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Web-Based Decision Support System for Paddy Planting Management

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ABSTRACT

Precision farming offers numerous benefits and advantages to the farming community for farm productivity improvement. Previous research has led to the development of the offline-based Precision Farmer©. Our current research extends further the previous work by developing a Web Paddy GIS©. The need for this arises due to limitations of Precision Farmer© such as portability, offline system accessibility and affordability by the end users, who include semi-literate farmers. This new system has been developed to function on Windows and Linux platforms. A user satisfaction assessment was conducted on website acceptability, and performance testing was made. This study demonstrates that Web Paddy GIS© can successfully run on both platforms. However, the Linux platform has proven to be superior to Windows, based on factors such as CPU usage, speed and user satisfaction. This paper presents a novel management tool of Web-based precision farming for the semi-literate paddy farming community of a developing country. The development of the Web Paddy GIS© is very useful for paddy farmers, farm managers, decision makers and researchers.

Keywords: Web GIS, precision farming, open source, Linux, Decision Support System

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INTRODUCTION

Background information

Site-specific crop management is a technique that is designed to utilise various technologies to provide spatially referenced information for

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better decision making. This management technique is also known as Precision Farming (PF) (Isgin *et al.*, 2008; Auernhammer, 2001; Zhang *et al.*, 2009; Camilli *et al.*, 2007). Agricultural practices and profitability benefit through the utilisation of this technique. Many researchers have proven that it can assist to increase crop productivity. Population growth makes the highest demand on rice productivity and on the sustainability of global rice farming and supplies (Matsumura *et al.*, 2009). Previously, Precision Farmer© was developed as a paddy Decision Support System (DSS) for managers and farmers (Azhan *et al.*, 2008) to assist users in rice farming. DSS can help decision makers to aid their decision process (Antonopoulou *et al.*, 2009). Precision Farmer© is very useful for users because it provides rich information on pests and diseases, scheduling of farming activities, farmer information and most importantly, contains a soil remedial fertiliser variability map function which provides a fertiliser application map. However, as the system is an offline system, it has major limitations as it requires installation of the software at the user's local computer. Consequently, the motivation for the investigated solution in this paper is to have an online internet-based version of the previously developed Precision Farmer©.

Internet Geographic Information System (GIS) is a topic of growing interest and is highly beneficial for many applications such as forestry, aquaculture, road network and agriculture. In developing countries like Malaysia, the agricultural sector may greatly benefit from Information and Communication Technology (ICT). The opportunity for the use of ICT in precision farming is in addressing the problems of humankind (Schuler, 2007). In rural areas, agriculture productivity can be increased by using ICT (Thadaboina, 2009). Moreover, according to Simao *et al.* (2009), by using sophisticated ICT, we may not have to employ traditional computers. Web-based GIS provides farming information updates through online knowledge, consultation and spatial data (Jayasinghe & Machida, 2008; Kirilenko *et al.*, 2007). Resource limitations such as time, data and communication can be resolved by using information technology and Spatial Decision Support System (SDSS) tools (Engel *et al.*, 2003; Jarupathirun & Zahedi, 2007; Antonopoulou *et al.*, 2009; Lemmens *et al.*, 2007).

Open Source software development aimed at developing map-server applications using free software is now rooted in the GIS community (Steiniger and Hay, 2009). Web GIS technologies can provide data dissemination and have little or no online geoprocessing capabilities (Marcheggiani *et al.*, 2009; Rao *et al.*, 2007; Martino *et al.*, 2007; Tsou, 2004). According to Flemons *et al.* (2007), the Web-based analysis in the raster data environment is slow and more complicated than a desktop upload. In this research we overcome this problem with the use of the Linux platform as it helps to analyse data faster. The development takes into account and fully utilises the open source and software. The merits of open source as we know are that it is free of charge, the coding can be shared with everyone in the world and it allows more support from others for any problem in the system.

Research on Web-based DSS

Antonopoulou *et al.* (2009) proposed a Web-based DSS capable of assisting farmers in the selection procedure of appropriate alternative crops. The crops involved were maize, soybean, sorghum, rapeseed and cardoon. They developed the DSS and offered its services via the internet. Zhang and Goddard (2007) presented an integrated method to help design and implement a Web-based DSS in a distributed environment. They focussed on the software's architecture and framework. Zhang (2009) implemented a Web-based DSS as a component-based application that helps to transform a traditional DSS into a dynamic and evolvable distributed system. Martino *et al.* (2007) described a Web GIS application design approach that uses only basic functions like pan, zoom, data organisation and attribute table tool display.

Efficient management of paddy planting is hampered by lack of information. If the PF process is applied efficiently and effectively in the paddy field, it will be very beneficial in reducing cost, energy, time and environment. The Web Paddy GIS© is developed based on the PF principle and the database techniques accordingly so that users can easily access the information free of charge and apply the knowledge to their paddy field.

One of the major challenges in agriculture is to optimally plan cropping initiatives, fertiliser management, soil condition farming, and post harvesting. Analysis of spatial temporal variability in soil and yield data is generally performed with the help of relatively expensive commercial GIS software. Furthermore, it is costly to share the data and maintain the software. This research proposes a method to overcome this situation. Our approach allows centralised data management, data sharing between users and data evaluation using open source. Linux is one of the open source software. In this research we did for both platforms to make sure that by using open source, the performance of the system can be improved.

Web GIS DSS for paddy PF in Malaysia is a new field and no local references are available. Many researchers have developed web GIS but most of them do not use open source software; for example, Deepak *et al.* (2008) and Rowshan *et al.* (2008) used commercial software which is very costly and requires an annual license. Furthermore their work focussed on the irrigation aspects of paddy farming. Another is the Rice Irrigation Management Information System (RIMIS) developed by Rowshon *et al.* (2008). It was originally developed for allocation of irrigation water. It is an offline system that focusses only on irrigation and uses the commercial software, ArcMap. It is a very good system but it needs to be improved in terms of cost effectiveness because it uses commercial software. Another system for rice application is the Web-based Paddy Irrigation Productivity Assessment (WEB-PIPA) that was developed by Deepak *et al.* (2008). It focusses on a database for online irrigation. WEP PIPA involves spatial data but does not perform internet mapping. This is a system for database management of irrigation. The Web Paddy GIS© makes important improvements through the use of DSS, open source software and operating in the Linux environment.

Decision Support System for Precision Farming

DSS can perform analysis and provide a decision using computer-based tools (Matthews *et al.*, 2008). There are many previously documented examples of DSS applied to crop production. Some of these are: Major Fields Crops (MAFIS-DSS) (Antonopoulou *et al.*, 2009), a web-based decision support tool and zone mapping application for precision farming (ZoneMap) (Zhang *et al.*, 2009), Worlds Inventory of Soil Emission Potentials (WISE) (Gijsman *et al.*, 2007), Integrated Water Resource Management (IWRM) (Awad *et al.*, 2009) and Web-based National Agricultural Decision Support System (NADSS) (Zhang & Goddard, 2007). These DSSs are aimed at information and knowledge dissemination as well as providing domain expertise to farmers and farm managers. ZoneMap has been developed as a tool that is simple to use with efficient and easy-to-use tools. The WISE database is one of the most comprehensive soil databases in the world with better sample distribution. The IWRM can assist in water resource management through a reduction of information redundancy, elimination of unnecessary expenses and the establishment of regional cooperation. NADSS provides computing and renders a suite of drought indices that can quantitatively describe the intensity, duration and magnitude of events at multiple windows of resolution with the aforementioned needs in mind. The current work is a DSS for the precision farming of rice.

The Web Paddy GIS© is an extension of a previously developed off-line system for precision farming of rice by Azhan *et al.* (2008). They used commercially available ArcGIS and Visual Basic software in their system called Precision Farmer©. In this work, an on-line work system was developed integrating all the components including PF, DSS, paddy management (irrigation, yield monitoring, soil and etc.) into one system. By using open source, no commercial license is required, implementation is easy and the sharing of information is free of charge. So the application developed for this research will be cost effective for the farm managers and farmers. There will be an opportunity to share open source web-based GIS between farm managers and farmers. In addition, the incorporation of DSS in Web Paddy GIS© makes it a complete system. This is in contrast to other previously developed web DSS for crop management which used commercial software and focussed on a single aspect. The Web Paddy GIS© solution can fill the gap by centralising all PF components in one system by using open source software.

METHODOLOGY

Architecture of Web Paddy GIS©

Fig.1 shows the architecture of Web Paddy GIS©. It consists of 3 tiers (i.e. client tier, Web tier and server tier). The client tier is utilised by Web users. In the client tier, users make requests through a Web-based Graphical User Interface (GUI) (e.g. in MapGuide Viewer, the Web tier will retrieve data from the server tier and submit them to users in the client tier). The MapGuide Web Server extension is accessed through the MapGuide Web Application Programming Interface (API) and is an internal component that performs the backend processes.

MapGuide Maestro is used for data editing and uploading to the server. In the server itself, there are a number of Web technologies used, Apache Web Server, MapGuide, and Maestro MapGuide. Users can visualise the maps such as maps of the paddy lot, fertiliser distribution, soil series and boundary of the study area in the map application. All the maps are displayed in a web portal based on MapGuide Viewer.

Decision Support System (DSS)

Fig.2 displays the flow chart of the DSS Web Paddy GIS©. It contains a list of five components: disease and pest information, scheduling, control, fertiliser map and Leaf Colour Chart (LCC) information. When users key in the name of a disease or pest, the results will be displayed from available information in the database. The results will show the estimated amount of pesticide to be applied based on the recommendations provided by the DOA. When users key in the date for planting paddy, a table that contains the date, activity, action and inputs needed for better management will be displayed. Users can find the yield and fertiliser map of previous seasons and they can compare the paddy production for each season based on these results. Users can know the nitrogen (N) content in the leaf based on the LCC chart, which is adapted from the International Rice Research Institute (IRRI). nitrogen application for the plant is necessary to assist in healthy plant growth and for the environment (Islam *et al.*, 2007). Results from the

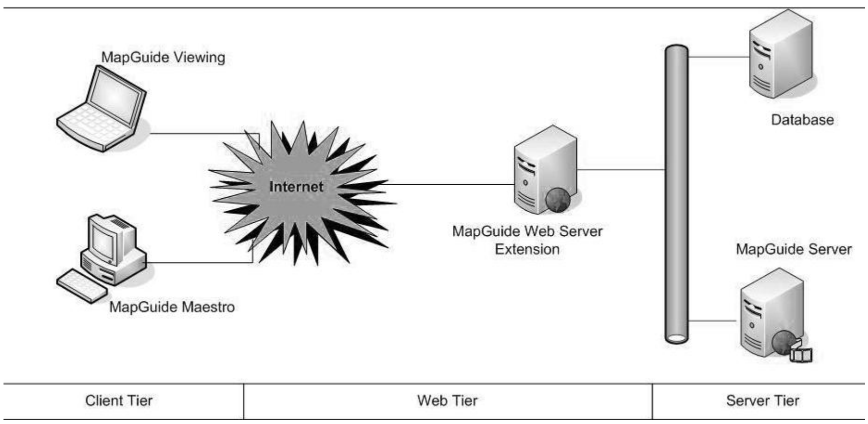


Fig.1: Architecture of Web Paddy GIS©

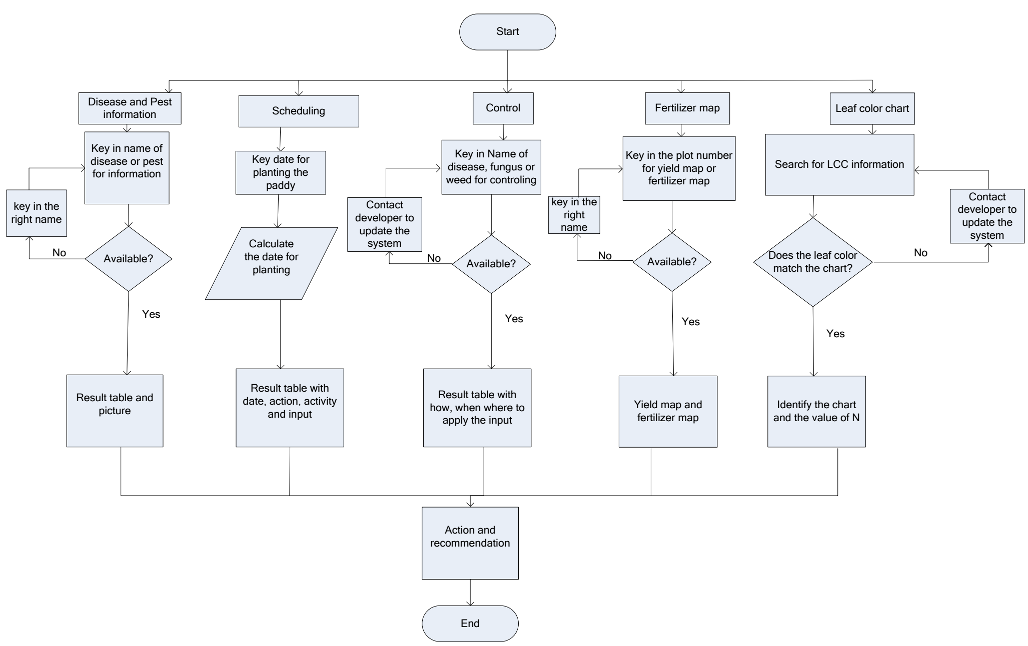


Fig.2: Flow chart of DSS in Web Paddy GIS©

LCC show the quantity of N- fertiliser needed (Islam *et al.*, 2008). A combination of all these results enables the managers or farmers to take action and make plans for better management in the next season. This will assist them to make good decisions and to work effectively.

System development in Windows platform

Software requirements for the Web Paddy GIS© on the Windows platform are MapGuide Server Open Source, MapGuide Web Extension, PHP 5.2.1, Apache, MySQL and Feature Data Object (FDO) (Rbray, 2007). Installation of the MapGuide Server and Extension is uncomplicated and straightforward. Microsoft Windows Server 2003 Standard Edition was used in this research.

System development in Linux

Software requirements for the Web Paddy GIS© on the Linux platform are the same as for Windows. Linux is free platform. However, there are many types of Linux; this research used Fedora Core 6. The Linux operating system is typically used by enterprises due to its reliability. In addition, Mono software is needed to install MapGuide Maestro. Mono is an open source alternative platform for Microsoft.Net technology (Rbray, 2007). The installation steps are not user-friendly for those who are not familiar with the Linux environment. All of the installations utilise the command-line prompt. All software is installed in Fedora Core 6.

Data preparation

Raw data were collected from various government agencies, specifically Remote Sensing Malaysia (RSM), Department of Agriculture (DOA), Integrated Agriculture and Development Area (IADA), Barat Laut Selangor and Universiti Putra Malaysia (UPM). Table 1 shows the data collected from each of these agencies. The data were converted into a spatial variability map, which allowed them to be utilised by farmers in the process of precision farming. The point-soil sampling from which the maps were created is also included in the Web Paddy GIS© to enable users or farmers to access the status of nutrients in their paddy plots for every season. Fig.3 shows the method of converting the point sampling to Shapefile format. The raw data were in Microsoft Excel database format. This data were converted to Shapefile format and the projection was defined. Then, using Precision Farmer©, the fertiliser maps were produced. Shapefile (*.shp) is a GIS data set representing the point, line and polygon (ESRI, 1998). The map is in a Rectified Skew Orthomorphic system (RSO) projection. The maps were prepared for uploading using MapGuide Maestro by initially creating a new folder connected with the database, after which a layer, map and layout were created. Subsequently, the fusion application was chosen, and finally, the maps were ready to be viewed through the Web-based map browser. All layers were uploaded and overlaid with others using MapGuide Maestro so that users could make decisions and forecast the forthcoming yield (Fig.1).

The assumption for this work was that all data provided by the various government agencies and those obtained through research work by UPM were reliable. Hence the system was applicable to the study area. The application of the system to other granny areas will require additional data collection relevant to those area.

TABLE 1
Sources for data acquisition

No	Type of data	Source of data
1	Boundary Sawah Sempadan map	MRSA, 2007
2	Block C map	UPM, 2007
3	Paddy lot map	UPM, 2007
4	ECa Zone map	UPM, 2007
5	Soil Sampling map	UPM, 2007
6	Fertiliser map	UPM, 2008
7	Soil Series map	DOA, 2007
8	Rice Check information	IADA, 2007
9	Pest and Disease information	DOA, 2007
10	Controlling pests and Diseases	DOA, 2007
11	LCC information	MRSA, 2007
12	Yield Value	IADA, 2007
13	Farmers information	IADA, 2007
14	Yield map	UPM, 2007

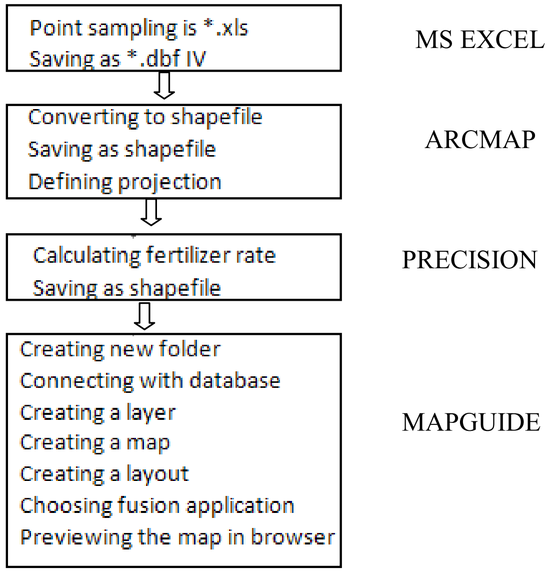


Fig.3: Data acquisition process

Performance evaluation on Linux and Windows

Although Linux is open source and free whereas Windows is a commercial product that is widely used, we wanted to test the implications of using Linux on the performance of the system. Testing was performed on the same machine and both operating systems were run in Virtual Machine Software (VMware) mode. The testing involved “zoom in”, “zoom out”, “zoom rectangle”, “pan”, “select” and “measure” functions. A good Web-based GIS application relies on its extensible functionality and the performance of presenting requested data to the users. Usually, users utilise the zooming functions to search the map content, and this is really beneficial. Consequently, these functions were tested to prove their effectiveness in the Web Paddy GIS©, where the Linux platform performed the function faster than the Windows platform. Users usually search their map and use the zoom function for map browsing or to do analysis-like buffering and so on. These activities were tested and the results were plotted on a graph.

User Satisfaction Test

User satisfaction tests were performed for both platforms. Questionnaire forms were designed and given to 36 users (farm managers and farmers) in 8 lots involved in this study. They were given the opportunity to use and explore the Web Paddy GIS© and at the end of the session they completed the questionnaires. A translated copy of the questionnaire is given in Appendix 1.

Web Paddy GIS© model

Fig.4 shows the components of Web Paddy GIS© in a diagram adapted from the DSS structure of Engel *et al.* (2003). Web Paddy GIS© is targetted at farmers, and all functionalities in the page help users to understand the results. Web Paddy GIS© can be used as a DSS tool; for example, users can request the fertiliser application map from the Web Paddy GIS© for each season. The maps are served using MapGuide Open Source. The maps will then appear in a web browser (Mozilla Firefox). Next, the user will interactively zoom to the location of interest. The fertiliser map will then show the location of the map and the attributes for N, P and K values. It shows the needed amounts for N, P and K for each plot and season. The maps produced by the system are reliable as they have gone through the validation process. Fertiliser recommendation maps can be used by managers and farmers to make a decision on the amount of fertiliser that is to be applied variably across their plot. Managers can follow and record these values for making comparisons for future and past seasons. Finally, the maps can help them make good decisions about how much input farmers apply for each plot and season.

RESULTS

Graphical User Interface (GUI) of Web Paddy GIS©

Fig.5 displays the GUI of Web Paddy GIS©. This page contains seven sections i.e. the main menu, introduction, agricultural information, e-paddy, pest, disease and weed control, forum and gallery. Web Paddy GIS© provides two language versions i.e. the Malay (Malaysian national language) version and the English version for worldwide use. The introduction page shows the map of Tanjung Karang. Fig.6 shows the map of Tanjung Karang from Google Maps. A single button click allows users to access the map directly from the web page.

Next is the agriculture information page, which provides access to the scheduling application. Scheduling is an application for deciding on the paddy planting schedule. Users input the date when they will start planting the rice crop, and the table will be updated

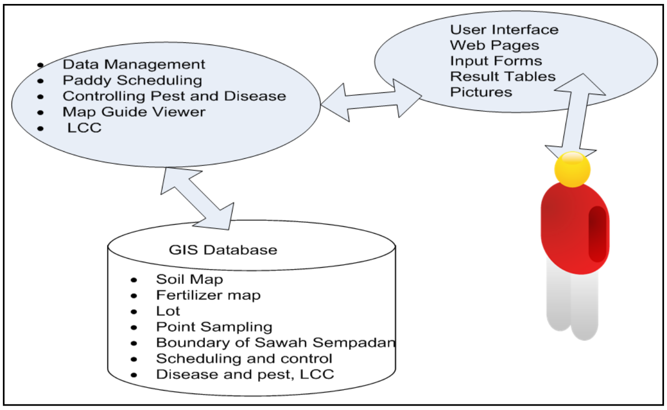


Fig.4: Description of Web Paddy GIS© as a DSS

Fig.5: The main menu for Web Paddy GIS© (English version)

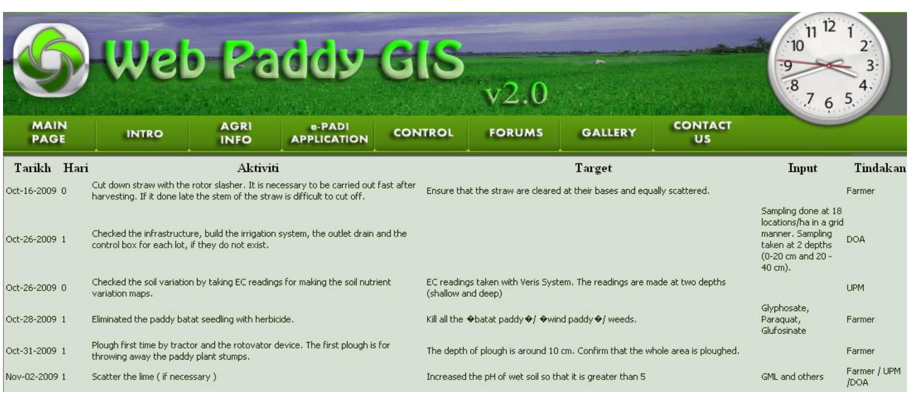
Fig.6: Map of Tanjung Karang from Google Map

accordingly. This schedule is very important for farmers, farm managers and others. Fig.7 shows the schedule with activities and the days on which they are to be performed.

Fig.8 shows the information on pests and diseases related to the rice crop. Users can search for pests and diseases to see related pictures. This is very important as it allows users to understand what can happen to their paddy field. Fig.9 shows the picture of "Hawar Seludang" disease, clearly identifying the pest in visual form for users.

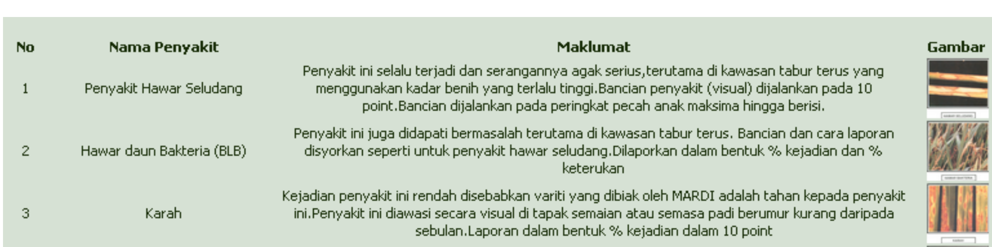
The LCC is an inexpensive plastic, ruler-shaped strip containing four panels that range in colour from yellowish green to dark green (Witt *et al.*, 2005). It is an easy-to-use diagnostic tool for monitoring the relative greenness of a rice leaf as an indicator of the plant's N status. It allows farmers to estimate plant nitrogen demand in real time for efficient fertiliser use and high rice yields. IRRI in collaboration with the University of California Cooperative Extension released a standardised LCC with improved quality assurance for the reproducibility of colours and enhanced matching of the colors to the reflectance spectra of rice leaves (Witt *et al.*, 2005). The Web Paddy GIS© provides information about the LCC online, allowing farmers to read the instructions on how to use the LCC and how much N fertiliser to add based on the chart (Fig.10). If a user has a Personal Digital Assistant (PDA), he may go online for the LCC as the LCC information can be accessed online through a portable PDA.

Fig.11 shows how to control the diseases and pests. A user can key in the name of the diseases or pests and the Web Paddy GIS© will show the controller type that suits that particular disease or pest. The information shows the name, amount, time and source of the control.



Tarikh	Hari	Aktiviti	Target	Input	Tindakan
Oct-16-2009	0	Cut down straw with the rotor slasher. It is necessary to be carried out fast after harvesting. If it done late the stem of the straw is difficult to cut off.	Ensure that the straw are cleared at their bases and equally scattered.		Farmer
Oct-26-2009	1	Checked the infrastructure, build the irrigation system, the outlet drain and the control box for each lot, if they do not exist.		Sampling done at 18 locations/ha in a grid manner. Sampling taken at 2 depths (0-20 cm and 20 - 40 cm).	DOA
Oct-26-2009	0	Checked the soil variation by taking EC readings for making the soil nutrient variation maps.	EC readings taken with Veris System. The readings are made at two depths (shallow and deep)		UPM
Oct-28-2009	1	Eliminated the paddy batat seedling with herbicide.	Kill all the �batat paddy�/ �wind paddy�/ weeds.	Glyphosate, Paraquat, Glufosinate	Farmer
Oct-31-2009	1	Plough first time by tractor and the rotovator device. The first plough is for throwing away the paddy plant stumps.	The depth of plough is around 10 cm. Confirm that the whole area is ploughed.		Farmer
Nov-02-2009	1	Scatter the lime (if necessary)	Increased the pH of wet soil so that it is greater than 5	GML and others	Farmer / UPM /DOA

Fig.7. Result for Scheduling after keying in the date for planting



No	Nama Penyakit	Maklumat	Gambar
1	Penyakit Hawar Seludang	Penyakit ini selalu terjadi dan serangannya agak serius,terutama di kawasan tabur terus yang menggunakan kadar benih yang terlalu tinggi.Bancian penyakit (visual) dijalankan pada 10 point.Bancian dijalankan pada peringkat pecah anak maksima hingga berisi.	
2	Hawar daun Bakteria (BLB)	Penyakit ini juga didapati bermasalah terutama di kawasan tabur terus. Bancian dan cara laporan disyorkan seperti untuk penyakit hawar seludang.Dilaporkan dalam bentuk % kejadian dan % keterukan	
3	Karah	Kejadian penyakit ini rendah disebabkan variti yang dibiak oleh MARDI adalah tahan kepada penyakit ini.Penyakit ini diawasi secara visual di tapak semaian atau semasa padi berumur kurang daripada sebulan.Laporan dalam bentuk % kejadian dalam 10 point	

Fig.8: Information on pests and diseases

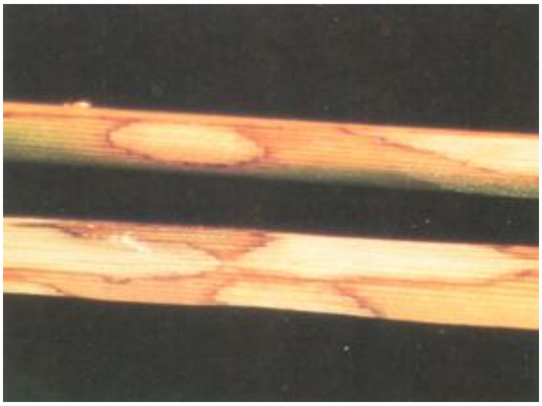


Fig.9: Picture of pest and disease

Fig.10: Leaf Colour Chart as a guide for farmers to check nitrogen deficiency

Kulat	Chilo polychrysa (ulat pengorek batang)
Perawais Aktif	beta-cypermethrin

Nama Dagangan	Chix
Formulasi	Pekatan Teremulsi (EC)
%Perawis Aktif	2.65
Kadar / Hektar	1.5 L
TDHM	14
REI	12 JAM

Nama Dagangan	Anfuran 3G
Formulasi	Butir (GR)
%Perawis Aktif	3
Kadar / Hektar	10 G/m.pers(tapak semaian)
TDHM	N/A
REI	24 JAM

Fig.11: Choosing the type of control for pest

Table 2 shows the description of each section. Web Paddy GIS© has proven benefits for management and has the potential to assist farmers to increase production efficiency provided all steps are completed. The GIS Info module is an application map from soil sampling and season yield. Users can compare their yield from one season to another. Information also plays a central role in the DSS process (Simao *et al.*, 2009).

Fig.12 also displays the map browser which allows users to browse (zoom in/out/pan) maps, change displayed layers and perform measurements and buffering. Users can view their map by clicking on the box of the menu layers. Users can also check the attributes by clicking on the right-hand side. This will show the attributes for each layer selected with the fertiliser map attributes so that users may see precisely how much fertiliser to apply and where to apply it. This will optimise their inputs, leading to efficient plot management.

One of the advantages of Web Paddy GIS© is the existence of a website forum. The forum provides an opportunity for users, especially farm managers and farmers, to share their experience and knowledge. These facilities also allow users to interact, communicate and network with others. Users are required to register in the forum, after which they may login using their username and password. They may create topics, promote their farms and upload photos in the forum. The topics are followed by experts who can provide guidance for farmers and managers.

TABLE 2
Description of each section

No	Section	Description
1	Main menu	Welcoming notes Website links to other organisations like DOA, RSM and MARDI
2	Introduction	Concept of PF Map of Tanjung Karang using Google Earth application Acknowledgments
3	Agricultural information	Crop scheduling for better management Pest and disease information Pest and disease pictures
4	E-paddy	Map (Spatial data), fertiliser map, boundary map, soil series map, soil sampling map Yield information for each season, name, no of plot and personal details User manual for paddy planting Soil Sampling Map LCC information and how to use the LCC Yield map for every season and for all criteria
5	Controlling pests and diseases	How to control fungus, weeds and pests
6	Gallery	Photo gallery
7	Forum	Forum discussion for users to interact with each other. They can also share their paddy planting experience and knowledge.

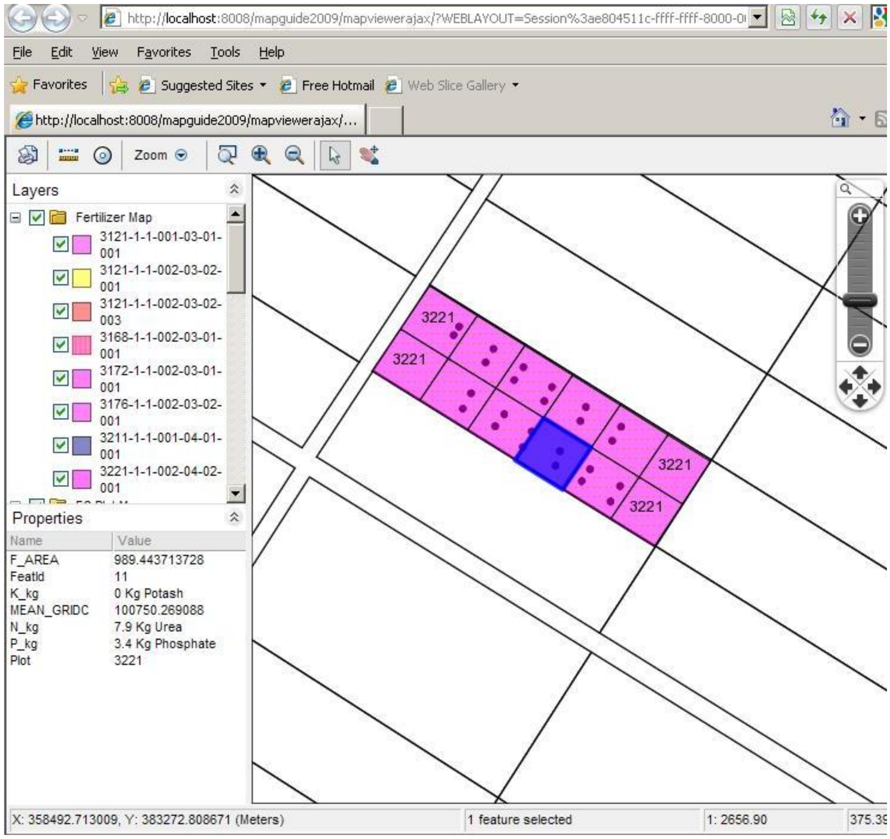
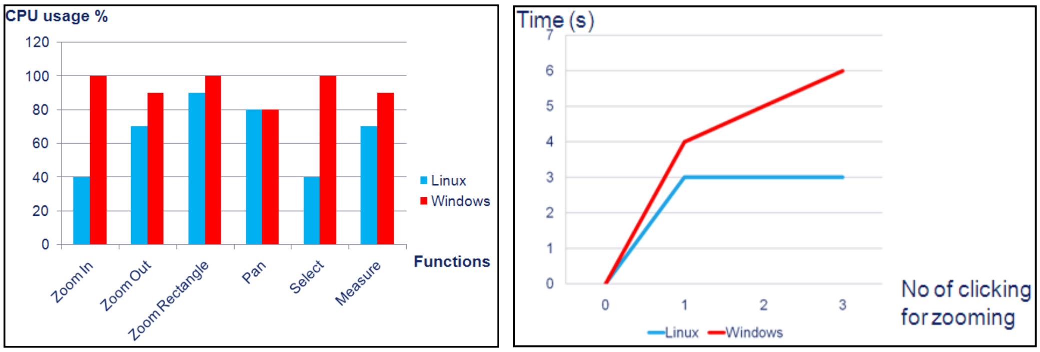


Fig.12: Map visualisation using MapGuide viewing

Performance evaluation on Linux and Windows

The performance of Web Paddy GIS© was tested using the function from MapGuide Viewer on two different platforms i.e. Linux and Windows. Fig.13 shows the performance of Web Paddy GIS© on Linux and Windows for each activity i.e. zoom-in, zoom-out and zoom rectangle, pan, select and measurement. The Linux platform has lower CPU usage than the Windows platform. This shows that the accessibility and flexibility of Linux is better than those of the Windows platform.

The zoom-in function required 40% CPU usage on Linux but 100% CPU usage on Windows. This means that Windows uses the CPU more than Linux does, thus slowing down the process. For the zoom-out function, performance on Linux was 70% while for Windows, it increased to 99%. Again, it appears that the Linux platform is better than the Windows platform. On Linux, CPU performance was 29% better than on Windows. Fig.13 displays the speed of Linux vs. Windows platforms; the speed of the Linux platform is faster than that of the Windows platform. In addition, passive speed for the Windows platform is 50% lower than for the Linux platform.



(a) Testing of various Linux and Windows functions (b) Comparison of speed between Linux and Windows

Fig.13: Results of testing each function to compare Linux and Windows

User satisfaction with Web Paddy GIS©

A questionnaire was designed for feedback on user satisfaction. The questionnaire begins with a survey of personal details such as age and experience in using computers. The evaluation survey involved 10 structured questionnaires, semi-structured interviews, and one-on-one testing of 18 farmers and 8 farm managers. From the analysis recorded using Ms Excel, it was found that 70% of the respondents think that Web Paddy GIS© makes their work more effective (Fig.14). Fig.15 shows the percentage of user satisfaction for Web Paddy GIS©. Four percent of the respondents were very satisfied with Web Paddy GIS©, 69% were satisfied and 27% were not satisfied. This shows that a high percentage of respondents were satisfied with Web Paddy GIS©. The farmer's responses show that more than 70% were satisfied and less than 30% were not satisfied with this website. The GUI is also user-friendly and easy to understand. Users were also satisfied with the latest information provided by Web Paddy GIS©. It can be used by both managers and farmers. The questionnaire is given as Appendix 1.

Web Paddy GIS© provides the DSS tools to distribute data and information. It may also be used as a database, reducing data redundancy. In addition, it runs on Windows and Linux operating systems platforms, which may be beneficial for developers working on both systems.

DISCUSSION

Web Paddy GIS© provides a new solution for farmers to share and search information pertaining to the management of their paddy fields through digital spatial data. According to Steinerger (2008), by integrating information management, the complexity of PF processes can be made simpler and flexible for farmers. This research accomplishes this aim. Web Paddy GIS© allows users to search their map, find pest and disease information and schedule management tasks. A major advantage of Web Paddy GIS© is that all the software used is open-source. According to Xia *et al.* (2009), the cost for commercial mapping software or internally developed software is much higher than for open-source software. This is an important contribution to aid poor rice farming communities in developing and under-developed countries.

The understanding of crop production systems can be increased through the development

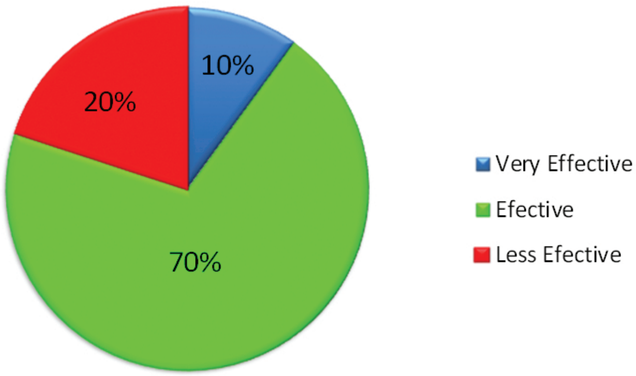


Fig.14: How effectively users work using Web Paddy GIS©

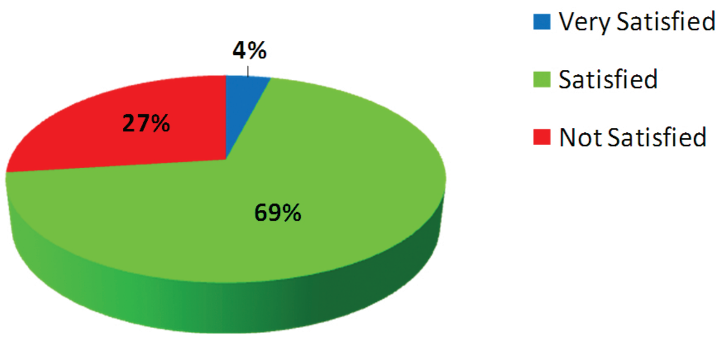


Fig.15: User satisfaction with Web Paddy GIS© usability

of educational materials available on the Internet (Fitz *et al.*, 2009); with the development of this Web-based application, all users will have access to a variety of information that is essential for land management decisions (Ellis *et al.*, 2005). Web Paddy GIS© provides information that will help users to manage their paddy farms. According to Nikkil *et al.* (2009), there are usability problems in agricultural information systems. Web Paddy GIS© is a knowledge base for users to acquire information about their plot, production for each season, information about pests and diseases as well as how to control pests and diseases with a user-friendly GUI. In order to control their pests and diseases, users can select the pest or disease from a scroll bar, and information on chemical product and input amount will be displayed. All the information can be searched from the Web Paddy GIS© and extended to the internet.

Web Paddy GIS© has an extensive search capability that provides users with good references to identify and understand pest and disease management and variable rate application of fertilisers and pesticides. As farmers are generally conversant in their own native language, the approach adopted in this research was to provide an online system for Malaysian farmers in the Malay language. The farmers and managers easily understand the contents and the information accessed. This is in agreement with Zhang *et al.* (2009) that to implement precision agriculture, ease of use is important. An English version is also provided for international users.

Farmers showed their satisfaction with the possibility of consulting the information. Results show that more than 70% of the respondents were satisfied with the Web Paddy GIS©. According to Sante *et al.* (2004), a long wait to visualise maps is one complaint forwarded by most farmers. Using the Linux platform, however, solves the problem because Linux runs faster than Windows. This was proven in the testing evaluation conducted in this research.

CONCLUSION

Web Paddy GIS© at its initial stage proved to be a useful and necessary tool for users, especially farm managers and farmers. The results proved that the installation in Linux was successful based on evaluations and that Linux has good potential. MapGuide Maestro is simple, easy-to-use and flexible, which is similar to commercial packages. The implementation progress was observed and the capability of the server was tested by the users. MapGuide Maestro provides a user-friendly GUI. This makes the development process of the system menu easier. It also offers an alternative for online mapping. Although Web Paddy GIS© is for paddy precision farming on the web, the concept can be applied elsewhere for similar applications. An evaluation of the performance of Web Paddy GIS© was carried out in terms of stability and efficiency. Linux provides a way to design and develop the application using free software technologies (Manca *et al.*, 2006). Linux has its own advantages; it is free and easy to integrate with other applications. Normally, most server applications and analysis services run on the Linux platform as they are easily integrated together as with large systems. The environmental application will be able to benefit from real-time data output, making protective management and preparation more efficient. The use of the open source Web Paddy GIS© application will thus benefit end-users immensely.

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REFERENCES

Antonopoulou, E., Karetsos, S. T., Maliappis, M., & Sideridis, A. B. (2009). Web and mobile technologies in a prototype DSS for major field crops, *Computers and Electronics in Agriculture, 70*(2), 292-301.

Auernhammer, H. (2001). Precision farming—the environmental challenge. *Computers and Electronics in Agriculture, 30*(1-3), 31-43.

Awad, M., Mohamad, K., & Talal, D. (2009). Web-Based Meta-database and its Role in improving Water Resources Management in the Mediterranean Basin. *Water Resources Management Journal*, *23*(13), 2669-2680.

Azhan, Shariff, A. R. M., Amin, M. S. M., Rahim, A. A., Jahanshiri, E., & Norasma, C. Y. N. (2008). *GIS based system for Paddy Precision Farmin.* pp. 417-422. Paper presented in AFITA in World Conference on Agricultural Information and IT, Tokyo University of Agriculture, Atsugi, 2008*,* Japan.

Camilli, A., Cugnasca, C. E., Saraiva, A. M., Hirakawa, A. R., & Corrêa, P. L. P. (2007). From wireless sensors to field mapping: Anatomy of an application for precision agriculture. *Computers and Electronics in Agriculture, 58*(1), 25-36.

Deepak, T. J., Amin, M.S.M., Shariff, A. R. M., & Ramli, A. R. (2008). *Web based paddy irrigation productivity assessment (WEB-PIPA)*. Paper presented at Consulting Workshop on Paddy Precision Farming, Malaysia Agro Exposition Park Serdang, Malaysia. August 2008.

Ellis, E. A., Nair, P. K. R., & Jeswani, S. D. (2005). Development of a Web-based application for agroforestry planning and tree selection. *Computers and Electronics in Agriculture, 49*(1), 129-141.

Engel, B. A., Choi, J.-Y., Harbor, J., & Pandey, S. (2003). Web-based DSS for hydrologic impact evaluation of small watershed land use changes. *Computers and Electronics in Agriculture,* 39(3), 241-249.

ESRI. (1998). ESRI Shapefile Technical Description. Retrieved on November 15, 2009 from http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf

Fitz, E., Kubota, C., Giacomelli, G. A., Tignor, M. E., Wilson, S. B., & McMahon, M. (2009). Dynamic modeling and simulation of greenhouse environments under several scenarios: A Web-based application. *Computers and Electronics in Agriculture, 70*(1), 105-116.

Flemons, P., Guralnick, R., Krieger, J., Ranipeta, A., & Neufeld, D. (2007). A Web-based GIS tool for exploring the world's biodiversity: The Global Biodiversity Information Facility Mapping and Analysis Portal Application (GBIF-MAPA). *Ecological Informatics, 2*(1), 49-60.

Gijsma, A. J., Philip, K. T., &Gerrit, H. (2007). Using the WISE database to parameterize soil inputs for crop simulation models. *Computers and Electronics in Agriculture*, *56*(2), 85-100.

Isgin, T., Bilgic, A., Forster, D. L., & Batte, M. T. (2008). Using count data models to determine the factors affecting farmers' quantity decisions of precision farming technology adoption. *Computers and Electronics in Agriculture, 62*(2), 231-242.

Islam, Z., Bagchi, B., & Hossain, M. (2007). Adoption of leaf color chart for nitrogen use efficiency in rice: Impact assessment of a farmer-participatory experiment in West Bengal, India. *Field Crops Research, 103*(1), 70-75.

Jarupathirun, S., & Zahedi, F. (2007). Exploring the influence of perceptual factors in the success of Web-based spatial DSS. *Decision Support Systems, 43*(3), 933-951.

Jayasinghe, P., & Machida, T. (2008). Web-Based GIS Online Consulting System with Crop-Land Suitability Identification. *Agricultural Information Research, 17*(1), 13-19.

Kirilenko, A., Chivoiu, B., Crick, J., Ross-Davis, A., Schaaf, K., Shao, G., *et al.,* (2007). An Internet-based decision support tool for non-industrial private forest landowners, *Environmental Modelling & Software Modelling, computer-assisted simulations, and mapping of dangerous phenomena for hazard assessment, 22*(10), 1498-1508.

Lemmens, R., By, R. d., Gould, M., Wytzisk, A., Granell, C., & Oosterom, P. v. (2007). Enhancing Geo-Service Chaining through Deep Service Descriptions. *Transactions in GIS, 11*(6), 849-871.

Manca, S., Cau, P., Bonomi, E., & Mazzella, A. (2006). *The Datacrossing DSS: A Data-GRID Based Decision Support System for Groundwater Management*. Paper presented at Second IEEE International Conference on e-Science and Grid Computing, 4-6 December, Amsterdam, Netherlands. Retrieved on February 20, 2009 from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4031080

Marcheggiani, E., Nucci, M., & Galli, A. (2009). New Prospects in Territorial Resource Management: The Semantic Web GIS. In Gervasi *et al.,* (Eds.). *Lecture Notes in Computer Science,* pp. 369-384. Springer-Verlag Berlin Heidelberg.

Martino, S. D., Ferrucci, F., Paolino, L., Sebillo, M., Vitiello, G., & Avagliano, G. (2007). A WebML-Based Approach for the Development of Web GIS Applications. *Lecture notes in computer science, pp. 4831*, 385.

Matsumura, K., Hijmans, R. J., Chemin, Y., Elvidge, C. D., Sugimoto, K., Wu, W., *et al.,* (2009). Mapping the global supply and demand structure of rice, *Sustainability Science, 4*(2) 301-313.

Matthews, K. B., G. Schwarz, K. Buchan, M. Rivington, & D. Miller. (2008). Wither agriculture DSS?. *Computers and Electronics in Agriculture*, *61*(2), 149-159.

Nikkil, R., Seilonen, I., & Koskinen, K. (2009). Software architecture for farm management information systems in precision agriculture. *Computers and Electronics in Agriculture, 70*(2), *328-336*.

Panagos, P., Van Liedekerke, M., Montanarella, L., & Jones, R. (2008). Soil organic carbon content indicators and Web mapping applications. *Environmental Modelling and Software, 23*(9), 1207-1209.

Rao, M., Fan, G., Thomas, J., Cherian, G., Chudiwale, V., & Awawdeh, M. (2007). A Web-based GIS Decision Support System for managing and planning USDA's Conservation Reserve Program (CRP). *Environmental Modelling & Software, 22*(9), 1270-1280.

Rbray, (2007). *MapGuide Project Home*. Retrievedn on November 12, 2008 from http://mapguide.osgeo.org/

Rowshan, M. K., Amin, M. S. M. (2008, August). *Rice irrigation management information system (RIMIS)*. Paper presented at Consulting Workshop on Paddy Precision Farming, Malaysia Agro Exposition Park Serdang, Malaysia.

Sante, I., Crecente, R., Miranda, D., Touri˜o, J., Canzobre, F., |& Doallo, R. (2004). A GIS Web-based tool for the management of the PGI potato of Galicia. *Computers and Electronics in Agriculture, 44*(2), 161-171.

Schuler, D. (2007). Community networks and the evolution of civic intelligence. *AI and Society Journal*, in press.

Simao, A., Densham, P. J., & (Muki) Haklay, M. (2009). Web-based GIS for collaborative planning and public participation: An application to the strategic planning of wind farm sites, *Journal of Environmental Management Collaborative GIS for spatial decision support and visualization, 90*(6), 2027-2040.

Steiniger, S., & Hay, G. J. (2009). Free and open source geographic information tools for landscape ecology. *Ecological Informatics, 4*(4), 183-195.

Thadaboina, V. (2009). ICT and Rural Development: a Study of Warana Wired Village Project in India. *Transition Studies Review, 16*(2), 560-570.

Tsou, M. H. (2004). Integrating Web-based GIS and image processing tools for environmental monitoring and natural resource management. *Journal of Geographical Systems,* 6(2), 155-174.

Witt, C., Pasuquin, J. M. C. A., Mutters, R., & Buresh R. J. (2005). New Leaf Color Chart for Effective Nitrogen Management in Rice. *Better Crops, 89*(1)*,* 37-39.

Xia, Y., Guru, S., & VanKirk, J. (2009). pestMapper—An internet-based software tool for reporting and mapping biological invasions and other geographical and temporal events. *Computers and Electronics in Agriculture, 69*(2), 209-212.

Zhang, S., & Goddard, S. (2007). A software architecture and framework for Web-based distributed Decision Support Systems. *Decision Support Systems, 43*(4), 1133-1150.

Zhang, X., Shi, L., Jia, X., Seielstad, G., & Helgason, C. (2009). Zone mapping application for precision-farming: a decision support tool for variable rate application. *Precision Agriculture*, *11*(2), 1-12

APPENDIX 1

QUESTIONNAIRE (TRANSLATED FROM BAHASA MELAYU)

I am Nik Norasma Che'Ya (GS19340), a Master's student in Universiti Putra Malaysia, and I am currently developing the Web Paddy GIS©. I hope you can complete this questionnaire so that improvements can be made. Thank you.

Personal information:

1. Are you a farmer or farm manager?

   ☐ Farmer ☐ Farm manager

2. How old are you?____________________(years)

3. Have you ever used a computer?

   ☐ Yes ☐ No

4. Have you ever used the Internet?

   ☐ Yes ☐ No

Questions:

1. Is Web Paddy GIS© easy to use?

   ☐ Very Easy ☐ Easy ☐ Difficult

2. Did you encounter any problems when using Web Paddy GIS©?

   ☐ No problem ☐ Some problems ☐ A lot of problems

3. Is the information on rice cultivation that is provided easy to understand?

   ☐ Very easy ☐ Easy ☐ Difficult

4. Was the information clear?

   ☐ Very clear ☐ Clear ☐ Not clear

5. The information I want is easily found in this website:

   ☐ Yes ☐ No

6. Web Paddy GIS© has all the functions to create a remedial action map:

   ☐ Strongly agree ☐ Agree ☐ Disagree

7. Web Paddy GIS© will help the performance of any daily tasks in rice cultivation to be more effective.

☐ More effective ☐ Effective ☐ Not effective

8. The web interface is attractive:

☐ Very attractive ☐ Attractive ☐ Not attractive

9. The colours, texts and photos on the webpage are clear and easy to read:

☐ Very clear ☐ Clear ☐ Not clear

10. Overall, are you satisfied with the current developed system of Web Paddy GIS©?

☐ Very satisfied ☐ Satisfied ☐ Not satisfied

THANK YOU