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GIS Technology for Agricultural Management of Tank Irrigation Systems in South India

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Abstract For many centuries village tanks have been the backbone of the village economy in South Asia. Tank storage structures are the prime water source to store rainwater and help farmers during crop growing period and provide stability to agricultural production. This resource has to be utilized properly by carrying out the On Farm Developmental works in its command area. The objective of the present study is to develop a GIS based Agricultural management of tank irrigation information system to facilitate the planning, operation and management of tank system. The study area selected was the Maragathapuram tank in Villupuram district served by the Ponnaiyar River. Developing agricultural tank information system involves the collection of various information of the command area. This information can be recorded and stored as different layers in GIS in the form of spatial and non-spatial data and GIS has the capability of integrating and analyzing spatial, non-spatial and multi-layered information available in different formats in framing various strategies for agricultural management and for socio-economic development. GIS based information system is also capable of generating outputs in the form of maps, tables and graphs that will help the irrigation engineers, agriculturalists, farmers and Government officials to monitor their performance of the tank at any place and time and take necessary steps to manage the resources effectively.

Keywords *Tank Irrigation; Agriculture; Information System; GIS; Framing Strategies; Managing Resources*

1. Introduction

Water is the primary resource for agriculture. The major source of irrigation in Tamil Nadu is mostly by tank water [1]. Tanks are low earthen bund which is constructed along slope of a valley or terrain to store the rain water. In Tamilnadu there are 39,202 tanks spread all over the state. A tank system comprises of catchment area, feeder channel, tank bund, water spread area, sluice outlets, command area, field distributaries and surplus weir. In recent years many of these tanks have started showing signs of big damage to their potential utility because of heavy siltation,

excessive pollution and encroachments. The potential returns from tank irrigation system was evaluated and concluded that tank irrigation is a profitable technology in economic, environmental and social terms but under present conditions of management it is rapidly deteriorating [2]. The tank irrigation system performance was evaluated in terms of economic output and revenue generation for irrigation and other uses [5]. The results indicate that irrigation and other productive uses put together raised the total value of output at tank level by 12% in 1996-97 and just 6% in 2009-10. Hence it is necessary to formulate agricultural management works of tank command area in a systematic, scientific and technical manner synchronously to achieve the sustained development by efficient utilization of the tank water [10].

Information plays a crucial role in the management and efficient utilization of resources. So, it is necessary to develop an information system for carrying out sustainable development [3]. A well-designed and comprehensive tank information system will result in substantial improvement in the efficiency of the agricultural sector and will also lead to better planning [6]. An interactive information system will facilitate the operation and management of resources effectively [7]. GIS with its capability of integration and analysis of spatial, a spatial, multi–layered information obtained in wide variety of formats has proved to be an effective tool in planning and managing the agricultural activity in the command area [8]. GIS is now being utilized not only as a system to monitor the rehabilitation process but also to measure changes in agricultural patterns and its management [11]. GIS and GPS technology are the most effective in examining the problems associated with the tank irrigation systems and to analyze rehabilitation works [4]. The significant benefit of GIS technology is its ability to visualize spatial data, to interpret information visually and to improve intuitive understanding of the distribution of and interrelationships among phenomena. GIS will be capable of delivering accurate, useful and timely information to various applications [9].

2. Materials and Methods

2.1. Study Area and Database

The study area taken is Maragathapuram village tank of Villupuram district in Tamil Nadu, India served by the Ponnaiyar river. It is located at the head reach of Ellis Choultry Anicut System. There are four sluices in Maragathapuram tank. The registered ayacut (command area) of this tank is 265.87 ha which is spread over the two revenue villages, Maragathapuram (whole) and Kandiyamadai (a part). In this study, all the required spatial and non-spatial data about the command area were collected for Maragathapuram tank and a digital database has been created in GIS environment. The secondary data collected are Command area map, rainfall data, ground water level data of the observation well, soil information and hydraulic particulars of Maragathapuram tank. In primary data collection, farmer's response survey directly from the beneficiaries had been carried out. For this a well-designed questionnaire had been prepared. Questionnaire was focused mainly on three aspects namely irrigation, agricultural and socio-economic aspects. Land parcel boundary was used as the primary database for the command area. The database consists of two components (i) Spatial data representing the distribution of features in the command area and (ii) attribute database representing agricultural, irrigation and social data of each of the land holdings. The spatial database was created using ArcGIS.

2.2. GIS Technology for Agricultural Management

GIS got a major role in developing the information system that is being adapted to the kind of decision and management functions that lie at the heart of the planning process of any development activities. Handling and analyzing data that are referenced to a geographic location are key capabilities of a GIS, the power of the system is most apparent when the quantity of data involved is too large to be handled manually. There may be hundreds of factors or thousands of

features to be considered, or there may be hundreds of factors associated with each feature or location. These data may exist as maps, tables or even as lists of names and addresses. Such large volumes of data are efficiently handled using GIS. Spatial analysis, the study of geographic features, and the relationships that exist between them can be applied to many areas of the agriculture sector. By better understanding how features within the landscape interact, decision makers can optimize operational efficiency and improve economic returns. GIS is becoming fully integrated and widely accepted for assisting government agencies to manage programs that support farmers and protect the environment.

As the Agricultural management of tank command area involves with spatial data, the database created (spatial and non-spatial) can be linked effectively only with the GIS concepts. The ability to manipulate, integrate and analyses the spatial data and its corresponding attributes at high speed is unmatched by any manual methods. Development of Agricultural Management Information System provides tools to handle, store, process, distribute and interpret the command area related data for assessment. The GIS based Agricultural management information system consists of menu driven modules for accessing, organizing, analyzing and displaying the tank command area information. The structure of the information system is shown in the Figure 1. Visual Basic was used as front end, MS access as back end for handling the attribute data and Arc GIS for maps. Object linking technique was used to link the ArcGIS maps and Access table and graphs with Visual Basic. Agricultural Management system is compiled with the Land System database integrated with all possible data available on the Agricultural tank command area. The database developed can be analyzed to identify a set of parameters together. Spatial analysis can be carried out to identify land unity matching with parameters. The Agricultural Management information system comprises of the following modules and shown in Figure 1. Each module has menus and submenus to access the relevant information of that particular module.

A. Water Resource module;
B. Agricultural module;
C. Irrigation module; and
D. Socio-economic module

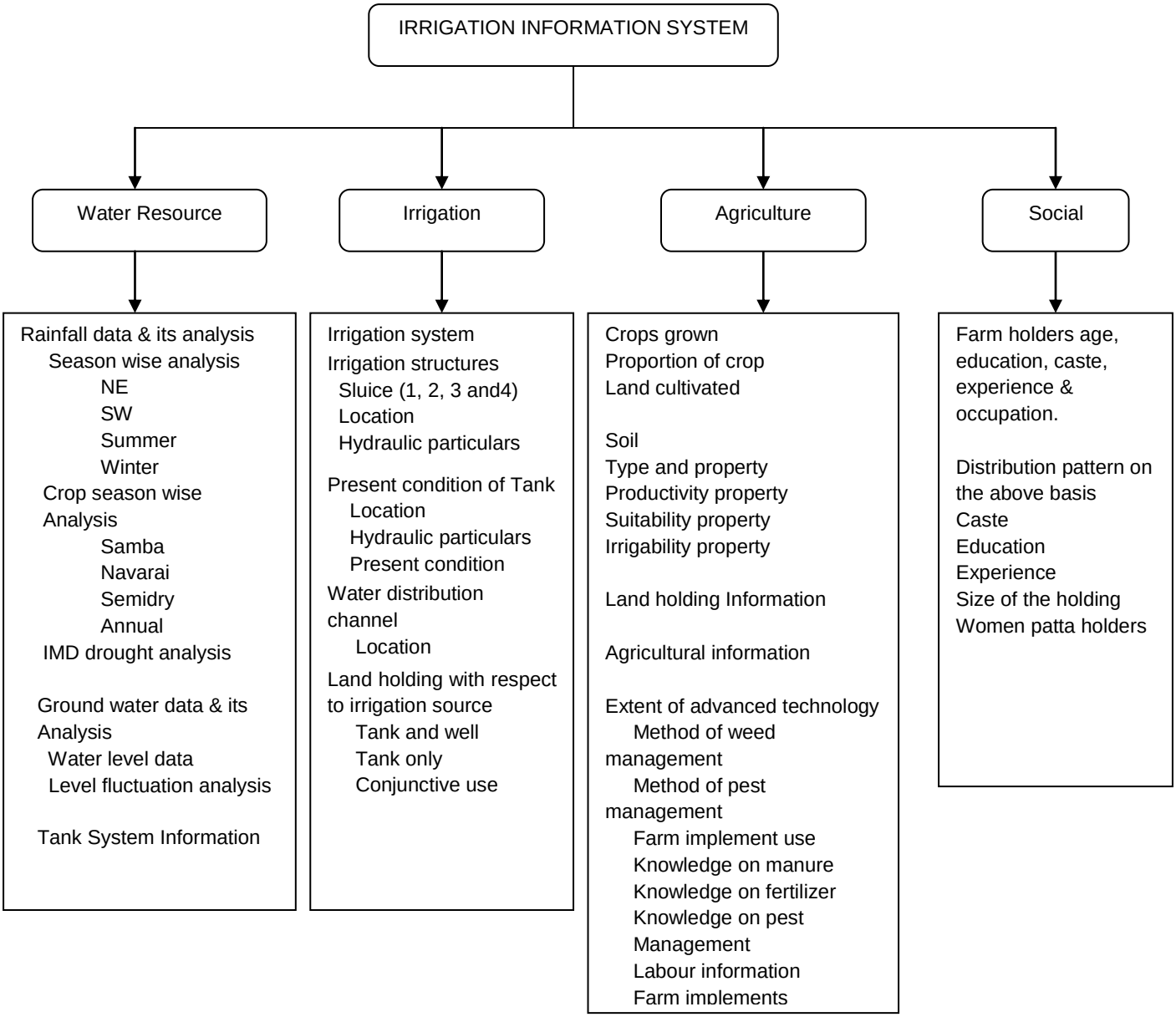

Figure 1: *Structure of GIS based Agricultural Management of Tank Irrigation Information System*

A. Water Resources Module

The water resource database module has the menus to display the water resource related information in the form of tables and analysis graphs. Mean monthly, monsoon seasonal and crop seasonal temporal rainfall pattern were determined for the study area, which are presented in the form of tables and graphs. The water resource database has information on rainfall, groundwater and specification of the tank details respectively. Rainfall menu consists of four submenus namely rainfall data, season wise rainfall distribution, crop season wise rainfall distribution, meteorological drought analysis and classification for the study area. The season wise rainfall analysis distribution consists of submenus of Northeast, Southwest, Summer and Winter. The graph showing the rainfall distribution over the years in the command area for that particular season can be obtained as shown in Figure 2. Similarly crop season wise rainfall analysis has submenus of Samba, Navarai, Summer (semi dry) and Annual respectively based on the crop season adopting in that command area. Each of this crop season will show the rainfall distribution pattern over years for

that particular crop season. The submenu of IMD drought analysis will provide information on the drought condition of the command area.

Groundwater menu consists of submenu of ground water level data and level fluctuation analysis of the observation well in the command area. This method of computation of ground water level fluctuation is a true reflection of the input and output from the ground water regime and is utilized in computation of ground water resources assessment. A geology and hydrogeology submenu gives the general information about the geology and hydrogeology information of the tank command area as a whole. Tank menu provides the general information about the tank system. The information in this module will help the water resource organization of public works department for carrying out the planning and implementation of irrigation structures and rehabilitation measures depending upon the requirement. It will also help the agricultural officers to know the availability of water resource potential of both surface and ground water and according to which they can suggest the cropping pattern.

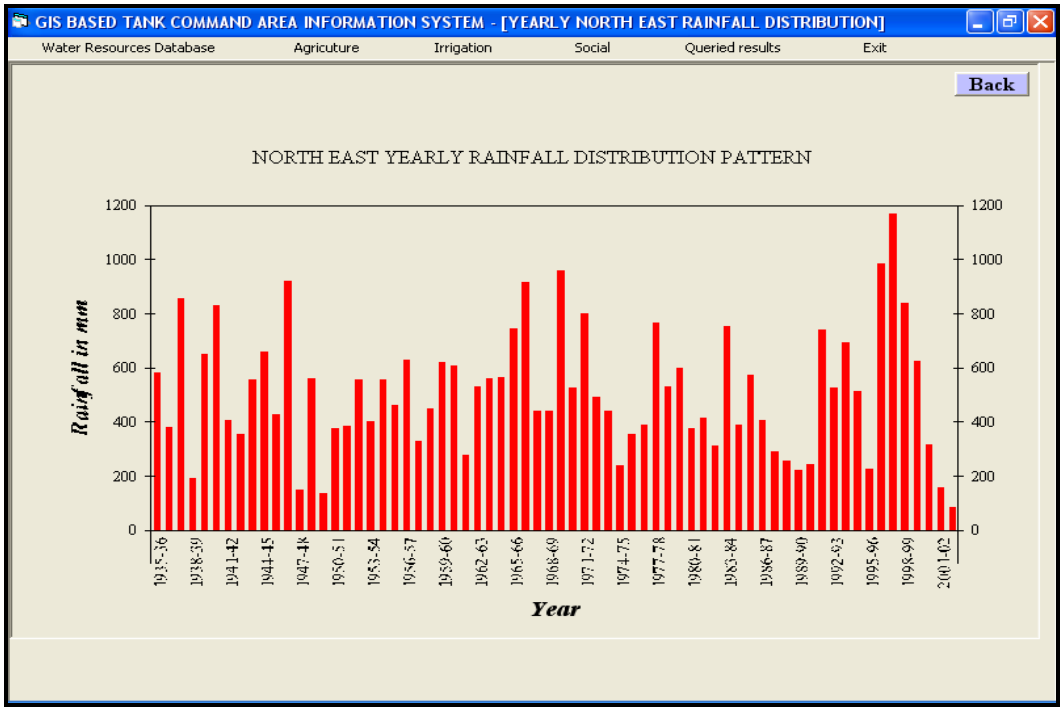

Figure 2: *Graph of Northeast Rainfall Distribution in the Tank Command Area*

B. Agriculture Module

This module consists of five menus for information about the crops grown, soil information, land holding information, agricultural information and extent of the transfer of advance technology respectively. First menu gives the information about the crops grown in the command area, which have land cultivated submenu, shows the land holdings that are cultivated in various seasons and the lands that were not under cultivation and proportion of the area under each crop submenu gives the information about the crops grown in the land holdings in that season as shown in Figure 3. Crop water requirement for different crops information along with data of water availability during entire year, crop calendar, soil suitability also can be accessed. Paddy is cultivated in the entire command area in the first season and is followed by a second crop of paddy if adequate water is available in the tank. Whenever the tank water supply is not sufficient enough, well owning farmers prefer to grow groundnut, ragi, pulses and also vegetables to a certain extent. Sugarcane cultivation is confined to farms having wells with sufficient water supplies. This menu provides land

use information, land suitability maps based on natural and social factors and information on the distribution of transmigration villagers. The information system developed led them to the evaluation of potential agricultural land and compilation of the possible agricultural development maps.

Soil forms the most important non-renewable natural resource determining the success of agriculture. Second menu is incorporated with Soil information containing information for researchers, planners, and scientist. It consists of information about the type of soil in the command area and its properties related with land capability, irrigability, productivity and crop suitability details. The third menu has the information on land holdings, which tells about the type, patta number and owner of each land holding and also gives the land holding map. Parcel level information can be the had in this menu by clicking the relevant land parcel or owner and the information is displayed in the forms designed for the specific table of information. The agricultural information menu gives the information of agricultural related activities of each of the land holding. Agricultural information such as crops grown, cultural practices the landholders adopt and the farm implements they use can be obtained from this menu by clicking the relevant land parcel or owner. Extent of transfer of advanced farming technology menu gives information on various aspects such as levels of inputs used, mechanization the farmer adopt in their fields, method of crop culture adopting in each of the land holdings can be obtained, for example Information regarding source of seed for the land holding as shown in Figure 4. Information in the module will help the Survey and land Record department for referring. Agricultural and Agricultural Engineering department can be better benefited by the information of this module to carry out any agricultural related developmental and management activities in the command area.

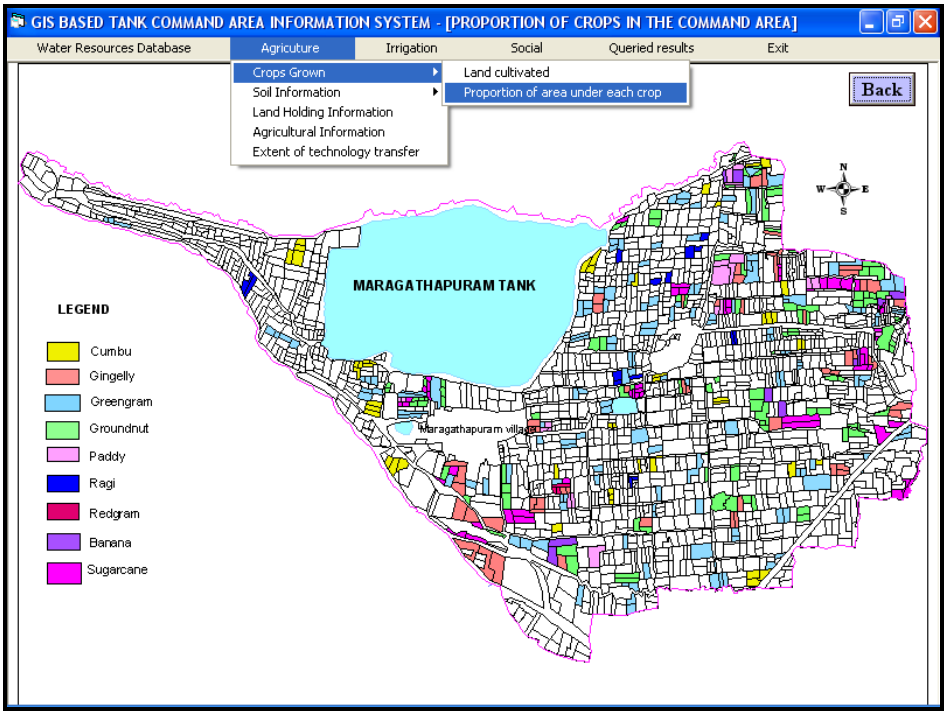

Figure 3: *Information on Proportion of Area under Each Crop in the Tank Command Area*

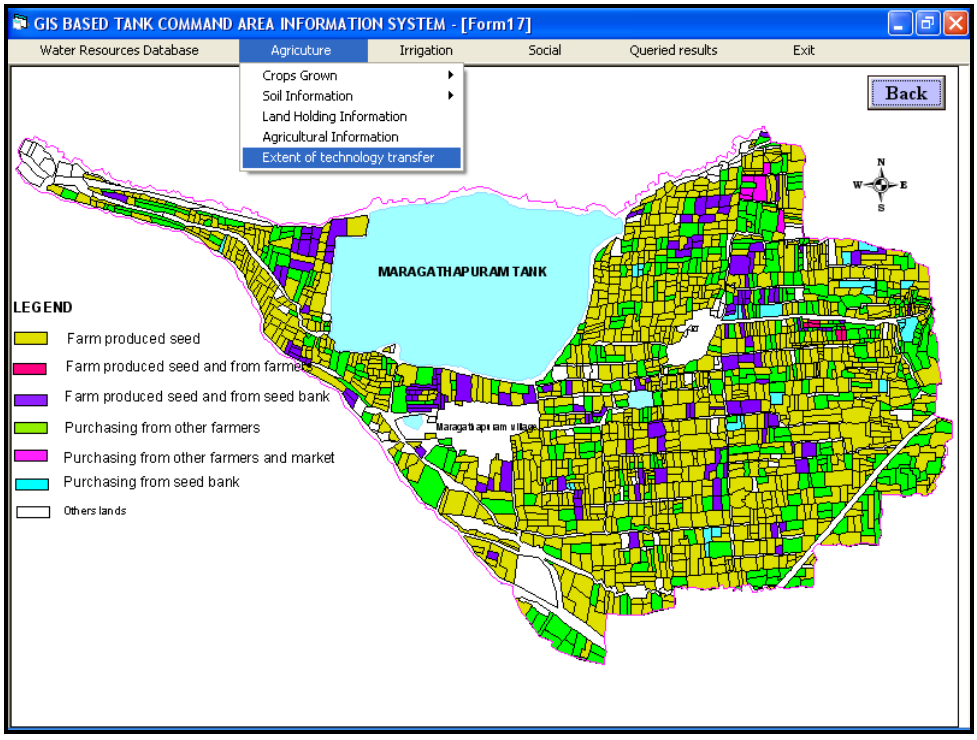

Figure 4: *Information on the Source of Seed for Each of the Land Holdings*

C. Irrigation Information Module

This module consists of three menus for information on irrigation related activities in each of the land holding, the irrigation structures, irrigation source wise area distribution respectively. General information on irrigated related activities menu gives the information about the source of irrigation, if well means Hp of motor, type of well, depth of well, reach of the land holding from the tank, method of irrigation practices as given in Figure 5. Irrigation structure menu provides access for information about the structures such as location of irrigation structures like tank, sluices, water distribution channels and wells in the command area. It also describes about the particulars of each structure such as hydraulic particulars of the tank, sill level and the area served under each sluices. This menu also provides information about the present condition of each of these structures. The condition of Sluice 2 can be obtained as shown in Figure 6. Information on land holding classification based on its irrigation source such as areas that are irrigated by tank water, well water and both tank and well water can be obtained. This menu also gives the information of the land holdings that are making conjunctive use of surface and ground water. There are four sluices in the tank for serving the command area. Information about the landholding covered under each of the sluices also made accessible from this menu. This module will help the water resource organization to plan, operate and maintenance of the irrigation systems.

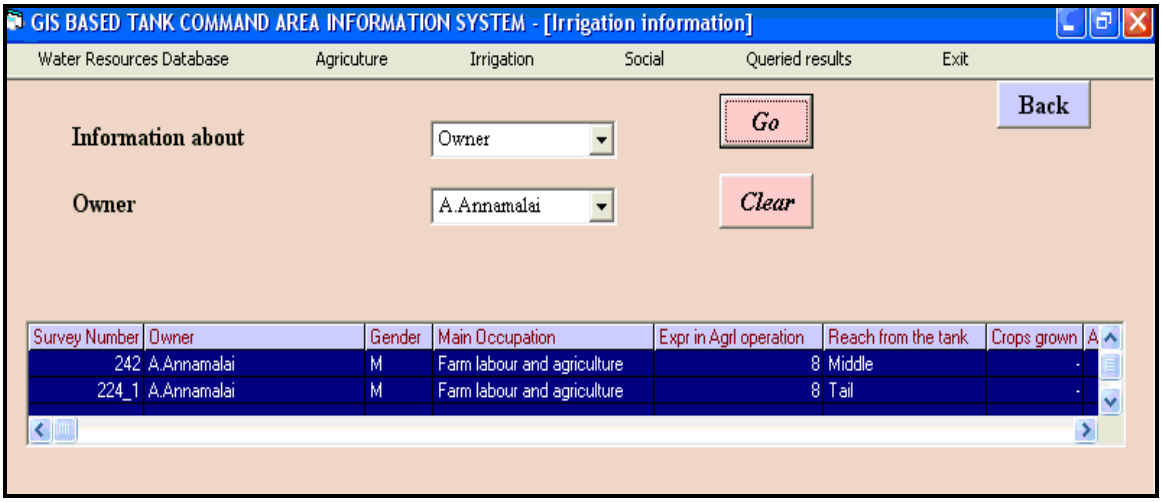

Figure 5: *Menu Showing the Irrigation Information of the Landholder*

Figure 6: *Menu Shows the Condition of Inlet and Outlet of Sluice 2*

D. Socio-economic Module

This module consists of information about the social aspects of land holding farmers such as caste, literacy level, age, occupation and their experience in agricultural operation which is available in tabular format and classification of land holding with respect to caste, education as shown in Figure 7, experience in agricultural operation, size of holding and women patta holders as shown in Figure 8 can be obtained respectively. Agricultural officers can get the information about the experience of the farming farmers with which they can conduct training programs. This module will also provide information to the Administrative officers to carry out any activities related with the upliftment of farming community based on their literacy level and their occupation.

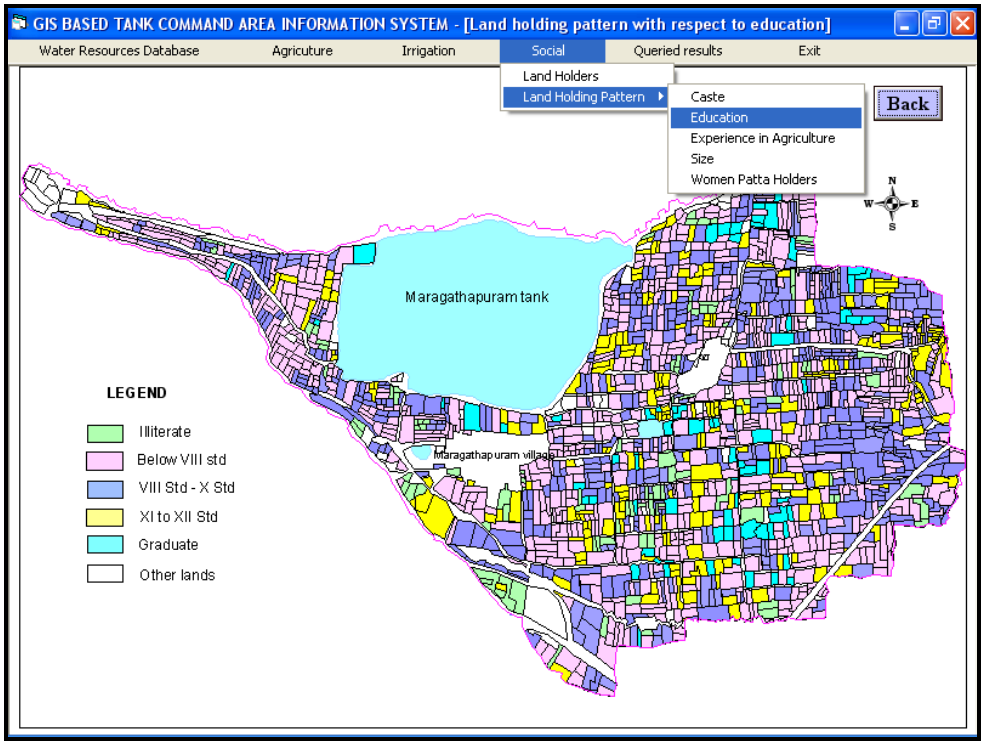

Figure 7: *Land Holding Pattern with Respect to Education of Land Holders*

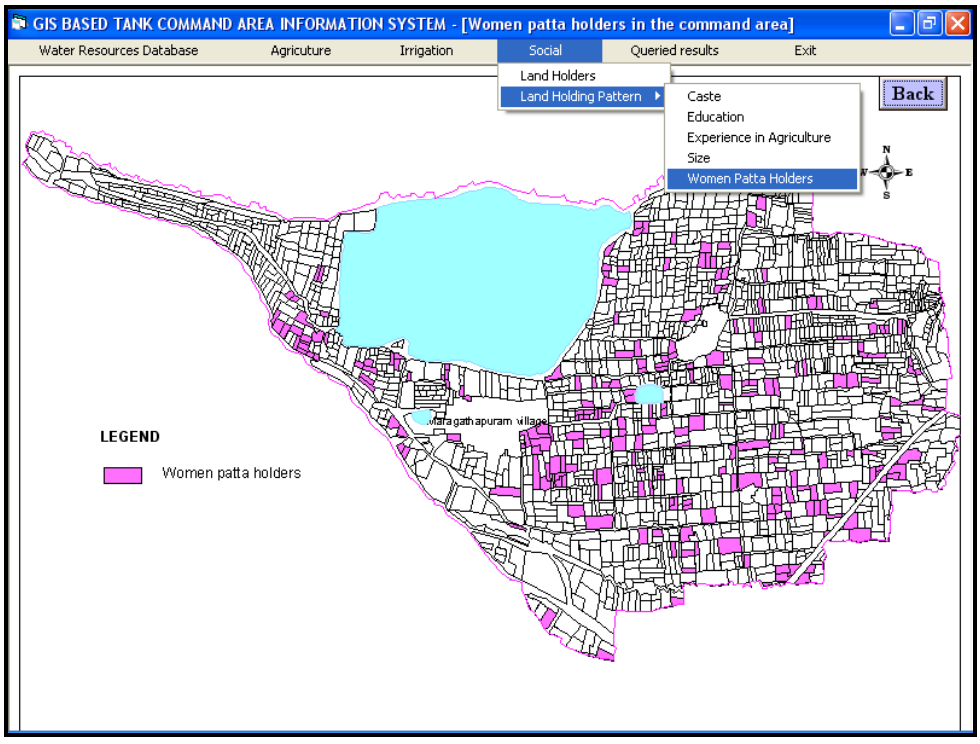

Figure 8: *Distribution of Land under Women Patta Holders in the Command Area*

3. Results and Discussion

A flexible and user friendly information system developed will assist planners for village level planning with reference to managing the resource of Maragathapuram tank command area. Furthermore the spatial analysis tool of the system is a handy option for the planners to correlate

spatial information. Agricultural management information system needs only the maintenance and updates of spatial as well as attributes data if changes occur in existing cropping patterns and management practices, it has become a valuable and cost-saving tool for decision-making. In natural resource management, there is a great need for timely and accurate information about what is on the ground. The task of optimal resources management and sustainable development has been greatly synergized by the enhanced speed and reliability with which spatial and temporal information is generated. Designing the GUI and data layer presentation help the landowners to use the data and information more easily. The information system gives access to data for agricultural resource management and to foster a better understanding of the local agricultural resource base.

4. Conclusion

Development of the agricultural management information system will help in effective use of the resources available for agricultural development. It also serves as a powerful media to create awareness about the various agricultural and command area related developmental activities visually to the farmers. This helps the engineers, agriculturalists and irrigation managers to understand the water needs and to develop schedules, operating procedures and maintenance requirement to maximize the benefit from the farm land. Also help them to develop and conduct training programs for the farmers by combining multimedia with the information system. Provide Information to various users such as Public Works Department for operation and maintenance of the irrigation systems, Revenue Department for the tax collection and Electricity Board for electric charges. It is important, for an agricultural country like India, that the classification of agricultural land, its measurement, the assessment of its produce and maintenance of land records are properly maintained and updated. It can be better used to channelize the existing manpower, resources and infrastructure right from the village level in a proper manner. The methodology thus developed for Agricultural management of tank command information system with the GIS concepts is found to be effective in utilizing the resources and for sustainable agricultural development

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