Developing a GIS Based Decision Support System for Sri Lankan Agriculture Sector

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1. Introduction

The agricultural sector in Sri Lanka plays a main role in the economic development of the island and it contributes nearly 12 % to the Gross National Products (GNP), generating employment opportunities for more than one third of the labour force and providing livelihood for more than 2,520,000 persons. Moreover, this sector also earns about 23.9 % of gross exports while earning foreign currency (Central Bank Report, 2010), provides inputs to the agricultural processing industry and contributes quintessentially to food security.

Experiences in the past have shown that this sector can generate a surplus that can in turn be invested in other sectors; mainly in the industrial and services sectors and contribute to the development of the overall economy by providing inputs.
The Sri Lankan agricultural sector can essentially be divided into two sub sectors; the plantation agricultural sector; which includes tea, rubber and coconut, focusing primarily on the export market and on the other hand the domestic agricultural sector; which includes paddy, other field crops, fruits, vegetables and sugarcane. In 2004, the domestic agricultural sector contributed 3.4 percent to GDP (Central Bank Report, 2004). Moreover, this sector has remarkably played a vital role in rural areas, where 75 % of the Sri Lankan population lives.

Approximately 50% of the rural population is engaged in agricultural activities. Since most of the poor are stationed in the rural areas, it is posited that there is a close relationship between agricultural development and poverty reduction in Sri Lanka (Prasanna, 2006). In addition to its economic importance, the agricultural sector plays an important cultural and symbolic role in Sri Lankan society.

According to above mentioned facts, it's proven that the agricultural sector plays a vital role in the Sri Lankan economy. There are several factors that affect the quality and quantity of the agricultural production. Several agriculture related agencies contribute to the agriculture development in Sri Lanka. However, they do not have proper Decision Support System (DSS) for better decision making practices. GIS is a decision support tool, which can be applied in a vast scope of subject areas. But so far agriculture

related agencies have limited or no application of any GIS based DSS in their operations. Yet it is important to evaluate the combined impact of these factors to come out with solid decisions.

Decision Support Systems (DSS) are a specific class of computerized information systems that supports decision-making activities. A properly designed DSS is an interactive software-based system intended to help decision makers compile useful information from raw data, documents and personal knowledge, in order to identify and solve problems and make decisions. (www.informationbuilders.com)

A Decision Support System (DSS) is a collection of integrated software applications and hardware that form the backbone of an organization's decision making process. Companies across all industries rely on decision support tools, techniques and models to help them assess and resolve everyday business questions. The decision support system is data-driven, as the entire process feeds off of the collection and availability of data to analyze. (www.microstrategy.com)

This study is based on developing a GIS based DSS for Sri Lankan agricultural sector, combining several vital agriculture related factors.

1.1 Importance of the study

Several DSSs have been developed earlier, for the purpose of managing agricultural activities around the world. There are many government and non government organizations which are involved in the agricultural sector in Sri Lanka. Agricultural development depends on many factors. When considering these factors; it is evident that Sri Lanka lacks a proper system to gather all related information. This situation highlights the fact that there is no Decision Support System for their day to day activities. GIS can be utilized to overcome these types of problems. This tool will help the users, in the agricultural sector, Research Institutions, educational sector; who are working with GIS and even users with non-GIS background, to find related information at GN division level. This will enhance the capacity of the users, to identify the *Suitable Crop, Suitable Place, Suitable Time* for farming and harvesting in Sri Lanka.

1.2 Aims and Objectives

Aims

Combining different agriculture related information systems for effective decision making process

Objectives

Developing a user friendly decision support GIS based tool for Sri Lankan agricultural sector

2. Literature Review

2.1 Introduction

A decision support system is a way to model data and make quality decisions based on it. Making the right decision in an organization is usually based on the quality of data and ability to filter through and analyze data to find trends, through which solutions and strategies can be created. DSS are usually computer applications along with a human component that can sift through large amounts of data and pick between the many choices (www.tech-faq.com). Several DSS has developed for the better decision making practices around the world. There are four requirements of high level DSS (www.microstrategy.com). Those are,

I. Data collection from multiple sources
II. Data formatting and collation
III. A suitable database location and format built for decision support -based reporting and analysis
IV. Robust tools and applications to report, monitor, and analyze the data

2.2 Types of DSS

According to the Power (2002), there are a number of Decision Support Systems. These can be categorized into six types:

i. Communication-driven DSS

Most communications-driven DSSs are targeted at internal teams, including partners. Its' purposes are to help conducting a meeting, or for users to collaborate. The most common technology used to deploy the DSS is a web or client server.

ii. Data-driven DSS

Most data-driven DSSs are targeted at managers, staff and also product/service suppliers. It is used to query a database or data warehouse to seek specific answers for specific purposes. It is organized via a main frame system, client/server link, or via the web.

iii. Document-driven DSS

Document-driven DSSs are more common, targeted at a broad base of user groups. The purpose of such a DSS is to search web pages and find documents on a specific set of keywords or search terms. The usual technology used to set up such DSSs is via the web or a client/server system.

iv. Knowledge-driven DSS

Knowledge-driven DSSs or 'knowledgebase', are a catch-all category covering a broad range of systems covering users within the organization setting it up, but may also include others interacting with the organization.

v. Model-driven DSS

Model-driven DSSs are complex systems that help analyze decisions or choose between different options. These are used by managers and staff members of a business, or people who interact with the organization, for a number of purposes depending on how the model is set up - scheduling, decision analyses etc. These DSSs can be positioned via software/hardware in stand-alone PCs, client/server systems, or the web.

vi. Web-based DSS

Beginning in approximately 1995, the World-wide Web and global Internet provided a technology platform for further extending the capabilities and deployment of computerized decision support. The release of the HTML 2.0 specifications with form tags and tables was a turning point in the development of web-based DSS. The computer server that is hosting the DSS application is linked to the user's computer by a network with the TCP/IP protocol.

2.3 Advantage of DSS

According to Power (2002), there are several advantages of DSS. Those are common advantages of all DSS. Therefore, some of following advantages can get developing a DSS for the agriculture sector.

i. Time savings.

For all categories of decision support systems, users have demonstrated and substantiated, reduced decision cycle time, increased employee productivity and more timely information for decision making. The time savings that have been documented from using computerized decision support are often important.

ii. *Enhance effectiveness*

A second advantage that has been widely discussed and examined is improved decision making effectiveness and better decisions. Decision quality and decision making effectiveness are hard to document and measure. Most research has examined soft measures like apparent decision quality rather than objective measures.

iii. *Improve interpersonal communication.*

DSS can improve communication and collaboration among decision makers. In appropriate circumstances, communications-driven and group DSS have had this impact. Model-driven DSS provide a means for sharing facts and assumptions. Data-driven DSS make "one version of the truth" about institutional operations available to managers and hence can encourage fact-based decision making.

iv. *Competitive advantage.*

Vendors frequently cite this advantage for business intelligence systems, performance management systems, and web-based DSS. Although it is possible to gain a competitive advantage from computerized decision support, this is not a likely outcome. Vendors routinely sell the same product to competitors and even help with the installation.

v. *Cost reduction.*

Some research and especially case studies have documented DSS cost saving from labor savings in making decisions and from lower infrastructure or technology costs. This is not always a goal of building DSS.

vi. *Increase decision maker satisfaction.*

The novelty of using computers has and may continue to confound analysis of this outcome. DSS may reduce frustrations of decision makers, create perceptions that better information is being used and/or create perceptions that the individual is a "better" decision maker. Satisfaction is a complex measure and often researcher's measure satisfaction with the DSS rather than satisfaction with using a DSS in decision making. Some studies have compared satisfaction with and without computerized decision aids.

vii. *Promote learning.*

Learning can occur as a by-product of initial and ongoing use of a DSS. Two types of learning seem to occur: learning of new concepts and the development of a better factual understanding of the business and decision making environment.

viii. Increase organizational control.

Data-driven DSS often make business transaction data available for performance monitoring and ad hoc querying. Such systems can enhance management understanding of business operations and managers perceive that this is useful. DSS provide summary data about decisions made, usage of the systems, and recommendations of the system. Managers need to be very careful about how decision-related information is collected and then used for organizational control purposes. This system can be used in government sector (especially agricultural department) also.

2.4 Decision Support Systems & Agriculture

There are several agricultural related DSS that have been developed for managing agricultural activities around the world. In this section there are brief descriptions about some studies related to the development of DSS for the agricultural activities.

i. Applications of Decision Support Systems in Agriculture (Pakistan)

Applications of decision support systems in Agriculture Pakistan are one of the five major cotton producers of the world. Population growth, in the 60's and 70's pesticides were identified as means for increasing yield in Pakistan. However, existence of an undesirable, sometime even negative correlation between pesticide usage and yield has been observed in Pakistan. Explaining such anomalies is very challenging, because of the very nature of the Agro-Metrological data, which is horizontally wide and vertically deep. Traditional data analysis techniques and expert judgment are not suitable for analysis of such large, multivariate and apparently unstructured data sets. In this context the application of decision support systems in Agriculture, using data mining and other data analysis techniques will be discussed, and demonstrated using real data. (www.sdpi.org)

ii. Web-Based GIS Decision Support System for Paddy Precision Farming (Malaysia)

Web based technology has revolutionized the way that the information is traded or shared across the internet. While e-commerce and information dissemination activities have benefited, there are communities that have been left out due to their inability to purchase commercial web mapping software. A potential solution is through the use of open source technology. However only a few web-based Geographic Information Systems (GIS) are currently developed based on open source for agricultural applications. Generally the web is free, accessible to all people in the world, anytime, anywhere without the need to purchase or software installation (www.gisdevelopment.net).

This study has explored the use of open source software, Minnesota Map Server (UMN), Hypertext Preprocessor (PHP), Apache Web server and MySQL database. The study area selected was the Sawah Sempadan rice growing area in Tanjung Karang, Selangor, Malaysia. The web-based system developed in this research allows the farmers access to the information about rice cultivation in their area. The system allows variable rate fertilizer application maps to be printed for the farmers. Farmers are aided by the historical data about yield per paddy lot and fertilizer application in the previous planting seasons (www.gisdevelopment.net).

This helps farmers to analyze and reflect on the best strategy for the coming growing season. The benefits of this work is that it allows information sharing among farmers especially on recommendations of fertilizer, and to provide equal access to web-based information from end-users to policy makers for improving the productivity and efficiency of rice production through precision farming (PF) (www.gisdevelopment.net).

iii. SSToolbox an Agricultural Spatial Decision Support System

Site-specific precision farming requires a spatial data management system that gives the user powerful decision making tools? a Spatial Decision Support System (SDSS). The SDSS must include tools for seamless storage, retrieval, manipulation, and analysis of geographically referenced agricultural data. "Site-specific tools" are needed to systematically integrate the various components of precision farming technologies, from farm field, to SDSS, back to farm field. SSToolbox an agricultural SDSS developed by SST Development Group, provides agricultural producers, farm input suppliers, agronomists, and crop consultants the necessary spatial and non-spatial data-handling tools needed to turn data into information and perform decision making at the farm level. This paper gives an overview of how SSToolbox functions, as an agricultural SDSS (www.proceedings.esri.com).

Information of all sorts has long been recognized as one of the keys to successful decision making in the management of an agricultural operation. The use of site-specific information is taking on a new importance with the rapid growth of new sources and ways of gathering and delivering data pertinent to an agricultural operation. Agricultural decision makers are beginning to feel a need for information management tools which can aid them in automating the process of turning the mountain of raw data now available into useful information (www.proceedings.esri.com).

Decision makers need these tools to remain competitive as economic and social pressures mount for ever more intensive yet sustainable or "wise" agricultural land use. This need is becoming more urgent, as new crop production technologies, farming practices, and record keeping needs continue to evolve. One of the common threads in almost all information pertinent to management decision making in agriculture is that it usually has some tie to a geographic location-a site-specific or spatial reference (www.proceedings.esri.com).

A GIS enables the user to relate otherwise dissimilar data into a meaningful information base, based on their spatial references, and provides the basis for what can be called a Spatial Decision Support System (SDSS). The effectiveness of such a system can be measured in terms of the degree in which it enables its users to turn raw data into management information for better decision making (www.proceedings.esri.com).

iv. GIS Based Decision Support Systems in Agriculture (India)

Decision Support Systems (DSS) provide a framework for integrating database management systems, analytical models, and graphics, in order to improve decision-making process. The decision support system concept was extended to the spatial context by integrating GIS and DSS into spatial decision support systems (SDSS). Because of lack of computer software to develop user friendly interfaces in the past, GIS have not been used as part of SDSS. Instead GIS have been used to generate and store spatial data which were then used as inputs for the analytical models (www.naarm.ernet.in).

GIS was used independently to display maps by inputting results of the analytical models. Much research has been done on the use of GIS in the visualization of the results of the analytical models. Developing user friendly graphical interfaces in incorporating analytical models into GIS to arrive at SDSSs is one of the active areas in agricultural management. Precision farming, a combination of GIS, GPS receivers, continuous yield sensors, geostatistics and variable rate applicators is an innovative approach to practice of sustainable agriculture. The other SDSS applications discussed in this paper are on watershed management, crop productivity management and policy decision analysis (http://www.naarm.ernet.in).

3. Methodology

The methodology of the study is mainly focused on developing a GIS based Decision Support System for Sri Lankan Agricultural sector. To achieve the set objectives, several steps have been followed (Figure 01).

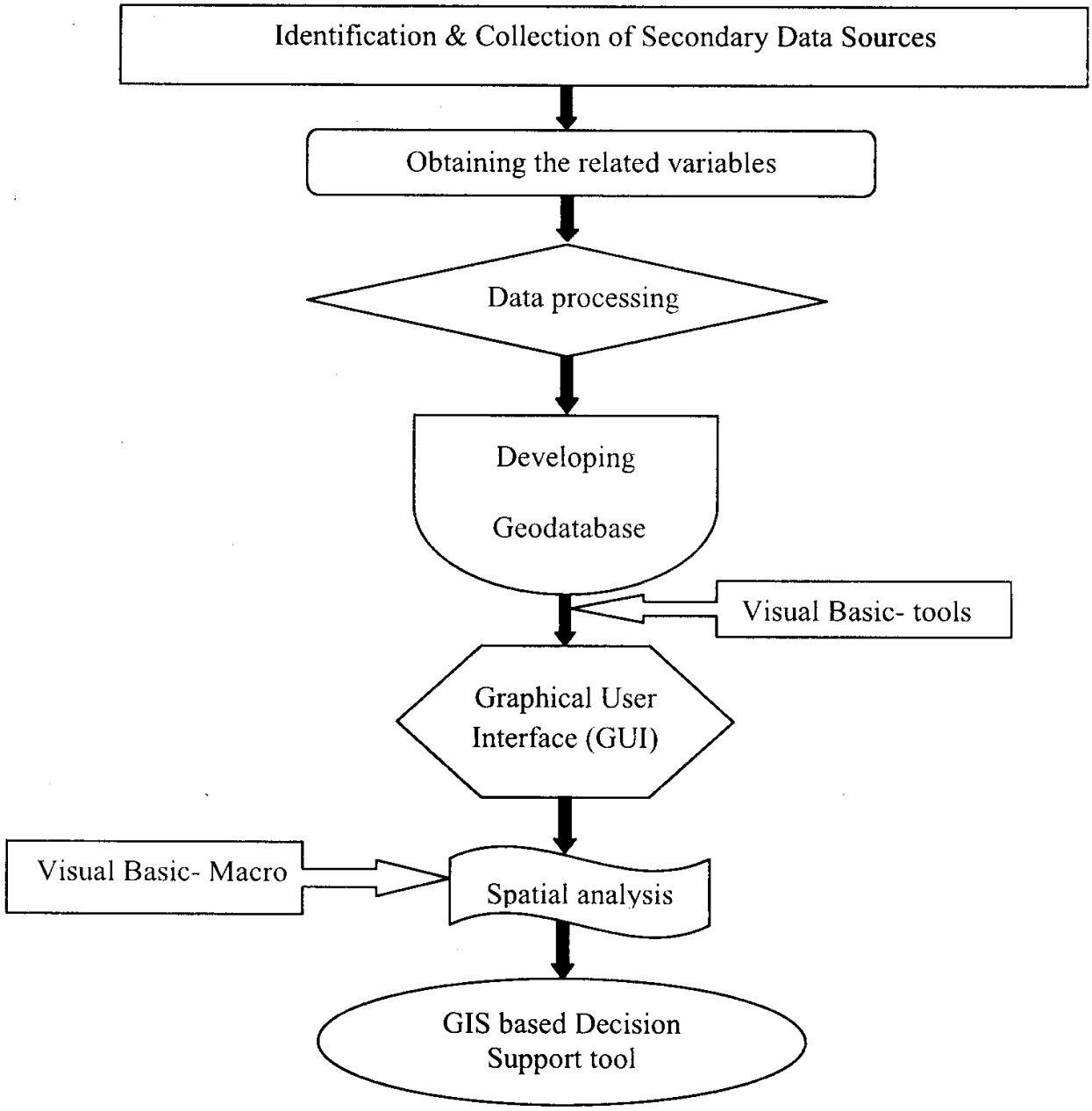


Figure 01: Flow Chart of the Methodology

3.1 Identification & Collection of Secondary Data Sources

Several variables affect the agricultural production. Hence identification and collection of secondary data are important for the development of a DSS, for better decision making practices. After identifying the agriculture related variables, they are categorized into five major groups: as administrative, climatic, geologic, land use & others. Table 01 indicates the secondary data which have been used to develop the expected tool.

Table 01: Data Layers Used for the Tool

Group	Data layers	Source	Year
Administrative	Province	Survey Department	2005
	District	Survey Department	2005
	DS division	Survey Department	2005
	GN division	Survey Department	2005
Climate	Rainfall observation location and rainfall data	Met department	2007
	Agro ecological zones	Met department	2007
Geology	Soil	Survey Department	1992
	River basin Boundaries	Survey Department	1992
	River network	Survey Department	1992
	Tanks	Survey Department	1992
Land use	Land use	Survey Department	1992
Others	Roads	Survey Department	1992
	Village Location	Survey Department	1992

3.2 Data processing

In the next step, data processing is required. Under this section several steps have been followed:

Coordinate Transformation - different agencies are dealing with agriculture related activities, and they do not use a common coordinate system. Some use latitude & longitude while others use national grid systems. Usage of a common coordinate system is valuable for the development of this GIS tool based on Sri Lankan National coordinate system. Furthermore coordinate transformation plays an important role in overlaying the related variables.

Preparation of rainfall amount for GN level – Rainfall observation locations are obtained as points and are presented in a point theme. This tool requires monthly and annual average rainfall in GN Level. Using Inversed Distance Weighted (IDW) Interpolation Method, annual average and monthly rainfall surfaces were created. After that all interpolation surfaces summarized into GN division level.

Preparation of GN level land use types- In Sri Lanka there is a deficit of GN Level information on any type of land use. Therefore it has been a difficult task to track the GN level land use data. This model is in prototypes and in order to overcome the above barrier, ecological zone-wise land use types, published in National Atlas 2009 have been summarized into GN level.

3.3 Preparation of Geodatabase

All GIS data layers and attribute data which have been mentioned in Table 01 are being stored in geodatabase. This database is profoundly utilized for the development of a NADSS.

3.4 Graphical User Interface (GUI)

Graphical User Interface (GUI) is an important component for any kind of user friendly DSS. GUI is developed using Visual Basic (VB) tool. DSS must be a very simple and understandable system, which any one should be able to use without any inconvenience. Visual basic tool gives a valuable combination with ArcGIS to develop a GUI. ArcGIS Geo database combined with VB tool and finally develop a user friendly GUI.

3.5 GIS based Decision Support tool (DSS)

Final object of this study is to develop the GIS based Decision Support Systems for agricultural sector with a spatial analysis component. The spatial analysis component was developed using VB macro. There is no GIS based DSS for our country though Sri Lanka is predominantly depending upon an agricultural related economy. Hence this DSS can be utilized for the agriculture sector for a better decision making process.

4. Overview of Nadss

4.1 Tools and Functions of NADSS

This is a GIS based Decision Support System that can be used by GIS and none GIS users to support better decision making process. NADSS stands for National Agricultural Decision Support System (NADSS). This tool comes with the setup file which can be used for easy setup in any computer; it avoids copying any data in your computer. This NADSS need ArcGIS 9.2 or above version and Macromedia Flash 8 for chart option. When NADSS is clicked, automated file users can see the following window (Figure 02).

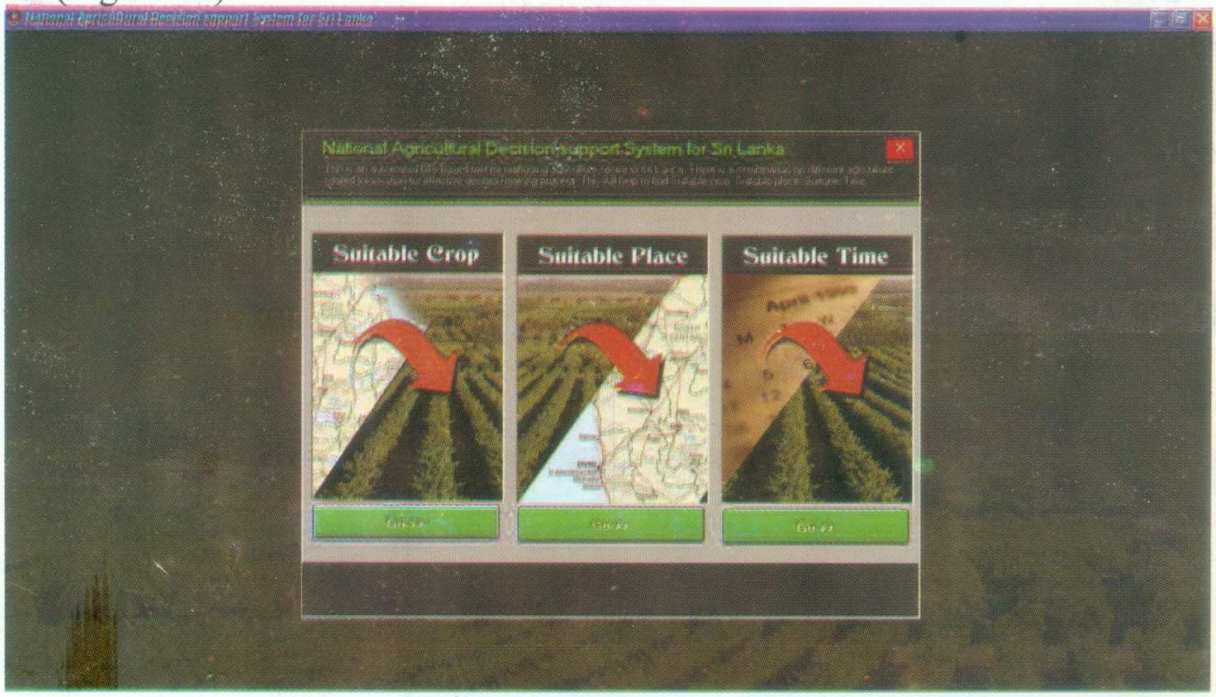


Figure 02: Starting window of the NADSS

Using this window the user can select Suitable Crop, Suitable Place or Suitable Time according to their requirements. By simply clicking the "GO" option the user can get user friendly NADSS tool (Figure 03 & 04). This tool has two main options to help users to get information related to the agriculture sector in Sri Lanka.

Using "By GN" option the user can obtain Administrative area wise data. It has been organized according to the administrative levels of Sri Lanka. Users can select: Province, District, DS division and GN divisions in Sri Lanka. Thereby all agriculture related information with their spatial distribution can be acquired as a Map or in report format.

Using "By XY" option the user can get GPS location data. This is a main component in NADSS tool. Many tools have administrative area wise selection in Sri Lanka. But it is very rare to get GPS location wise tools. Users can enter Sri Lankan National coordinate system data for X and Y locations. Then automatically maps will open and the exact

location of the required coordinates appears as a point. After that, using the "select tool", the user can select administrative boundary and by using "Get data" option all information related to the Sri Lankan Agriculture sector can be observed.

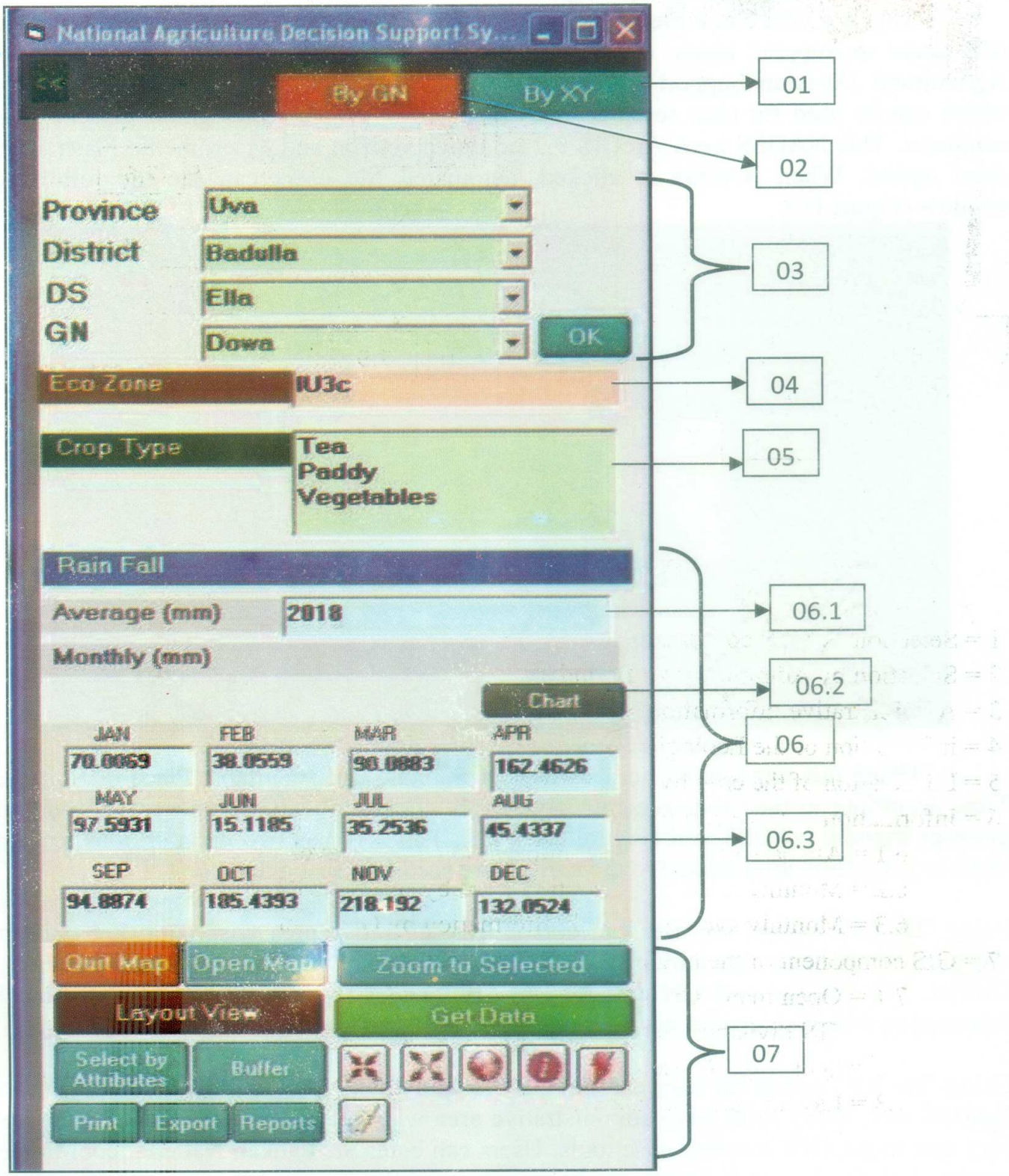


Figure 03: Data Viewing Window

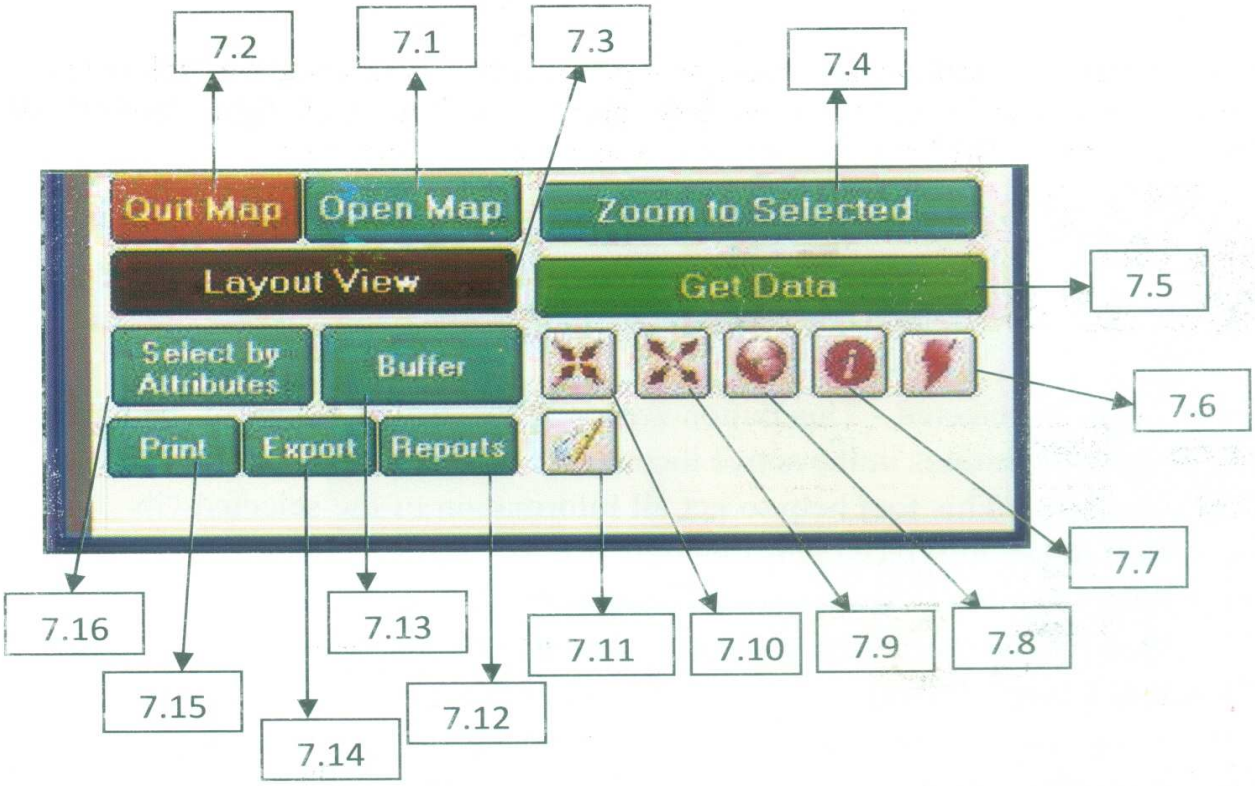


Figure 04: Map Control Window

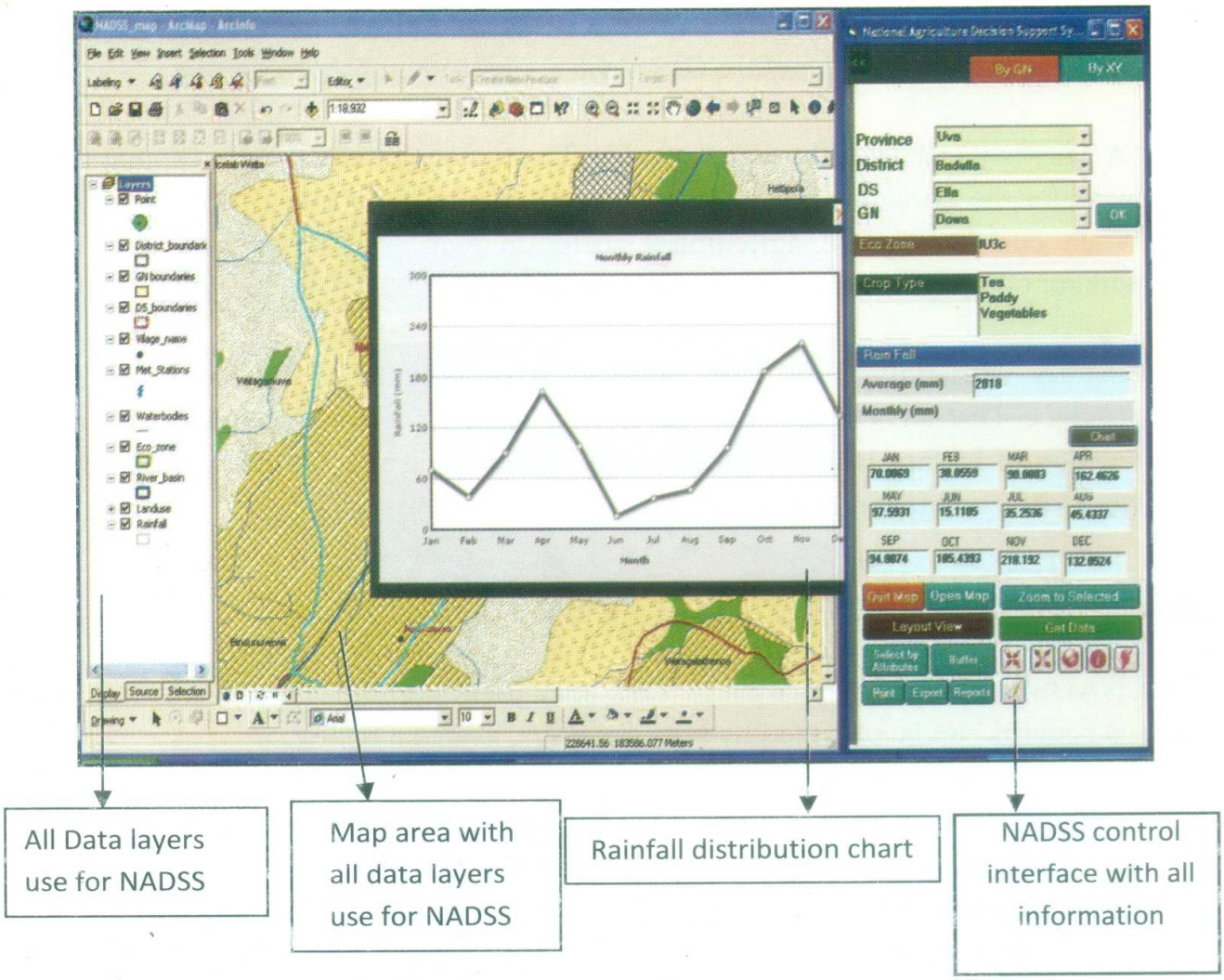
1 = Selection by GPS coordinate
2 = Selection by Administrative Boundary
3 = Administrative Information
4 = information of the Ecological Zone
5 = Information of the crop by GN level
6 = Information of the Rainfall distribution
    6.1 = Annual average rainfall information by GN level
    6.2 = Monthly rainfall distribution chart by selected GN
    6.3 = Monthly average rainfall information by GN level
7 = GIS component of the NADSS tool (spatial data management component)
    7.1 = Open map - Open ArcGIS software and automatically zoom to the selected GN divisions or coordinate
    7.2 = Quit map - Close ArcGIS software
    7.3 = Layout view or Data view -

Layout view - The arrangement of elements on a map, possibly including a title, legend, north arrow, scale bar, and geographic data.

Data view - An all purpose view in ArcMap and ArcReader for exploring, displaying, and querying geographic data. This view hides all map elements, such as titles, north arrows, and scale bars.

7.4 = Zoom to selected - This button zooms to the spatial extent of the currently selected features in the active theme(s).
7.5 = Get data - This tool help to get all information of the selected GN division to NADSS interface (This tool only use for "By XY" option)
7.6 = Select features - Always select features by clicking or dragging a box
7.7 = Identify - Identifies the geographic feature or place on which you click
7.8 = Full Extent - Always you to zoom to the full extent of your map
7.9 = Zoom out - Allows you to zoom out from a geographic window by clicking a point or dragging a box
7.10 = Zoom in - Allows you to zoom in to a geographic window by clicking a point or dragging a box
7.11 = Measure tool - Measures distance on the map
7.12 = Report - user can get a detail report for the selected GN division
7.13 = Buffer - User can create a buffer of selected GN division or GPS location
7.14 = Export - User can export map as an image format
7.15 = Print - This command direct printing map
7.16 = Select by attribute - This option help to select features on the data base

The above is a detailed but brief account of the details of the tools and the functions of the NADSS. There are several options for users to get information for their decision making practices. GIS and non GIS users can easily use this NADSS. NADSS interface facilitate users to control ArcGIS interface according to their requirement. Figure 05 describe all components in NADSS with GIS, chart and NADSS interface.



4.2 Why We Need GIS for NADSS

This NADSS tool is a combination of agriculture related variables in Sri Lanka. This tool is based on GIS, which is developed as a user friendly system. There are several reasons behind the utilization of GIS for NADSS.

Agriculture depends on several spatial variables such as climate, elevation, soil, geology, water availability etc. According to the *Burrough (1986) GIS is a* powerful set of tools for collecting, storing, retrieving, transforming and displacing spatial data for the real world. Therefore the use of GIS gives considerable benefits for NADSS. Water availability predominantly depends on rainfall variation. Hence suitable crops for the area are depending on the amount of rainfall achieved. This kind of spatial variables can be easily analyzed and visualized using GIS. Spatial variation of the

monthly rainfall distribution pattern can be identified and plotted using charts available in the tool. Therefore GIS plays a vital role in NADSS.

"A Map is worth than thousand words". This statement clearly shows, that the use of maps for the decision making process is much more important than a lengthy report. When considering the agricultural sector, a map plays a crucial role; therefore without GIS it makes no sense to talk about maps.

NADSS is mainly built with administrative boundaries of Sri Lanka such as Province, District, DS division and GN divisions. If anyone interested in finding the location of his/her land, it can be easily found using this NADSS, because NADSS has a GIS component to assist them.

4.3 Benefit of NADSS

This NADSS facilitates the user to find all agricultural related information. Hence, several benefits can be obtained by NADSS users, as listed below.

In the Sri Lankan context, there is no any agriculture related organizations, using all agriculture related variables in a single database or a tool. This is a great barrier for a sound decision making process. This tool is a collection of both spatial and non spatial data in agriculture sector. Therefore this NADSS tool will essentially contributes as a fine database for their decision making practices.

Any user can get all related information very speedily. Hence when someone needs to make a decision, they don't need to go in search of data. Users can easily get all the information in one database. Therefore this tool is both cost-effective and time-effective and enhances effectiveness of the workers too. Thereby NADSS help users to increase the employee productivity and while acquiring more timely information for decision making.

GIS is also vital for the agricultural management activities, as it is dealing with spatial data. Therefore NADSS tool has developed with a GIS component. But non GIS users can also tool for their activities by using GUI. GUI will assist them in achieving their requirements easily.

This tool has powerful data exporting facilities. Users can get spatial information as a map or a report. Especially using chart option, monthly rainfall distribution pattern can be clearly plotted. Users can select the area of their choice and can easily export as a map with administrative boundaries, other information as a report and rainfall distribution as a chart.

All agricultural related government and non government agencies can use NADSS. Therefore they can work with "one version of the truth" for the better development for agricultural sector. It opens avenues for the users to improve interpersonal communication and collaboration among decision makers. If all related agencies can use common DSS for their day to day activities, it inevitably helps to buildup comparative advantages among them.

NADSS is a combination of all related variables and therefore no need to search all directions to find information which decision makers want. And there is no need to file all information in manual form. NADSS is cost effective which saves intense requirement of labor in making decisions and also lessens the infrastructure or technology costs.

NADSS may reduce disturbances for decision makers, create perceptions where better information is being used and/or create perceptions that the individual is a "better" decision maker.

NADSS provide summary information what decision makers want. Hence it is easy to handle a system with small staff and it will also help to direct the organization towards one target. Managers need to work with caution about how decision-related information is collected and then used for organizational control purposes without proper DSS. But NADSS will help managers to relax their minds.

Conclusions

NADSS is a collecting, analyzing and visualizing tool of the agriculture related spatial and non spatial variables of Sri Lanka. The decision makers will be very comfortable when there are enough data to make their decisions. This is a GIS based tool, which anyone can use for their specific agriculture related requirement. If anyone wants to find information of the GN division, he/she can simply go to NADSS tool and find all administrative boundaries, suitable crop types, rainfall, ecological zone, river basin and village names easily.

Recommendations

It is recommended that the NADSS tool should undergo many further developments. It is better to implement this NADSS in small scale agricultural industries and then the users can come forward with their comments. Thereby it can be easily developed into a more useful level. NADSS can be used for government and non government organizations for better decision making processes.

This is the basic level of NADSS. Hence following developments can be suggested to make it more applicable in future.

NADSS does not have solid Land use data. Ecological zone wise land use types, published in National Atlas 2009 summarized into GN level has been used here. In the future this can be developed for district levels with real suitable crop types.

Agriculture mainly varies with the underlying topography. Therefore elevation data can also be added to this system.

This level NADSS has been developed for administrative and GPS location wise information. In the future it could be developed with crop wise and time wise selections.

NADSS have both GIS and non GIS components. In the future all information (Selected GN divisions of GPS location) will be able to be published with Google Earth.