Annals of Sri Lanka Department of Agriculture 2017. 19: 209 - 228

DEVELOPMENT OF GEO-DATABASE TO RECOMMEND SUITABLE CROPS AT VILLAGE LEVEL IN SRI LANKA

S.S. SENANAYAKE, M.A.K. MUNASINGHE
AND W.M.A.D.B. WICKRAMASINGHE

Natural Resources Management Centre, Peradeniya, Sri Lanka

ABSTRACT

Information Communication Technology (ICT) and informatics has been emerged as technologies that support in decision making for agricultural production. These technologies can also be applied to manage risks in agriculture due to climate variability and climate change. The aim of this research was to provide development perspectives of a user-friendly information system developed by Natural Resource Management Centre for selecting suitable crops against agro-ecological variation at Grama Niladhari division (GN) level using ICT and Geo-informatic techniques for decision making in crop production. The 'Merise method' was used to design the conceptual data model. Microsoft Access 2007 software was used to develop geo-database as Relational Database Management System (RDBMS) to store spatial and non-spatial data. The special data was integrated into arcgis software for thematic map generation. The "CROPREC" desktop software was developed for offline access while web portal was developed to online access using geo-database for this information system, which provides location based agriculture information. A user-friendly interface allows easy entry, viewing, querying and analyzing agricultural information geographically for better decision making. The study concludes that spatial reference data application benefits for planning to increase crop production in farming.

Keywords: Crop Suitability, Geo-database, Information Communication Technology

INTRODUCTION

Over the last decade, the Informatics and communication technologies have emerged as planning tools that support and enhance planning process and sustaining the agricultural production. The novel approaches in the application of information and communication technology to solutions that allow improving the agricultural production in climate change scenarios (Singh and Singh, 2012). Climatic variation greatly affects on environmental condition and it continues to degrade land and water resources at present. An effective information system is a prerequisite for planning to combat such degradation.

The process of integrated planning approach requires knowledge of data management, analyzing tools and techniques for large amount of data handling. The work of De Freitas and Tagliani, (2009) as cited in Konan-Waidhet *et al.* (2013) revealed that integration, manipulation and visualization of large amounts of data can be done using spatial information systems as a useful approach.

Updated reliable data on suitable food crops and their requirements are very important for agricultural activities to promote crop production against situations of climate variation. A proper user guide for suitable crop selection is required for local level decision making in farming as a climate change adaptation strategy. A user guide for crop recommendations at Grama Nialadhari (GN) division level was developed by the Department of Agriculture (DOA) of Sri Lanka in 1990. However, this guide has not been updated since a longer period and information are not available in a user-friendly manner for users' quick reference to source relevant information. If this time consuming process continues, there are negative consequences in dissemination of crop information for farmers. Hence, there is a necessity of less time-consuming process to identify suitable crops for particular area to make a better decision on farming.

Konan-Waidhet *et al.* (2013) suggested that it is appropriated where available data are organized into an information system to facilitate decision making as a solution to reduce long search time. There are several challenges with effective data management in an information system according to Peng *et al.* (2011). Hence, application of geospatial technology together with ICT can be used for transferring agricultural technology (Dhaka and Chayal, 2010) in efficiently to identify the suitable crops and growing potential by aiming of increasing crop production. The geo-database can commonly be shared among a large user community (Cloban *et al.,* 2011). The spatial database supports topologically integrated data such as the geographic features in real world in digital forms and store in a database that can be presented into maps. It also can manipulate in spatial analysis for decision making.

The aim of this paper is to describe the design structure, components and development perspectives of geo-database using ICT and Geo-informatics techniques in response to the need for better management of information on crop suitability recommendation against agro ecological variation at GN division level for growers and policy makers in Sri Lanka.

MATERIALS AND METHODS

Geo-graphical coverage

Sri Lanka is fallen in the 7^0 North latitude and 81^0 East longitudes. There are nine provinces, twenty five districts and 14022 GN divisions which is the smallest administration unit in Sri Lanka. Sri Lanka has been delineated into 46 Agro Ecological Regions (aers) that spread across three major climatic zones, namely Wet, Intermediate and Dry zones of the country. These aers represent uniform climatic, soil, and terrain conditions and landuse (Punyawardena, 2008).

Materials

The research was conducted in the Natural Resources Management Centre of the Department of Agriculture (DOA) Peradeniya in 2015 and digital data sets and software were used as materials. Data sets used were monthly average rainfall, temperature, demographic data and crop related information. The maps used were land use, topographic, AER and soil maps in 1: 50000 scale. The software used were Microsoft(MS) Office 2007, ArcGIS software 10.1, Inno Setup 5, web development languages (HTML, PHP) and database software like MySQL for the design of this information system.

Design methodology of Geo-database development

The 'Merise method' was used to start the conceptualization in design of geo-database on crop suitability recommendation. The 'Merise' is a methodology widely used in information system design and model development. It provides mapping data rules and process of outline for data models. These information systems can be further developed when required and new directions can be incorporated into the model. Three cycles: 1). abstraction cycle, 2). approval cycle and 3). life cycle were used for this method. Conceptual, logical and physical modelling of database levels was done at the abstraction cycle. The necessity of identifying decision points was recognized during the development of the information system in the approval cycle. Whilst planning, initial study, detailed study, implementation, launching and maintenance of the information system were consisted in life cycle (Rochfeld and Tardieu, 1983; Konan-Waidhet *et al.* 2013).

The database is delineated as "a collection of non-redundant data stored in a structured manner on a same support type, with the management and storage process provided by software named Databases Management System (DBMS)". The Merise method allows the spatial and non spatial data chosen for the data model storage and manages in tables as Databases Management System (DBMS) in the geo-database and geographic information integrate as Relational Database Management System (RDBMS) standard. A data model is described as a collection of conceptual tools for describing data, data relationships, data semantics and consistency constraints. Relational Database Management System (RDBMS) is the most popular choice among different data models for large scale application. The RDBMS can be used for collection of tables to represent both data and the relationships among those data (Patil *et al*., 2012).

Data modelling

Konan-Waidhet *et al*. (2014) describe that "a model is a representation of reality used to simulate a process, predict an outcome or analyze a problem". Two main phases were consisted with modelling of the database: the first concerns the conceptual modelling of data and the second relates to modelling logical and physical data according to Merise method. Conceptual modelling is described as building the database with a solid structure was to optimize data exchange in an efficient manner between applications. An Entity-Relationship diagram was designed as the conceptual model and a unique identifier for each entity was referred as a primary key. In addition, a concise, schematic, and univocal description of the organization of the data to be archived in the database were presented by the conceptual model (Carrion *et al*., 2009 and Konan-Waidhet *et al.* 2013). The conceptual framework of model is presented in Figure 1 below.

Konan-Waidhet *et al. (*2013) revealed RDBMS as a logical representation of data according to the data model. Furthermore, they indicated "The physical model expresses the logical structure of the database and provides a transition from conceptual description to the physical implementation of the database". The modelling of logical and physical data related to setting up the RDBMS was carried on the following tasks: In this phase of the research allowed an inventory of existing, being acquired and available data about the region.

Therefore, setting up a database that includes all the data tables was constructed as following. The association among the database created as relational database was used to design the structure of Geo-database. The geo-database was designed and constructed using MS Access 2007 as its underlying structure outside the ArcGIS environment. The constructed geo-database was imported into ArcGIS software 10.1 to be used for thematic mapping. This geo-database consists with range of spatial and non-spatial data such as data tables, vector and raster map layers and numeric information, numbers and texts. These spatial and non-spatial data are combined within the RDBMS as a geo-database for retrieve of information. The available and collectable data related to agro ecological region: soil type, rainfall, relative humidity, temperature and landuse data, potential and suitable high yielding crops for main two seasons (*Yala*, *Maha* and third season in potential areas) best cultivation periods (cropping calendar), geographical locations suitable GN divisions, Agrarian service divisions (ASD) and geographical boundaries were initially stored in MS Excel tables. After revitalizing the data were export in to the MS Access and ArcGIS software.

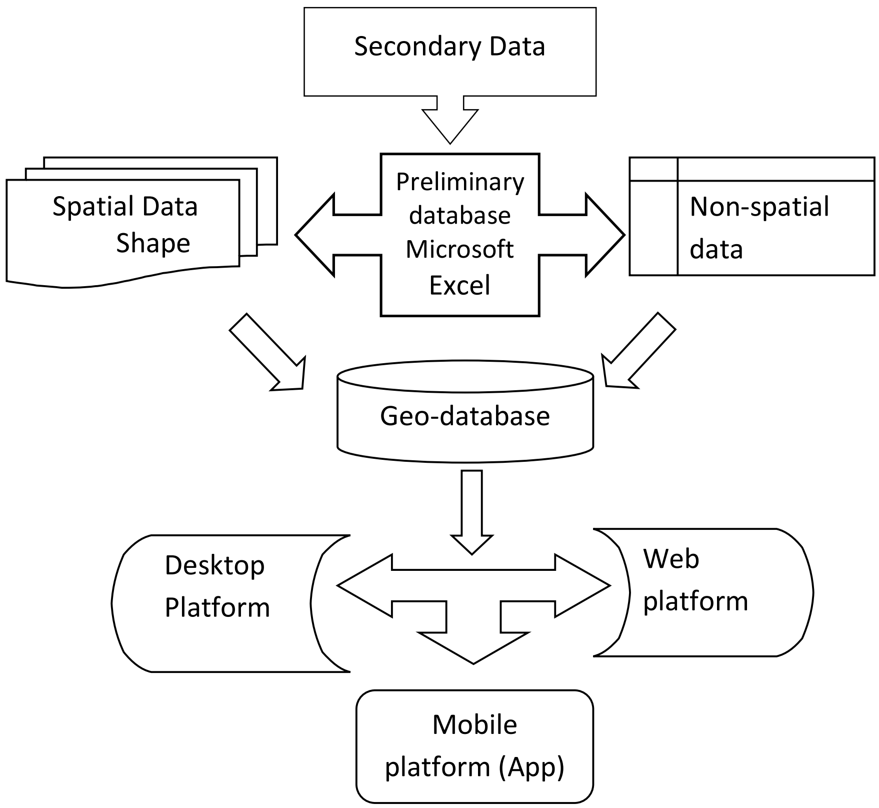

Figure 1. The conceptual model.

User access platforms

Proposition of an interface allows the update and retrieval of data. Thus, the constructed geo-database was further improved into two access platforms in the approval cycle: user friendly desktop software "CROPREC" for comprehensive detailed information and a web portal for quick reference (information on crops and cropping calendar for online users to access even at the farmer fields). Finally, creation of queries on the data tables and the map display were constructed to search information.

Data collection and compilation

Basic crop recommendations and relevant secondary information were extracted from respective publications and materials made by Plant Breeders, Agronomists, other Agricultural Scientist and Extension officers in the

Department of Agriculture and other relevant agencies. The information about the new improved crop varieties, growing periods and the suitable areas for cultivation were obtained from researchers at research institutes in DOA. Extension officers in the DOA provided the information on field level ground situations and growing conditions. Validation of gathered information was done through the respective officials of Provincial DOA. Spatial data on administrative boundaries were obtained from Department of Agrarian Development (DAD). The web hosting was facilitated by National Information & Communication Centre, Peradeniya. The updated information was obtained from respective parties and consolidated them for compilation of technical information. All information was digitally compiled in to MS Excel formats and then exported into MS Access database. Systematically compilation of information in different subject areas was done as required. An accuracy assessment was done by random field visits made to Polonnaruwa, Ampara, Badulla, Kegalla, Gampaha and Moneragalla districts for the pilot testing and validation.

RESULTS AND DISCUSSION

Conceptual modelling and structure of Geo-database

The conceptual model shows the structure of the geo-database and the relationships between the various data entities and their attributes. It identifies layers, data table and attributes and hides the internal detail of physical storage and target on describing entities, data type relationships and contains. Finally, performance considerations were analyzed and shown compatible with application requirements. As Konan-Waidhet *et al.* (2013) indicated with their work; the integration of all the concepts is necessary to support the various application views. Data appear in a structure is most perspicuous for concept integration at the conceptual level. It explicitly defines how concepts are related one to another; it should not contain any implementation detail; and it should be locally modifiable.

The geo-database (built in MS Access and ArcGIS software) sources spatial data and non spatial data from the preliminary database and generate basic maps and tables which are available in three platforms namely: Desktop Platform (CROPREC software for offline access), Web Platform (online access), and Mobile Platform (mobile app for online access from any mobile devices). The associations between feature classes and tables in the geo-database were created and managed in MS Access representing the principle of referential integrity (Blaha 2005 and Konan-Waidhet *et al.,* 2013). The structure of the database showing the relationships among various entities and attributions are presented in Figure 2 below.

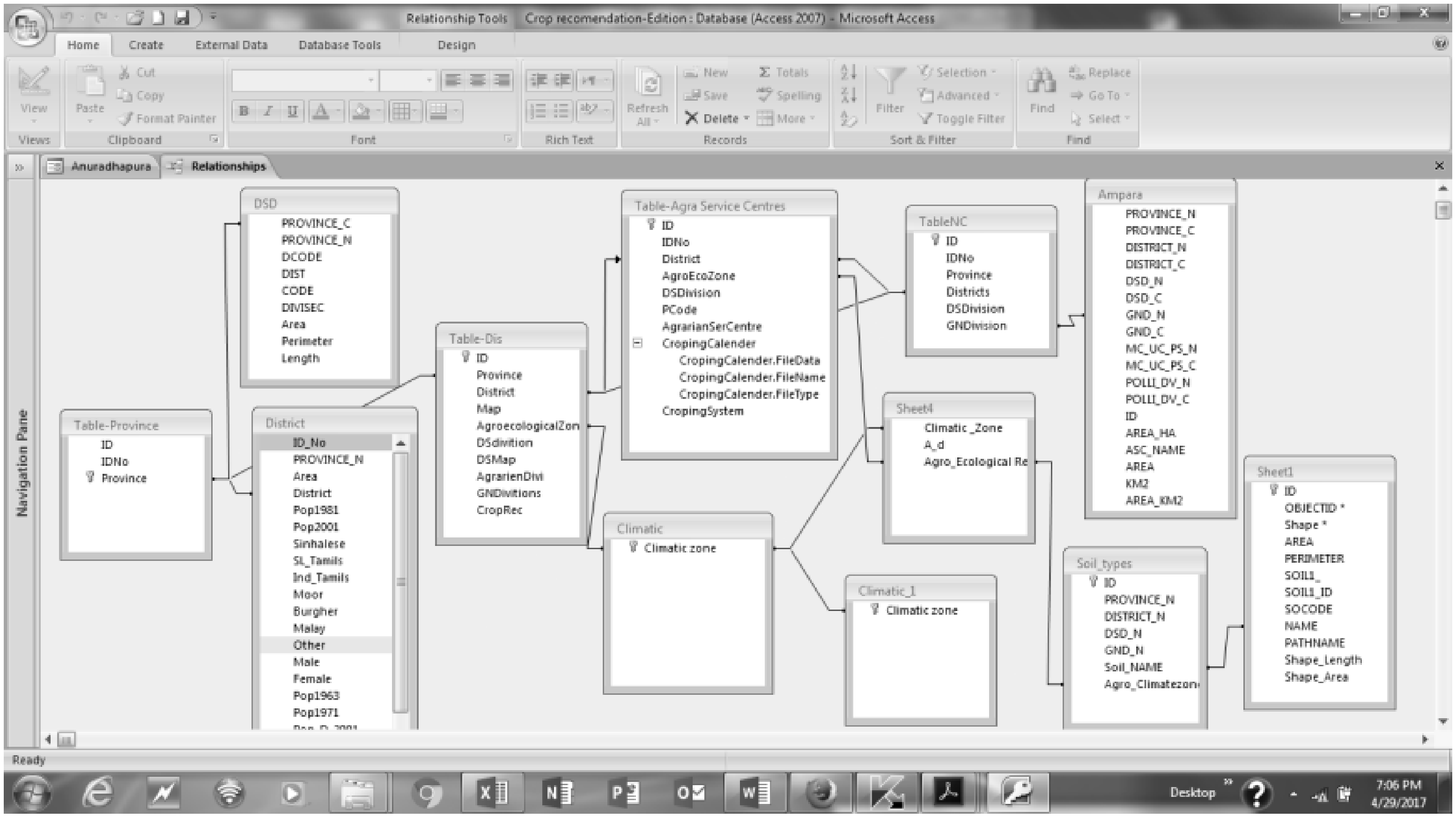

Figure 2. Structure of the database

The design structure of geo-database can be used to generate other databases by improving shape files or coverage of existing data. All data can be stored and managed in one database as a uniform repository of geographic data warehouse. Thus, data entry and editing is more accurate in the geo-database and it can be accommodated very large sets of features.

Presentation of the Geo-database application

A geo-database model can be either personal or multiuser. Personal geo-databases are stored as MS Access database files and allow many readers, but with a single editor. The geo-database was created to reflect the relationships that exist between the various feature classes and tables within the feature data set. Hence, this database was developed as a personal geo-database. Data were stored as spatial layers in raster files (.tiff, .img, .jpeg, .bmp) and vector files (.shp) and non spatial data as tables or database formats in files (.exe, .txt, .dbf). These data can be used to query, retrieve and update features.

The descriptive tables were created in MS Access. A total of 12 Tables were used for each district level. These 25 forms were separately hyperlink on to the main menu of the application. Combo boxes and list boxes are a great way to control user experience by limiting the values that a user can choose to a known list. In MS Access, a common need is to have multiple combo boxes or list boxes on a form, and hyperlinks to have the selection in one combo box limit the choices in a second combo box. For instance; when you select a district, all relevant features such as administrative boundaries and demography, AER, landuse and soil types, cropping calendars etc. are appeared in separate tabs. The application provides the user with a series of functions enabling to establish dynamic links between ArcGIS maps and MS Access tables forms. The constructed data on geographical information were imported into the geo-database as feature classes. The files with extension ".shp" were developed in ArcGIS software 10.1 for thematic mapping. The data model for ArcGIS is a raster type object-oriented model.

The constructed Geo-database was further improved into two access platforms: i). user friendly desktop software "CROPREC” for comprehensive detailed information for off line users and ii). web portal for quick reference, information on crops and cropping calendar for online users to access even at the farmer fields.

CROPREC software

The access platform of geo-database was developed as desktop software “CROPREC” (.exe setup file) using software of “Inno Setup 5”. Users can install this software for offline usage. The main screen of geo-database is given in Figure 3(a).

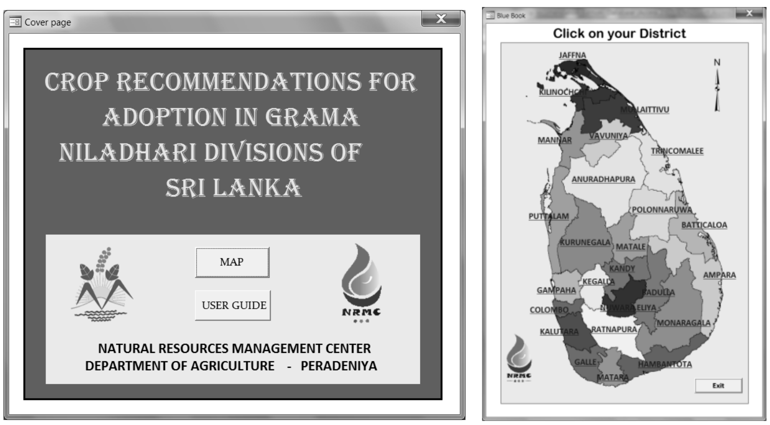

Figure 3. (a) Main Screen (b) Map menu of the CROPREC software.

The main screen consiting with two separate button oppotions for user guide and map manu. Map manu can be used to make queries and reviews for the geograpical locations. Spacial data (maps) and non spacial data (data tablets and texts files) were intigrated into MS Access forms of perticular geograpical locations through different tab opptions which allows to select set of feature classes. Map interface in the tab options were hyperlinked to feature class in the perticular geograpical location.

The abbility to access for spatial and non spatial information in the CROPREC software is illustrated in the following example. This example relates query on spatial distribution of AER map and relavent croping calander of ASD in a perticular district. The results of this query shows in Figure 4 (a) and (b).

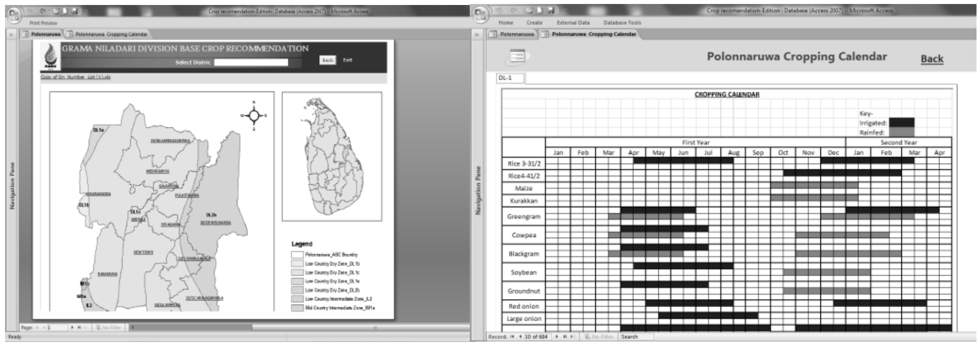

Figure 4. (a) spatial distribution of AER map (b) relavent croping calander(non spatial data) of agariance service division.

In this query, seven AERs : DL1b, DL1c, DL1e, DL2b, IL2, IM1a and IM1b have been identified in Polonaruwa district. In the DL2b, four agariance service divisions (Welikanda, Dimbulagala, Aralaganwila and Pulastigama) have also been identifed. The results further illusterates croping calander of Welikanda agariance service division as given in Figure 4(b) of this query. However, there are few limitations with this application. Raster files in CROPREC software are having limited zooming facilities ("in and out") within the capabilities of MS Access. Hence, special access is only available up to ASC levels. Furthermore, CROPREC software was developed for MS Office 2007. This application is therefore not supported to early version of MS Office.

Web Interface

Interactive web interface for this geo-database was developed as a quick online access platform (www.doa.gov.lk/ crop suitability or http://nrmc.lk/ crop_ suitability/). Users can access to this web interface at anywhere, anytime, even by using smart phones, tablets, etc.

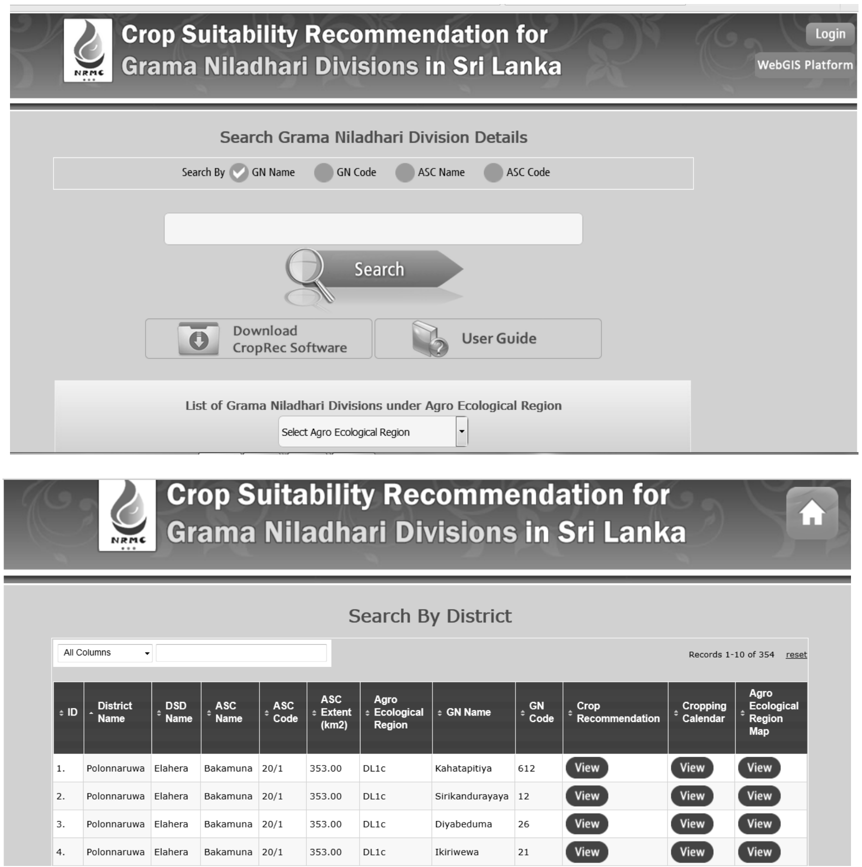

Figure 4. (a) The quarry interface of the web portal (b) Web page for MySQL geo-database.

This web interface consists of search menu and dropdown menu which allows users to start queries and retrieve. Users have easy access to MySQL geo-database as a web page. MS Access geo-database was integrated into MySQL geo-database to enhance the user efficiency.

The abbility to access for spatial and non spatial information of MySQL geo-database is ilustrated by the following example for queries and retrieve as showing in the figure 4 (b). In query, relavent AER map , croping calender and suitable crops for perticular location (GN division) can be obtained via three consecutive button opptions in the web page. The figure 6 (a), (b), and (c) shows the results of this query.

Crop Recommendation

RECOMMENDED CROPS

MAHA				YALA				PERENNIAL
UPLAND		LOWLAND		UPLAND		LOWLAND		
RAINFED	IRRIGATED	RAINFED	IRRIGATED	RAINFED	IRRIGATED	RAINFED	IRRIGATED	
Group I	**Group I**	**Group II***	**Group I**	**Group III**	**Group I**	**Group III**	**Group I**	**Group II**
Chilli	Chilli	Greengram	Rice	Gingelly	Chilli	Cowpea	Rice	Banana
Red onion	Gherkins	Cowpea			Gherkins	Groundnut	Chilli	Cashew
	Red onion	Soya bean			Large onion	Gingelly	Large onion	Lime
	Tomato	Groundnut			Red onion		Red onion	DragonFruit
Group II	**Group II**				**Group II**		**Group II**	**Group III**
Blackgram	Capsicum				Cucurbits		Beet	Coconut
Cowpea	Groundnut				Capsicum		Capsicum	Caster
Greengram					Greengram		Soya bean	Mango
Maize					Tomato		Tomato	Murunga
Soya bean							Brinjal	Papaya
Tobacco							Cucurbits	Woodapple

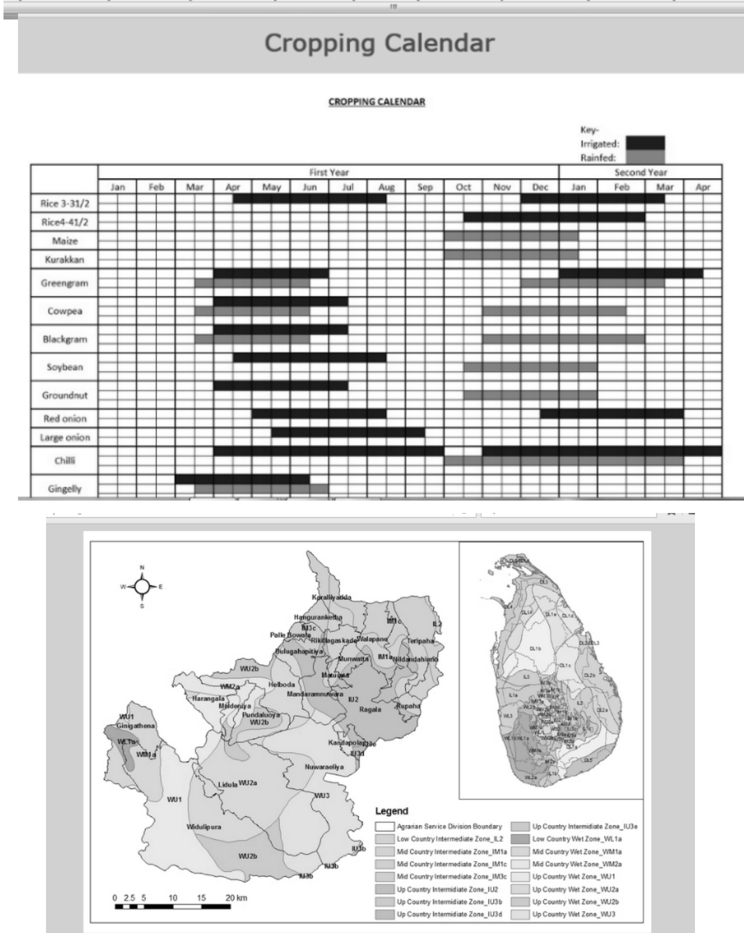

Figure 6. (a) Suitable crops (b) Cropping calendar (c) map of AER and ASD boundaries.

Thus, each AER represent uniform agro climate, soil and terrain conditions and as such as would support a particular farming system where certain range of crops and farming practices find their best expression. GN divisions 14,022 and Agrarian Service Divisions 557 have been used to display the details. The crop recommendations were given according to the Agro Ecological Regional (AER) requirement. In contrast, following limitation is with this application. It is unable to retrieve information in reference to the GPS coordinates (latitudes and longitudes) at village level.

Aforementioned two examples demonstrated the capability to access information in the geo-database via online and off line platforms. This geo-database provides following features: visualization of the spatial distribution of AERs, administrative boundaries, identification of suitable crops according to climatic condition (AERs), cropping calendars as well as landuse and soil types and management tool as information bank for decision supports. In addition, a single administrator can update this geo-database. The two access platforms (CROPREC software and web portal) can be used for fast dissemination, sharing, displaying and data processing which help in dissection making for various cropping patterns at the commercial scale farming activities. This study provides how GIS application can be coupled with a relational database management system as geo-database for decision making in crop production. Satti and Jacobs (2004) revealed that such an information system provides an easy interface to access data. Thus, policy makers, extension officers, researchers, academia and other relevant users are able to use aforesaid both access platforms for helping farmers to obtain maximum output from their farming activities. Thus, this geo-database helps to provide the easy and timely access to reliable information for users to address the issues pertaining crop suitability information.

This application underlies two types of information systems: a GIS and a relational database management system (RDBMS). GIS can be used to organize data in layers and together geography for analyzing and maintain geographic data by Martin *et al.* (2004). In addition, earlier work of several authors reported that the central structural abstraction for data collection, storage, retrieval and update in an information system are data forms (Shu *et* *al*., 1982; Tsichritzis, 1982; Yao *et al.,* 1984; Konan-Waidhet *et al*., 2013). Choobineh and Venkatraman, (1992) noted that the data forms can be often well organized and can easily be formalized. However, ensuring the integrity between geographic and relational data physically separation is the main challenge according to Barbier *et al*., (2009) as cited in Konan-Waidhet *et al., (*2013).

Barnolas, and Llasat in 2007 denoted geo-database is a helpful tool and is a more efficient way to store information and to analyses climatic variation applications, concerning spatial and temporal analysis, aiming to improve risk assessment and vulnerability information. Previous works of several researchers denoted that there are various application areas of geo-databases where it was widely used ranging from environmental management, agricultural and mineral resources, urban changes monitoring to the medical field (Busgeeth and Rivett, 2004; Mathiyalagan *et al*., 2005; Petrisor, 2010; Yang *et al.,* 2011; Doxani *et al.,* 2012, Konan-Waidhet *et al.,* 2013).

However, awareness and usage level in this information system among the users may depend on several factors such as computer literacy, appropriate instruments and facilities, users interest and personal attitudes. The works of many researchers have found that information technology is underutilized in many organizations. As results, many theories in field of the Information Systems have been developed to study information technology acceptance. Among these theories and models, Davis (1989) proposed his technology acceptance model (TAM) which revealed that the two most important individual beliefs about using an information technology are perceived usefulness and perceived ease of use. Moore and Benbasat, (1991) suggested that perceived ease of use has a significant influence on perceived usefulness, behaviour attitude, intention, and actual use through their technical acceptance (TA) model. Therefore, authors suggest that excising gap between agriculture information supply and acceptance of information systems can be studied further by using TA models. Hence, further studies are needed to be done to identify the level of usage and drivers of user awareness on this geo-database among the DOA staff. Authors also made following suggestion to develop a mobile app with location data as a next stage of improvement in this geo-database to be better appearance.

CONCLUSION

The geo-database can be used to store and manage the spatially referenced data relevant to crop suitability recommendations. Queries allow visualizing data tables and maps. The coupled capabilities of MS Access and ArcGIS have proved effectiveness in such approaches. The user interface comprises three distinct modes of interrogation: offline desktop software, web base platform and Mobile App that will help to agriculture information dissemination.

REFERENCES

Blaha M. 2005. Referential integrity is important for databases. http://www.odbms.org/wp-content/uploads/2005/11/007.02-Blaha-Referential-Integrity-Is-Important-For-Databases-November-2005.pdf. (Accessed on: 25.03.2017)

Barnolas, M. and M. C. Llasat. 2007, Food geo-database and its climatological applications: the case of Catalonia for the last century. Natural Hazards and Earth System Science, Copernicus, Publications on behalf of the European Geosciences Union. 2007. 7 (2): 271-281.

Barbier Y., P. Lejeune, M. Dufrêne, J. Rondeux. 2009. An ArcGIS-based tool for the relational data management assistance of Natura 2000 habitat units in the Walloon Region, Belgium. 13: 243-248.

Busgeeth K., U. Rivett 2004. The use of a spatial information system in the management of HIV/AIDS in South Africa, International Journal of Health Geographies. 3: 1-8.

Carrion D., A. Maffeis, F. Migliaccio. 2009. A database oriented approach to GIS designing, Applied Geomatics. 1: 75-84.

Choobineh J., S.S. Venkatraman 1992. A methodology and tool for derivation of functional-dependencies from business forms, Information Systems. 17: 269-282.

De Freitas D.M., and P.R.A. Tagliani 2009. The use of GIS for the integration of traditional and scientific knowledge in supporting artisanal fisheries management in southern Brazil, Journal of Environmental Management, 90: 2071-2080.

Dhaka, B.L. and K. Chayal. 2010. Farmers' Experience with ICTs on Transfer of Technology in Changing Agri-rural Environment. Indian Research Journal of Extension Education. 10 (3): 114-118.

Cloban A., F. Matei, I. Pop and A. Rotaru. 2011. The Importance of Geo databases in a Geographic Information System, Bulletin UASVM, Horticulture. 68(2)/2011, ISSN1843-5394

Davis, F. D. 1989. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology, MIS Quarterly. 13(3): 319-339.

Doxani G., K. Karantzalos, M. Tsakiri-Strati. 2012. Monitoring urban changes based on scale-space filtering and object-oriented classification, International Journal of Applied Earth Observation and Geoinformation. 15: 38-48.

Konan-Waidhet A.B., B. Dibi, K.E. Kouadio, I. Savane, N. Valentin and G. Lazar. 2013. Improving food security using GIS database from mechanized rice farms management in North western cote'divoire ,Environmental Engineering and Management Journal 12 (2013), 1: 41-48

Konan-Waidhet A.B., B. Dibi, Z.A. Kouadio , I. Savane, and K.F. Kouame. 2014. Conception of a Geo-database for the Monitoring of Groundwater Quality in Watershed of Ehania, Southeast of Côte d'Ivoire, International Journal of Applied Science and Technology. 4 (6)

Martin P.H., E.J. Le Boeuf, E.B. Daniel, J.P. Dobbins, M.D. Abkowitz. 2004. Development of a GIS-based Spill Management Information System, Journal of Hazardous Materials. 112: 239-252.

Mathiyalagan V., S. Grunwald, K.R. Reddy, S.A. Bloom. 2005. A WebGIS and geo-database for Florida's wetlands, Computers and Electronics in Agriculture. 47: 69-75.

Moore, G. C., and I. Benbasat. 1991. "Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation," Information Systems Research (2:3) 192-222.

Patil, M. E., R. N. Mulchandani, and R. A. Ravikumar. 2012. Design and Implementation of Graphical User Interface for Relational Database Management System, International Journal of Computer Science and Information Technologies. 3 (3): 3871-3874

Peng Y., Y. Zhang, Y. Tang, S. Li. 2011. An incident information management framework based on data integration, data mining, and multi-criteria decision making, Decision Support Systems. 51: 316-327.

Petrisor A.I. 2010. GIS analysis of wetland covered by NATURA 2000 sites, Environmental Engineering and Management Journal. 9: 269-273.

Punyawardena, B.V.R. 2008. Rainfall and Agro ecological zones in Sri Lanka, Agro Ecological zones and watershed handbook Department of Agrarian Development.

Rochfeld A. and H. Tardieu. 2002. MERISE: An information system design and development methodology Information & Management. 6 (3): 143-159

Rochfeld A. and H. Tardieu. 1983. MERISE: An information system design and development methodology. in Information & Management 6(3):143-159 (Accessed on 30. 04. 2017).

Satti S.R., J.M. Jacobs. 2004. A GIS-based model to estimate the regionally distributed drought water demand, Agricultural Water Management. 66: 1-13.

Singh, R. K. P. and Singh, M. Krishna. 2012. Climate Change, Agriculture and ICT: An Exploratory Analysis, ICT for agricultural development under changing climate. pp. 17-28.

Singh P. S., D. Chutia and S. Sudhakar. 2012. Development of a Web Based GIS Application for Spatial Natural Resources Information System Using Effective Open Source Software and Standards, Journal of Geographic Information System, 4, 261-266 http://dx.doi.org/10.4236/jgis.2012.43031 Published Online June 2012 (http://www.SciRP.org/journal/jgis) (Accessed on 30. 04. 2017).

Shu N.C., V.Y. Lum, F.C. Tung, C.L. Chang. 1982. Specification of forms processing and business procedures for office automation, IEEE Transactions on Software Engineering. 8: 499-512.

Tsichritzis D. 1982. Form management, Communications of the ACM. 25: 453-478.

Yang Y., L.T. Wilson, J. Wang, X. Li. 2011. Development of an integrated Cropland and Soil Data Management system for cropping system applications, Computers and Electronics in Agriculture. 76: 105-118.

Yao S.B., A.R. Hevner, Z. Shi, D. Luo. 1984. FORMANAGER: An Office Forms Management System, ACM Transactions of Office Information Systems. 2: 235-262.