Application of Web Geospatial Decision Support System for Tanjung Karang Rice Precision Irrigation Water Management

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Abstract—Huge amount of water is lost especially at farm level due to lack of information on water demand and supply. The SWAMP (Soil Water Assessment and Management for Paddies) was built for managing paddy irrigation. This system was built using ArcGIS viewer for flex, Microsoft SQL database and ArcGIS Server 10.1 advance. The developed system is web based, interactive and user friendly graphic user interface by widgets technology and provide information concerning irrigation water demand and supply. Compute yields and performance indicators such as irrigation efficiency, relative water supply, water productivity index which are vital information for farmers and irrigation water managers. The results viewed in the form of thematic maps, tables, and charts for easy interpretation. SWAMP is simplified for non GIS expert to explore and retrieve information to make decision for best practices.

Keywords— ArcGIS for Server, Decision Support System, Irrigation, Rice, WebGIS.

I. INTRODUCTION

The web applications development is growing faster than ever before and this is an evolutionary transformation of usual individual activities on desktop to a multi interactive manipulation of data and information worldwide. The advent of Web GIS brought about new generation of Internet services and technology which supports user interaction significantly [1]; [2]. This evolution leads GIS further away from only data viewing. Browsing, analysing and managing for individual decisions, and more towards group participating and communicating on both scientific and social decision issues [3]; [5]. As [4] described the Public Participation GIS principles as accessibility and accountability, hence Web GIS continues to draw attention as a public participation tool [6].

Nowadays, Google Maps, Google explorer, Bing maps, Google Earth, Yahoo Maps, and many other open sources and commercial applications provide different kinds of geographical related information such as detailed maps, city maps, satellite images and terrain maps covering all over the world [7]. Irrigation schemes were not left out to explore these technologies to its benefits, more especially for the water management.

Water management of lowland irrigated rice is becoming crucial in global water resource management. Many irrigation schemes were exploring different, cheaper and more efficient ways of curbing huge water losses from flood irrigation system of rice. The application of modern technology such as GIS, GPS, and Remote Sensing to agriculture has brought a new revolution in agricultural water management. Good water management means applying the precise amount of water at the right time in the right place and as at when needed. Many computer aided tools have already been developed aimed at improving water management of irrigation schemes [8].

Integrating GIS functionality with internet capacity will redefine the way of decision-making, sharing and processing of information. In irrigation systems weather plays crucial role in decision making, implementing and forecasting. Temperature, humidity, precipitation, and solar radiation are the most important parameters to calculate Evapotranspiration which is key to irrigation scheduling. A Decision Support System (DSS) is a set of tools and procedures that work interactively to manage a particular system; it is capable of enhancing the quality of the decision-making processes in the system. Decision support systems are sub-set of computer-based information systems. Information system played important role in supporting managers in their decision making activities. As decisions are irreversible and have far-reaching consequences, effective decision making can never be overemphasized especially in high capital investments like irrigation schemes. The concepts of computerized (DSS) that assist users in complex decision making processes have been in use for the past three decades. However, decision support systems that model soil, plant and weather conditions have been used to calculate when to irrigate based on crop water requirements [9]. It is known that if DSS-derived irrigation schedules were followed, water savings can be achieved through efficiency and yield gains.

[10]Stated that some of the advantages of the web-based GIS are that, it reduces the software cost. Others include; easy
to support and carry out maintenance services, shortens the users learning curve and provides a superior environment for DBMS integration and presentation. Much more literatures were unfolding on Decision Support System. Many of the early researches were on automated report generation using main frame computers [11]. Some were on business problem and water quality issues [12]. It is worth reiterates that DSS support decision and not making decision, this was due to the fact that it addresses the advantage of computer to manipulate large amount of data but yet rely on decision maker’s judgment. [13] Present several positive arguments concerning the early application and development of DSS including the most recent ones which were often design based on spatial database in Geographic Information System (GIS) format. Multi-objectives decision making tool can also be incorporated in GIS application [14], which opens a new window for transforming decision making approach in spatial agriculture systems.

Due to the emergence of new communication hand held devices, it become necessary to develop an integrated system for easy monitoring and accessing remote information for the farmers and water managers. It is then necessary to develop a quick-response software system for daily crop water needs; real-time water resources assessment especially the field water depth for lowland rice [15]. Such a prediction and assessment system can provide scientific decision support for water resources regulation. The development of distributed hydrologic models and WebGIS provides good conditions for establishing these types of systems. To practice smart farming effectively is to be able to keep close monitoring of the farm without necessarily travel to the farm.

The focus of this study is to develop Web GIS DSS tool that is user friendly interface for quick access and generate various reports and charts essential for effecting decision in irrigation management of Tanjung Karang Irrigation Scheme.

II. MATERIALS AND METHODS

A. Location

The base station chosen for this study was Tanjung Karang Irrigation Scheme which is located in the Middle West part of Peninsular Malaysia and sited north of Kuala Lumpur. Sawah Sempadan is one of the eight irrigation compartment of Tanjung Karang Irrigation Scheme (Figure 1), the research area ‘Block C’ located at 3o28’09.63465”N 101o13’26.48399”E with an average altitude of 6.2.0m above mean sea level (Figure 2).

B. Field Data Acquisition

Data for the model was obtained from the Telemetry system installed at the field, the system consists of sixteen Microflex-C Sensors that monitored the field water level, Lysimeter water level (opened and closed bottom), shallow ground water level, canal water level and evaporation pan water level at every fifteen minutes for two seasons. These readings gave good understanding of what is happening with regards to irrigation water at on-farm level. The Sensors were calibrated on the field during installation and were connected to the remote terminal unit. There were two remote terminal units at the fields each were attached with eight pieces of Sensors (Microflex-C). The Remote terminal unit transmit the data to the data server through wireless communication. The data used to be accessed from the server directly and wireless access through hand phone by sending a request query to the server to obtain a real time data (Figure 3).

![Fig. 1 Map of Tanjung Karang irrigation scheme showing Sawah Sempadan area](image1)

![Fig. 2 Experimental plot Block C Sawah Sempadan](image2)

![Fig. 3 Telemetry system architecture](image3)
C. Model and Web GIS System Development

The irrigation water balance models and other key indicators that will be useful in the irrigation operations were presented in equations 1 - 9.

$$SWD = IRR + ER - ET - SP - DR + GW \quad (1)$$

Where;
- **SWD** = field Standing water depth (mm)
- **IRR** = Irrigation (mm)
- **ER** = Effective rainfall (mm)
- **SP** = Seepage percolation (mm)
- **DR** = Drainage and Runoff (mm)
- **GW** = Ground water influence (mm)

$$ETc = K_c \times ETo \quad (2)$$

Where;
- **K_c** = Crop Coefficient
- **ETo** = Potential Evapotranspiration
- **ETc** = Actual crop Evapotranspiration

$$K_c = ET_c / ET_o \quad (3)$$

D. Irrigation Performance Indicators

1. Water Productivity Index (WPI)

   Water productivity is defined as a ratio of yield output to the crop water consumptive use and it is a concept of partial productivity. In rice production, discrepancies are large in reported values of water productivity of rice ([14]).

   $$\text{Water Productivity Index} = (\text{Yield (kg)}) / (\text{Total water consume (m}^3\text{)}) \quad (4)$$

2. Water delivery capacity

   Water delivery capacity is the ratio of the canal capacity to deliver water at head to the peak irrigation requirement.

   $$\text{Water Delivery Capacity} = \frac{\text{(canal capacity to deliver water at head)}}{\text{(Peak irrigation Requirement)}} \quad (5)$$

3. Dependability of Supply

   Dependability of water supply is the ratio of the delivery loss to the scheduled delivery subtracted from one.

   $$\text{Dependability of delivery} = 1 - \frac{((\text{Schedule water delivery}-\text{Actual water delivery})}{(\text{Schedule water delivery})) \quad (6)}$$

4. Reliabilities of deliveries

   This is the ratio of loss of discharge to the schedule discharge subtracted from one.

   $$\text{Reliabilities of delivery} = 1 - \frac{((\text{Schedule discharge}-\text{Actual discharge})}{(\text{Schedule discharge})}) \quad (7)$$

5. Equity of supply

   Equity of Supply is the ratio of applied depth minus average applied depth to the average applied depth subtracted from one.

   $$\text{Equity of supply} = 1 - \frac{((\text{applied depth-average applied depth})}{(\text{average applied depth})}) \quad (8)$$

6. Water Use Efficiency (WUE)

   $$\text{WUE} = \frac{ET + SP}{IR + ER} \quad (9)$$

E. Web GIS Development

ArcGIS Server is a software that makes spatial information available online for secure or public access. This is accomplished through web services, which allowed a powerful server computer to receive and process requests for information received from other devices and were interconnected in the development process (Figure 4). There are many ways to create web applications, one which was adopted here is ArcGIS viewer for flex which is a configurable web application builder based on ArcGIS API for Flex. It allows creating customized GIS web map applications with minimal programming. The ArcGIS Viewer for Flex is designed to work with services from GIS server. It can also reference intelligent web maps that were authored using ArcGIS.com or Portal for ArcGIS. The ArcGIS Viewer for Flex supports data display, interactive querying, web editing, data extraction, geocoding, printing, and more.

ArcGIS Server allows developing web application to share GIS resources across an enterprise and the web. GIS resources are the maps, address locators, geodatabases, and tools. These resources are shared by first hosting them on ArcGIS Server system and then allowing client applications to use and interact with the resources (Figure 5).
ArcGIS Server also consists of services, applications, and KML network links that have been published to the server. In addition, a Manager application is responsible for creating and organizing services and basic applications. ArcGIS Server is used to introduce advanced GIS function to the internet environment and to publish information based on GIS platform.

F. Data Preparations, Publishing and System Design

All information were prepared in the GIS platform arranged as layers and stored in a registered database, these layer information are then configured and publish as service. The service will be analysed by service editor to ensure error free before published to the server as map service and feature service (figure 6).

This system used a Microsoft SQL database 2012 enterprise in conjunction with Arc SDE to manage the way spatial and attribute data are stored in a relational table. The database is registered with the ArcGIS Server in order for the Server to read data from the database. All services were prepared and publish in ArcGIS for desktop as shown in Figure 6.

G. Architecture of Flex Viewer

Flex Viewer is a plugin based on Adobe flash, it is an application builder framework developed by ESRI’s company based on the technology of ArcGIS Server REST services. This framework offered the basic modules for designers. Designers only need to add the configuration code into the xml file to deploy a new module to the existing Flex Viewer rapidly in the form of widgets. The flex Viewer allows building a highly powerful system that displays the information published in the ArcGIS Server for visualising, querying and conducting geoprocessing services. The widgets can be customize to suit designers choice, the final output depends on individual skills. Real time information can be assessed when incorporated with the appropriate field instrumentation.

III. RESULTS

A number of geographical features and real-time information are used in the procedure of management, and it is difficult to analyse and display with the traditional management information system. GIS technology makes the system easily and quickly for decision-makers to access information and analyse the information because GIS is more expressly and effectively to describe the information in terms of visual image, charts and tables.

A. System Frame work and Functions

SWAMP system developed from this study as shown in Figure 7 is equipped with several widgets for displaying, querying and processing information from the database and ArcGIS Server. The user interface is interactive and intuitive such that pop-up displays information on pointing at a selected layer. Also draw widget can be used to draw using the shape icons and to display information on that area based on the selected layer. As the web application loads, the Attribute Table widget check and populates the attribute table with feature(s). These feature(s) can be selected, deselected, and zoomed-to by interacting with the attribute table. If these feature layers are editable, the corresponding feature attributes will also be editable.

B. System functions

The end users can connect to the central server using a Web browser, signing in using their respective login details. The users are divided into three categories, common users, farmers and professional users, each of which have different rights and roles. Common users can only check for information like present status of the water level at fields while farmers can in addition query the existing computation results.
While professional users can do their own computations and analysis in addition to querying the system and add the result as a layer to be approved for publishing by the publisher or admin. We also acknowledge the support from SMART Farming Technology Research Centre, Faculty of Engineering Universiti Putra Malaysia.

REFERENCES


IV. DISCUSSIONS

The web is equipped with widgets which execute different functions, in this case the geoprocessing widget process the layer task to a layer output and final product added to the service. The attribute table is displayed to enable select a layer from table and execute some query (Figure 8). Real time information is made possible as the displayed results can be viewed immediately. The search widget enable easy and quick search of the system and zoom to the area searched and selected. This GIS application is user-friendly such that the system makes it easy to understand the information. The layers have legends to help interpret which layer represents what activity or aspect of the farm services.

This system saves time and resources and is flexible and high accuracy in its overall output. The systems also function as tool to know at any instance what activity is taking place at any of the eight compartments. For fertilizer application it will enable farmers to know exactly the application rate of fertilizer base on the soil fertility map of the area. The geoprocessing functions is a powerful tool for conducting spatial analyst built using the ModelBuilder to process and output as a layer added to the map. This system is user friendly irrigation water management tool for viewing, modelling and conduct spatial analysis. The developed system is very interactive and the interface is simplified such that non-GIS expert can also explore and retrieve information to make decision for best practices on rice irrigation water management.

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