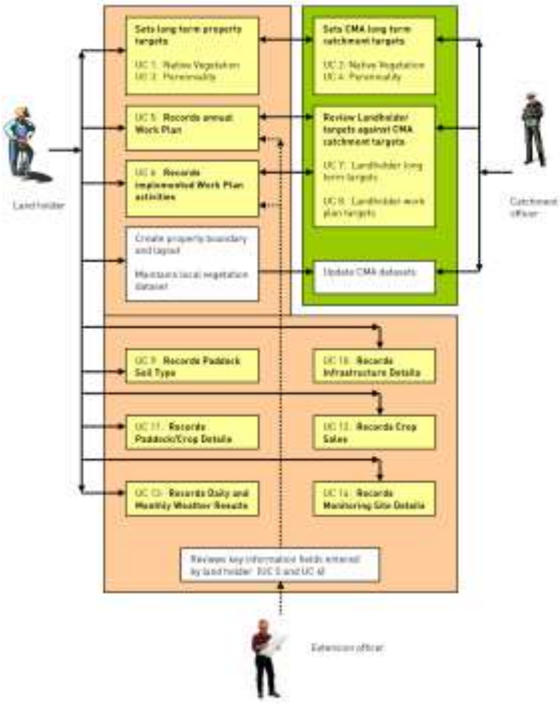

Figure 1. System users and use cases

Based on the design principles and requirements elicited in previous stage, the vendor then developed mock up of the proposed WMP application. This mock up took the form of sample user interface screens to illustrate workflows or functions (use cases) that the proposed WMP would support. It was also used to assist in an understanding of the proposed application to the users and then gain their review or capture the emerging functional requirements.

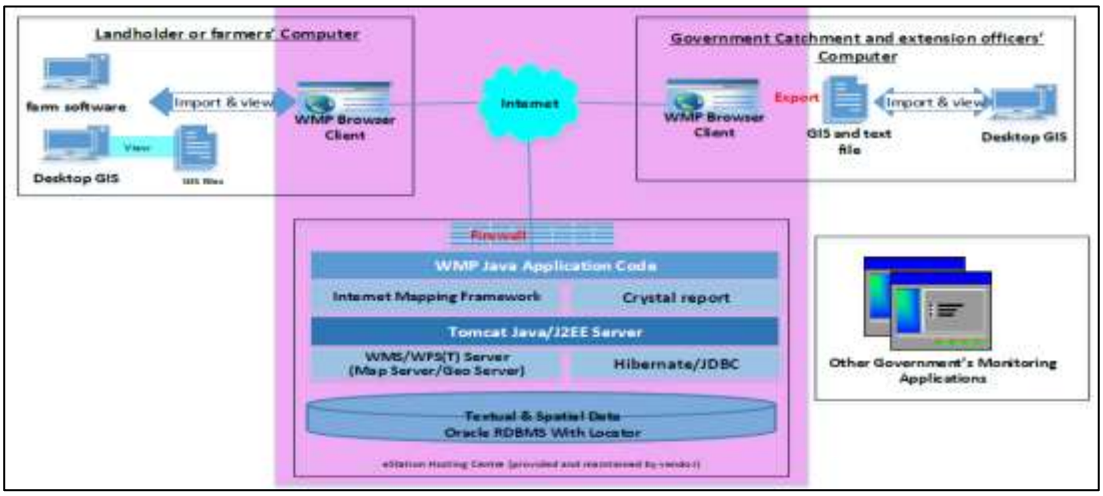


Figure 2. WMP proposed system architecture

The vendor also used the mock up to run consultations with steering committee and reference group members to discuss about how the WMP worked from a technical perspective. Example included the software technologies, architecture, the mapping and other data that the system would need to use. The overall architecture and the software components are further shown in Figure 2.

Based on Figure 2, the overall WMP architecture can be explained as following:

a. Reporting Engine: Crystal Reports which would be used for delivering the reporting requirements of the WMP application. Based on the Developer edition of Crystal Reports, the Crystal Reports Java API would be implemented within the Java application.
b. Data Access/Persistence Library: The open source Hibernate data persistence library would be implemented as the interface between the prototype application and the underlying Oracle RDBMS. There were two expected main benefits in using such a persistence layer over a simple JDBC connection. Firstly, Hibernate would take over the management of most of the database interaction, allowing the application code to operate at the object/class level and removing the need to explicitly code the detailed database interaction as Hibernate would manage the object/relational mapping. Hibernate would also manage the database queries and updates in a highly optimised way, providing the best possible performance without requiring a lot of performance-specific coding. Secondly, Hibernate would provide RDBMS independence, since it could provide a common and standard interface to data. To achieve this, Hibernate would use a high level query language known as HQL which uses SQL-like syntax to specify queries but in an RDBMS-independent way, although native SQL could be specified if required for some specialised purpose. Hibernate would then translated these HQL statements into native SQL for the specific RDBMS. Hibernate also supported all of the commonly used RDBMSs. As a result, the WMP application would be easier to move to another RDBMS type in the future if desired, although any selected RDBMS would need to support the storage of spatial features.
c. Spatial Interface Library: To provide the spatial functionality in the prototype, it was proposed to use the Internet Mapping Framework (IMF) Java library from Moxi-Media. IMF is a commercial product and will need to be licensed on a server-basis. IMF is available in two versions, one that uses ESRI’s ArcIMS as its underlying spatial services engine, and IMF-OWS which uses WMS/WFS compliant services. IMF comprises a Java library which implements the WMS/WFS interface and a JSP web application which implements the user mapping interface. IMF is highly configurable – new map layers and queries can easily be added via a small number of XML files. IMF is also highly customisable by modifying the provided JSP files or creating new ones. As a fully Java/JSP based application, thus, IMF could be completely integrated with the prototype and participate in its security and help systems. IMF is broadly used in Australia and around the world which is an excellent, cost effective, spatial interface library. Note also that IMF-OWS provides support for direct spatial data editing via a WFS(T) compliant server
d. OpenGIS Server: To provide the OpenGIS (WMS/WFS) spatial services for the WMP it was proposed to use the open source servers MapServer and GeoServer. MapServer is a very mature WMS/WFS server used in hundreds if not thousands of government organisations around Australia and the world. MapServer, which is built on a series of open-source libraries, can utilise a wide range of data sources including shapefiles, MapInfo tables, ArcSDE, Oracle Spatial and a wide range of georeferenced image formats. MapServer runs on Windows and a variety of flavours of Unix including Solaris and Linux. Whilst an excellent WMS/WFS server, MapServer does not (currently) implement the transactional components of the WFS specification which enables the insertion and update of features. GeoServer is an open source Java server which implement WMS and WFS(T) services and is proposed for the transactional WFS components.

e. Prototype Hosting: It was proposed that the prototype be hosted on vendor owned servers within a commercial hosting environment. The vendor would supply all servers and software and the hosting cost would include all ISP costs, all network traffic and the use of the vendor's servers and software licences. Hosting must include a nightly backup of the WMP textual and spatial databases.

Finally, after went through about five months and based on the technical consultations, the vendor than started building the functional WMP prototype which would be tested in the pilot testing as discussed next section

## STAGE III: WMP EVALUATION AND IMPLEMENTATION

After went through about a five-month software development process, a fully initial version of WMP was released and sent off for the evaluation. In this phase, the vendor and steering committee organised two rounds of pilot testings, each would involved tutorials of the use of WMP application, individual or group trials and workshops or feedbacks sessions. The idea of this approach was to validate the WMP design principles, capture the emerging requirements and obtain feedback about the functionalities, usefulness and usability from users.

The first pilot testing was run involving a number of government extension officers from four different catchment regions. During the pilot testing, the extension officers were invited to attend a one-day training of the use of WMP. They were then offered follow-up training and support via telephone as well as an online ‘help-desk’ if they had any difficulties in using the application. Finally they were encouraged individually to spend time becoming familiar with application and required to provide feedbacks through questionnaire and fill out session log book.

Having completed the first round of pilot testing, the steering committee in collaboration with those experienced extension officers from four regions ran second round pilot testing involving farmers. This second pilot testing was run regionally for flexibility in delivery and fitting with the farmers' local natural resources condition and needs. It was aimed at assessing how useable and useful the WMP application was based on farmers' conditions and point of view.

Similar to the first pilot testing, in this second round, farmers were invited to attend a half-day training sessions held in community centres, library, public facilities or schools where broadband access and multiple computers were available. Some additional training was offered to farmers who were interested and needed support to use WMP as monitoring tool. Once the training session was finished and farmers became familiar with WMP, they were then encouraged to use the application at home, and to contact extension staffs if they required help and further assistances.

After four month period of individual trial, farmers were then invited to take part in the evaluation to describe their experiences and provide feedback. Farmers were mainly asked how easy they found WMP to use and navigate their way around. They were also asked about training and support needs and major hindrances using the application for farm and environmental management. Later, farmers were invited in semi structure interviews to better understand their different levels of need and interests. Data from the interview were recorded and transcribed with major themes extracted to identify emerging needs and for future improvement.

Based on two rounds of evaluations, major conclusions indicated that the WMP had demonstrated the ‘proof-of-concept’ of the web-based spatial information for on-farm environmental information monitoring. A number of feedbacks from participants were also obtained for future improvement. Examples of improvement suggestions or new features derived from the pilot testings that were not available previously shown in Table 2.

Result from the evaluation also suggested numerous additional workflows that had not been included in the WMP application.

Table 2. WMP improvement

| Feature | Examples of Improvement |
|---|---|
| Security and privacy | A range of log-in levels were added with differing data available based on user group and level including early farmer, advanced farmer, farmer group and extension officer. In addition, privacy information for each user and detail who can see what (e.g. extension officers could have access on work history and data provided by farmers). |
| Layout and imagery | Incorporate high resolution image, the map would be enlarged and the using most recent photo. |
| Mapping tools and data layer | Ability to draw various shapes on the map especially circle; ability to create label on the data set; create and delete unnecessary datasets |
| Usability | Configuration of the features by the user was required). For example, using drop down list users would be able to refine lists of vegetation types and crops so that they would not be presented with the full, non-customised version of the list every time they enter these details. |
| Performance | The system must be capable of being used via a dial-up modem. |
| Supportability | The system would have a modular design to assist system additions. It would be capable of being supported and enhanced by a broad number of commercial packages. |
| help system | An on-line help system was added which would provide and display a help link to the specific HTML page based on the topic. It also provided user manual |

Therefore for future improvement, the initial use cases (see Figure 1) were then expanded to include some additional use cases including:

a. Create and maintain property boundary
b. End of year processes to update base datasets, or set new Action Plan

The UML diagram (see Figure 3) sets out the sequence and dependencies for these use cases, across the three roles. Note that in practice, as described in the use case details below, some of the use cases will be carried out a number of times as required basis.

Coming out from the pilot testings, the vendor than undertook some enhancements on the initial WMP application which incorporated the feedbacks. When the revision was done, the WMP was then sent to the steering committee, as the owner, for final check and approval before it went live as fully function system. Of importance throughout these processes was that, the newly-developed WMP gain wide acceptance from the users especially farmers.

For example, after the pilot testing, four additional regions and 12 other interstate regional organisations expressed their interest in using WMP and requested user account for their farmers. After the initial test period of 5 months, the level of WMP use was increased among the farmers, over 27,000 maps (including 11,000 with aerial photography) was produced. In addition, from the original 40 farmers, over the next three years it grew to more than 1600 farmers being registered on WMP. All These evidences indicated that the WMP was found to be practical, useful and usable given the limited technical supports and training sessions for the new users. Figure 4, taken during pilot testing, illustrates how a senior farmer, with no prior experience and skill in spatial technology, was confidently developing a complete map of his farm and showing the size of individual paddocks (Figure 4) as well as generating report on the possible nutrient loss on his paddock using WMP (Figure 5).

## RESULT AND DISCUSSION

This paper was designed to extend the IS knowledge in line with prior studies **[**10**] [**11**]** suggesting the need for more study investigating the IS design to support environmental sustainability practices and considered as EIMS.

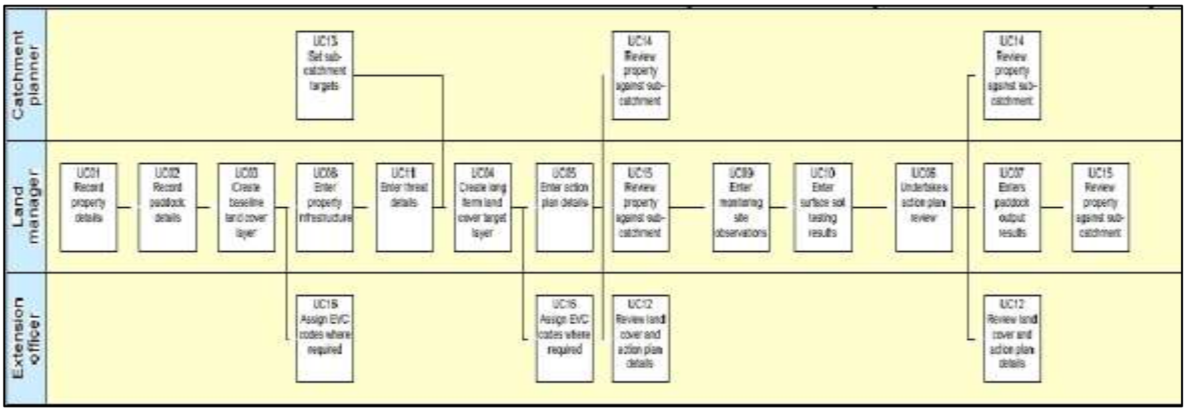

Figure.3 Finalised WMP use cases

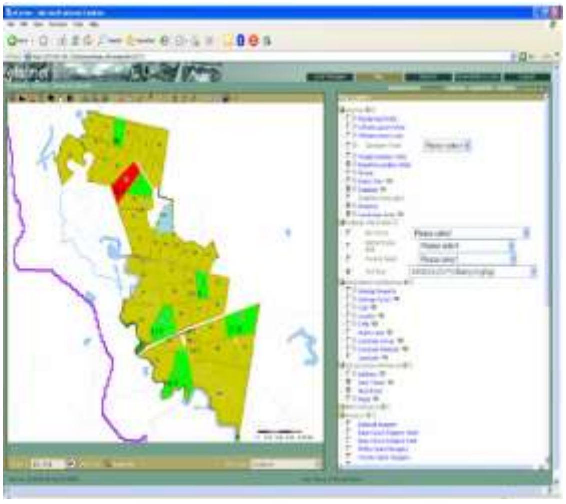
Figure 4. Example of farm map

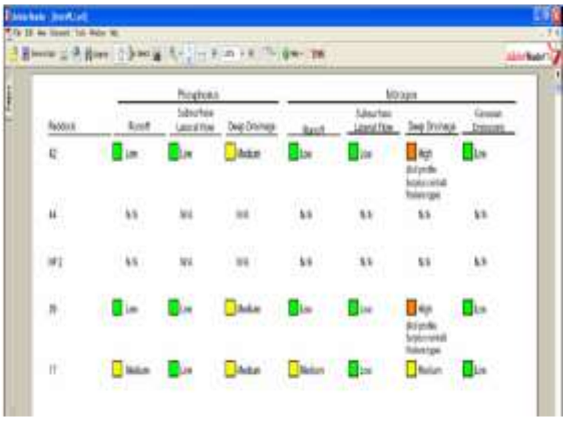
Figure 5. Example of report indicating nutrient condition of the paddock

A new Web Mapping Portal (WMP) development project undertaken by one state government in Australia, mainly to provide farmers with spatial web-based monitoring system, was considered as fruitful empirical context to better understand the design process of an EIMS. The analysis from the pilot testing and implementation revealed that using the WMP farmers were able to plan, record and monitor what farming activities were being done along with the environmental improvement they had made at their paddocks and then share the information to related parties.

Another interesting finding is, given the infancy of spatial technology when the project started, the resulting system was found to have a unique nature which was no comparable application publicly available in Australia. This was because WMP not just allowed farmers but also related parties (e.g. extension officers and catchment planners) to manage the complex environmental information collection and monitoring into more practical and based on scientific standard by using spatial data, aerial photo, and satellite imagery at the farm and regional as well as state-wide level.

Further, with respect to prior findings in the literature regarding the negativity when it comes to the implementation [32-34], this study found that it was viable to develop a successful IS in agriculture and EIMS in particular suitable for use by farmers. Analysis from the case study of WMP development project indicated that a major factor contributing to this result is the involvement of farmers, as intended users, throughout design process to understand their needs and increase the chances the resulting system would be of interest to farmers. Another possible explanation for this result was likely related to how the government as the initiator sought to devise appropriate requirements analysis activities (e.g. discussions, workshops, prototyping and pilot testing) to accurately define farmers (users) needs. Finally, given the growing number of users, the advance development of IS and spatial technology in particular, it is suggested that future study may investigate the evolvement of WMP design in respond to those emerging issues.

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