DOMIS: a decision support system for design and cost estimation of micro-irrigation systems

Neelam Patel[1,*], T. B. S. Rajput[1], Deepak Kumar Dinkar[1], Sita Ram[2] and Sushil Kumar Singla[3]

[1]Water Technology Centre, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India
[2]National Bureau of Soil Survey and Land Use Planning, Salt Lake City, D. K. Block, Sector-II, Bidhan Nagar, Kolkata 700 091, India
[3]Department of Land Resources, NBO Building, G-Wings, Nirman Bhawan, Moulana Azad Road, New Delhi 110 011, India

The decision support system (DSS), namely Design of Micro Irrigation Systems (DOMIS) has been developed to design drip, sprinkler and micro-sprinkler irrigation systems. This provides expert opinion for optimal layout plans for MI system design by using the necessary data on crops, soil characteristics, groundwater and agri-climatic conditions as default options with a provision to modify as preferred by the user. The design includes selection of pipe sizes, pumping system, filters and fertilizer application systems along with possible shifts per day in case of sprinkler irrigation system and total time of irrigation. The web-based system (http://domis.iari.res.in) uses scientific algorithms and expert suggestions; the flexibility of DSS and ease of use make the DSS-DOMIS a superior tool for designing micro-irrigation systems with a view to enhance water productivity in agriculture. It also provides general information about different Government schemes, central and state agencies promoting micro irrigation, approved system suppliers in different states and general information about different districts in the country. The DSS helps farmers as well as policy makers and researchers obtain optimal design and cost estimates of a micro-irrigation system.

Keywords: Decision support system, DOMIS, micro-irrigation software, micro-irrigation system design, precision farming software.

WITH increase in efficiency of agricultural production system, we can meet the demand of food, fuel, fibre and feed. Return per unit of investment is a measure of efficiency in the water resources and the agricultural sectors[1]. Decision making is restricted in performance appraisement of crop yield. Fields will be evaluated based on their yield, nutrients, energy, return per unit input of water and impact of improved genetics as well as management practices[2]. Precision agriculture (PA) is formally interpreted as the 'electronic monitoring and control applied to data collection, information processing and decision support for the temporal and spatial allocation of inputs for crop production'[3]. PA expertise helps a farmer's decision making, related to the use of applicable fertilizer, based on type of soil texture, grown crop and their properties and pesticides used for different diseases. These types of expert advices are analysed based on agricultural engineering formulae, algorithms and agri-climatic conditions. The system will affect the quality and quantity of crop, its environmental impact and profitability[4]. Water is becoming scarce globally[5]. In India the water requirement is expected to increase to 1178 BCM (billion cubic metre) in the year 2050 from 708 BCM in 2010. On the other hand, the groundwater recharge is only 433 BCM. Most of the irrigation water is applied on the land surface in India. Water-use efficiency can be greatly increased by micro irrigation[6,7]. In order to produce 'more crop per drop', farmers are adopting the latest micro-irrigation techniques to save water. In the modern irrigation system, water is applied in the root zone of crops, which helps save large volume of water[8]. The irrigation company, i.e. the system provider or the farmers manually design the micro-irrigation system. Micro irrigation is one of the most recent innovations in irrigation which gives the precise water application in agriculture[9]. This process sometimes consumes more time in design due to lack of agricultural engineering practices and scientific knowledge and often results in inefficient designs.

With the development of internet worldwide and particularly with its increase in developing countries, web-based decision support system (DSS) applications open new vista for the use of software in agriculture with its advantages in server side maintenance of application software and, from the users' point of view, real time update of dynamic data required by the DSS. 'A decision support system is an algorithmic way to any decision-making process, which integrates various databases, modelling tools that are useful in analysing and providing several set of alternatives[10]. Offering a decision means helping the user generate alternatives, make choices and rank them accordingly[11], which is mostly useful for design. The main advantages of a decision support system are: various alternatives can be examined; identification

*For correspondence. (e-mail: neelam@iari.res.in)

of unforeseen situations; better perceptive of the business/processes; cost savings; improved communication; manpower saving; time savings; better use of data and available resources[12,13]'.

Although computers have revolutionized different sectors, their use in agriculture is limited due to less number of expert systems. A different sector in agriculture needs computer technologies. In the field of irrigation, there is a need for interactive and user friendly, menu driven software for designing efficient irrigation systems by using the local soil, crop, water and climatic conditions[14]. Keeping these considerations in view, a DSS for designing efficient micro-irrigation system, namely Design of Micro Irrigation Systems (DOMIS) has been developed to fill the gap. The DOMIS is fulfilling the goals of digital India initiative and 'per drop more crop' vision of the Government of India.

The DSS, DOMIS provides a solution for designing efficient micro-irrigation systems. In addition, the DSS also provides the basic information about Government schemes, all the districts of the country, implementing agencies in different states of India, agencies promoting micro irrigation and approved system suppliers in different states. It contains the district level agro-climatic information, major crops, soil, crops and their properties as well as the ground level water quality with availability data.

Design of micro irrigation systems

DOMIS is capable of designing different micro-irrigation systems, i.e. drip irrigation, sprinkler and micro-sprinkler systems for different horticultural, cereal and fruit crops. As a part of the system design mechanism, DSS provides expert opinion based on datasets of crops, soil, water and climate as default options and also provides an option to modify the data.

There are nine basic elements that make up the design of a micro-irrigation system that include: (i) irrigation water requirement, (ii) capacity of drip main line, (iii) size of main pipe, (iv) capacity of sub-main and lateral pipes, (v) diameter of lateral pipe, (vi) diameter of sub-main and main pipe, (vii) number of drippers and laterals, (viii) size of pumping unit, and (ix) cost of micro-irrigation system[15,16]. DOMIS suggests most optimal layout plans and efficient system design with specifications of lateral, sub-main and main pipes. It also gives the estimation of costs to install the system. In the DSS, scientific algorithms and procedures are adopted for calculating plant-based water requirements based on the agro-climatic data. It also provides possible shifts per day and total time of irrigation.

Development of DSS is an incremental process. The life cycle of DSS involves four main stages: (1) knowledge acquisition, (2) problem structuring and system design, (3) problem encoding, and (4) system testing. There are several sources of knowledge employed in the development of DSS. These sources are textbooks, manuals, research articles, personal and professional experiences and expert advices[17,18]. The DSS has been developed in the form of a computer program and seamlessly integrated into a user-friendly interface (Figure 1), which incorporates knowledge and expertise which has been implemented in the framework of the DSS with open source web development languages, i.e. PHP, MySQL and other web-based tools[19]. DSS can be operated on any standard web browser, and therefore can be accessed from computers, laptops, mobiles, phablets, tablets or any other internet-enabled device having assured internet connectivity. It runs on Apache server and uses large datasets of crops, soil, climatic data, MI equipments, and quality of water and depends on the availability of micro-irrigation equipment in different states of the country. DSS could be used without the aid of professional knowledge of agricultural engineering/micro-irrigation systems design. Though DSS provides in-built expert advice at all stages by offering almost all the data needed in designing of micro-irrigation systems, the DSS also enables the user to apply their expertise by way of allowing them to alter any/all parameters as per their knowledge and understanding.

DOMIS provides default data as well as guidance for selection of suitable micro-irrigation components taking the user through different design steps interactively as follows:

(i) Partitioning the whole field into blocks of desired dimensions for achieving uniform water distribution and realizing higher water-use efficiencies.
(ii) Determination of the most appropriate layout plan for the main, sub-main and lateral pipes in the field to result in the most economic system design.
(iii) Estimation of water requirements at plant, lateral, sub-main and main pipe level based on long-term agro-climatic data.
(iv) Determination of suitable water application rate as per the soil properties.
(v) Determination of sizes of laterals, sub-main and main pipes, based on their frictional loss analysis.
(vi) Estimation of size and type of accessories such as filters and fertigation equipment, based on water quality and crop demand.
(vii) Determination of largest fraction of area that can be irrigated in one go based on the size and type of the water source.
(viii) Determination of possible shifts and time of irrigation for each irrigation.
(ix) Determination of total head requirement including the lift involved from groundwater data.
(x) Determination of size of motor pumping unit and the power requirement.

Figure 1. Home screen of DOMIS (http://domis.iari.res.in).

(xi) Estimation of the cost of the system based on costs of different components.

Layers of DOMIS

We employed a hierarchical architectural view to effectively organize and understand the data, information, knowledge and related tools in DSS (Figure 2). The selected architecture consists of five layers: (1) presentation layer, (2) data layer, (3) knowledge layer, (4) algorithms/logic layer, and (5) layout or final report layer. In the presentation layer, it uses the web-portal for the DSS, providing friendly graphics user interface-based interfaces, based on the calculated/generated information and efficient system design from the underlying data, information, knowledge and logic layer. The data layer, agro-climatic information, crop, soil and the groundwater information have been arranged for all the 642 districts of 29 states and 7 union territories of India. These datasets provide the fundamental base for the information layer.

The knowledge/information layer is prepared to advise the user on DSS required data that provide additional information. This allows the user to modify/update the information based on his/her own expertise of local climate, crop and other relevant data.

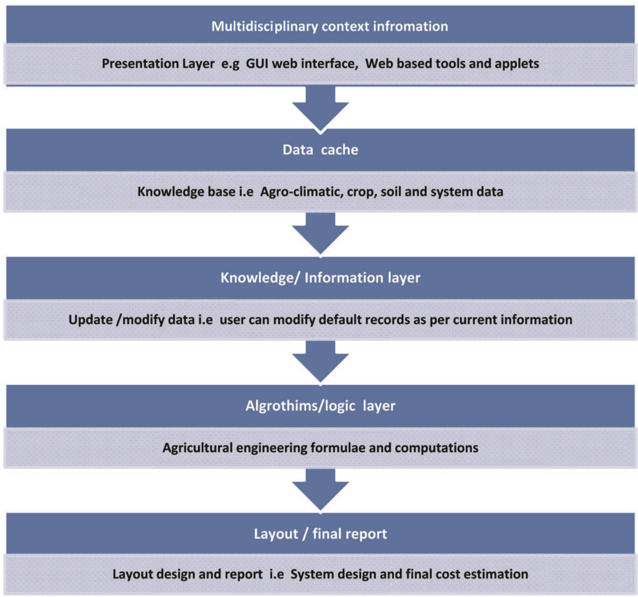


Figure 2. Layers of DOMIS.

The logic/algorithms layer provides the logic equations for calculation of system design equipments. The scientific agricultural engineering principles and formulae have been used to calculate the size of main pipe, sub-main pipe, lateral pipes, drippers, numbers of sprinkler/micro-sprinklers and other design parameters[20]. This layer will provide the total estimated cost for the complete system design, simulation models and knowledge discovery algorithms to combine information into valuable knowledge for decision-making.

At the end, the design/report layer will summarize the input values provided by the user, the output values calculated by the logic/algorithm, cost estimation based on system-provided or user-inserted equipment cost. This layer also provides the appropriate system layout with details of the designed system for the field. Users can take printouts, save or send it to their e-mail ids for further use.

Databases

The DSS-DOMIS uses a large dataset which was prepared on the basis of information collected from Government authorized sources. It includes historical daily agro-climate data, i.e. evapotranspiration (ET_0), soil properties and groundwater table depths for all the 642 districts of 29 states and 7 union territories. The range of these databases is inconsistent across different parts of the country. In addition, there is the crop database that has all the crop characteristics including all major crops. The crop parameters include crop spacing, crop coefficients (K_c), effective rooting depths and recommended micro-irrigation system[21]. The dataset of the DSS offers suggested data, but the user has the overriding authority to modify the data as per the best of knowledge of the user. The dataset embedded in DSS consists of the following:

(a) Location information: The agro-climate data were downloaded for all the districts of the 29 states and 7 union territories of India from Indiawaterportal website (http://indiawaterportal.org). Monthly averaged ET_0 (mm/day) data of the earlier 40 years was compiled for all districts for use in the DOMIS.

(b) Soil information: Soil physico-chemical parameters were extracted from the collected data and Harmonized World Soil Database Viewer ver. 1.21 software developed by Food and Agriculture Organization (FAO), ISRIC – International Soil Reference and Information Centre, Joint Research Centre of the European Commission (JRC), etc., using Arc GIS, MS Access and MS Excel. World images were extracted in .bill format and then converted into shape file format for GIS data analysis.

Later, the boundary of India was overlayed and clipped from the shape file and a new shape file was generated containing soil information of each district at a scale of 1 : 1000000 after applying many image and data processing algorithms. Soil data table contains the records of district-wise soil types and their properties. A user has to select the district and accordingly, the soil and its properties are displayed from soil data table. Soil data were collected and downloaded from different sources like scanned maps, published research papers, websites of soil-related national and international research agencies such as NBSS&LUP and ISRIC (Figure 3).

(c) Groundwater information: District-wise groundwater level data were downloaded for the whole of India from Central Ground Water Board/NIC website for the period 2015–16. This data was refined further and the outlier figures were deleted from the data to avoid disparity, and average value for each given location was calculated. Data of all available locations in a district were collected and made part of the dataset.

(d) System manufacturers/suppliers: Several companies provide different types of irrigation equipment. A standard table was prepared for equipment size, discharge, operating pressure, cost and other parameters. The same record was used for cost calculation and for suggesting the appropriate size of irrigation equipment.

(e) Crop information: Crop coefficient data were compiled for horticulture, cereals, pulses, spices, ornamental and medicinal crops according to the length of crop development stages. The data were collected from FAO 24 and FAO 56, and some from research papers and other sources. Crop spacing data were collected from the book *Handbook of Horticulture* (ICAR, New Delhi) and from the Guidelines of Mission for Integrated Development of Horticulture programme, Government of India. This dataset also contains the details about which crop is suitable for which irrigation system. Based on this dataset, a user will get a list of only those crops which are suitable for their selected system, i.e. drip/sprinkler/micro-sprinkler. This information was used for sorting the state-level selection of crop.

(f) Wind information: District-wise wind speed data were downloaded and compiled in the form of monthly and yearly average data. The wind details have been used for suggesting the micro-irrigation systems.

(g) User details: After final execution of DOMIS, the DSS saves the records submitted by the user for internal review and analysis. These records can be used to enhance the output, trace errors/bugs in the program as well as its usage. User details such as, name, address, e-mail, phone number are never shared publicly; this informational is for internal use only.

(h) District profile: Information about agro-climatic data, maps, water resources, water quality, rainfall, wind speed, solar energy, source of irrigation, major soil type, land utilization, major crops cultivated,

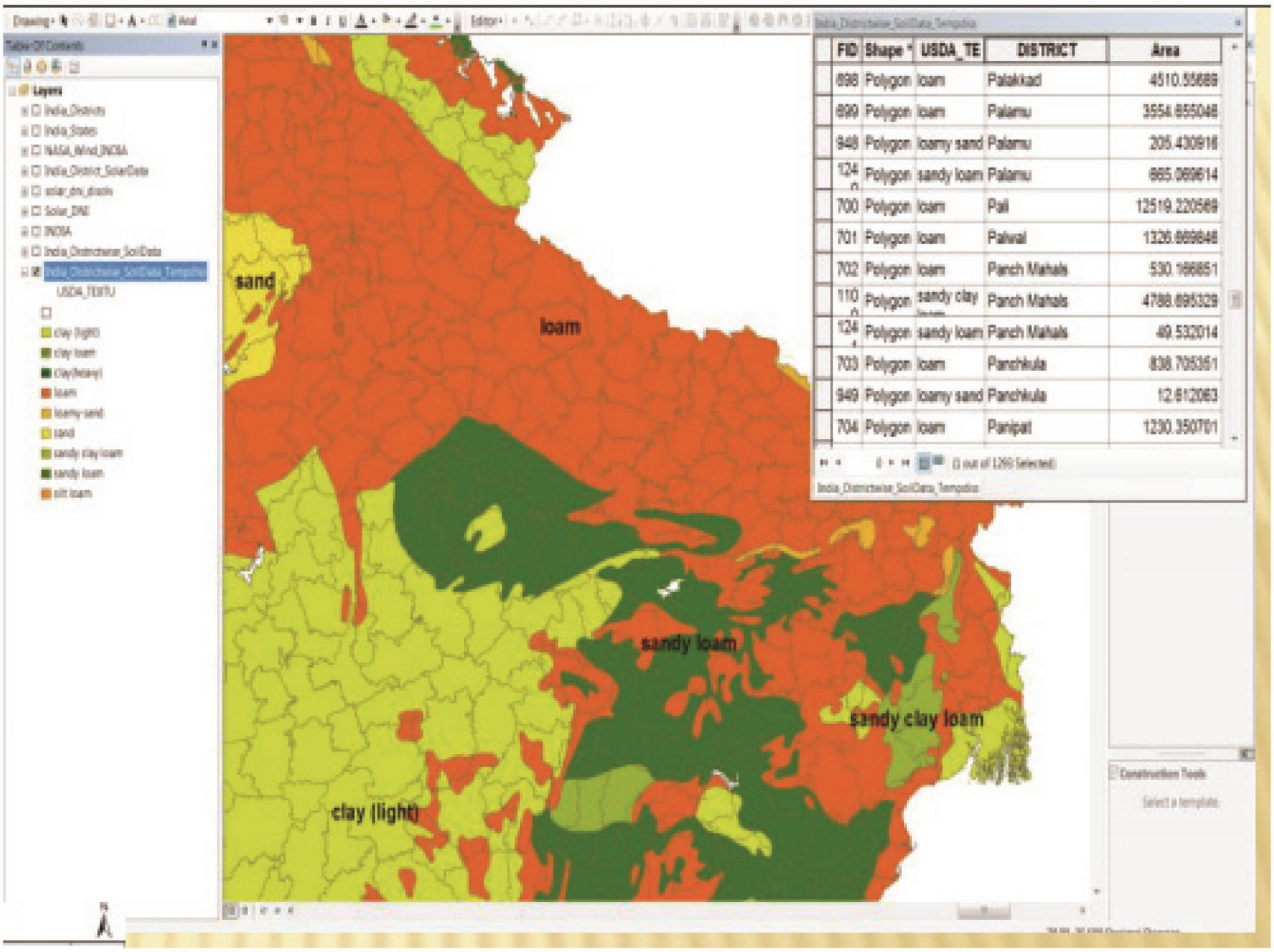


Figure 3. District level soil map for India.

agriculture institute and KVKs, agriculture land use, etc., were also downloaded and compiled for each district to provide general information about the districts.

Methods and interface

The DSS has an interactive Graphical User Interface and responsive web-based system. The user has to input the required information and based on developed algorithms and scientifically accepted formulae[21], the system provides the layout design, specification of lateral, sub-main and main pipes with estimated cost (Figure 4).

These are the required inputs for DSS.

(a) Basic information: The user has to enter or select the basic information, i.e. name, state, district, e-mail and phone number (Figure 5). State and district are required parameters as the agro-climatic information is based on district, but e-mail and phone number are optional. By entering the e-mail id, the user will receive the DSS-generated report on his/her entered e-mail (Figure 6).

(b) Field and soil information: The user has to enter the length and width of his/her field along with soil and soil infiltration rate. Based on the selected district, the district level soil map is displayed on the right panel. The user can select based on soil map or any soil type listed in the database. Accordingly, soil infiltration rate (SIR) is fetched from the database. The user has the privilege to modify the SIR as per his/her knowledge, if required.

(c) Crop information: There are several types of crops such as horticulture, cereals, pulses, spices, ornamental and medicinal crops that are available with the corresponding district. The user has to select among the major crops. Based on the crop selection, crop coefficient, canopy factor, lateral spacing and plant spacing are fetched from the database of the DSS.

(d) Water, filter and fertilizer applicator: The user has to select the source of water, location of water source and depth of ground water. For the user's help, groundwater table of various locations in the selected district will be available on the right side of the panel. The user then has to select filters and fertilizer applicators from the given options. To help in filter selection, an image has been provided with water quality details indicating the suitability of different filters under different water quality situations.

(e) Selection of pipes: For selecting the size of the main, sub-main and lateral pipes, the required flow capacities are considered. By trial and error procedure the smallest sizes of pipes are selected, which result in head loss because of friction in acceptable limits. Flow capacities of different pipes were estimated with the help of crop water needs of the area covered by the concerned pipes[22]. For example, the flow capacity of a lateral was taken as just equal to the plant water needs of one or more rows of crops served by one lateral. Similarly the flow capacities of sub-main and main pipes were considered equal to the crop water needs of a block served by sub-main pipe[23]. Water requirement of the crops was estimated based on the real crop evapotranspiration calculated on the basis of reference crop evapotranspiration and the crop factor (FAO 56). Crop water requirement was then estimated based on the real crop evapotranspiration and extended irrigation efficiency.

(f) System layout, equipment specification and estimated cost: The dataset of the DSS contains different possible sizes of main, sub-main and lateral pipes, dripper and other components of micro-irrigation systems along with their normal market prices. The cost of all different components of the designed micro-irrigation system is picked up by the DSS from its database and total cost of the designed system is displayed in the final report layer of the DSS. The final report page displayed by the DSS may be sent to an e-mail or printed out as desired by the user.

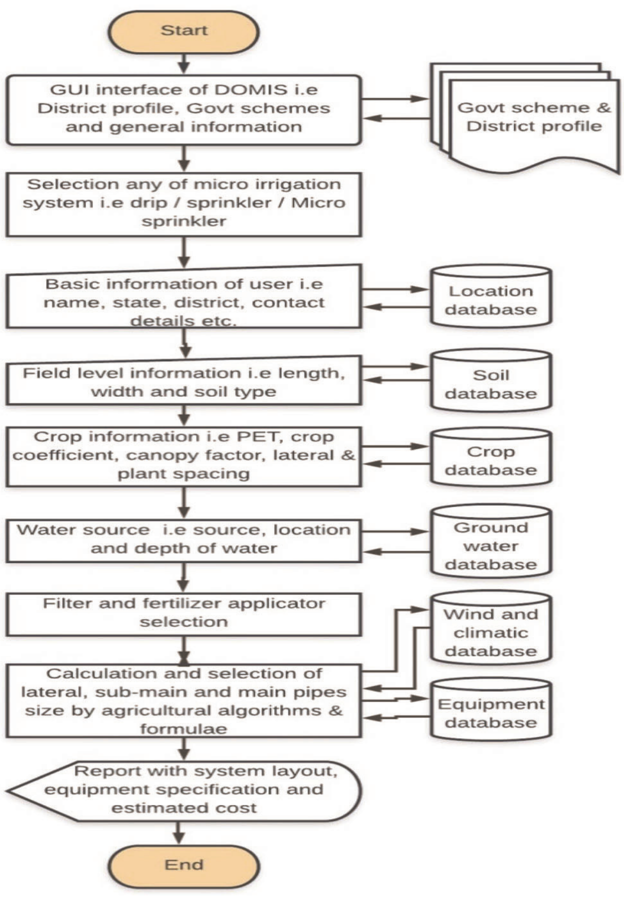


Figure 4. Conceptual design and flow chart.

Suggested field layout

The user submitted records along with agro-climatic details are processed by standard irrigation formulae such as water requirement of crop, agro-climate database of field location, source of water and water availability; a field layout of the micro-irrigation system is suggested and displayed by the DSS (Figure 7). The suggested layout with partitioning of the whole field into blocks of desired dimensions and design present the most appropriate layout plan for main, sub-main and lateral pipes in one block. The DOMIS-DSS suggests the layout for three major micro-irrigation systems, i.e. drip, sprinkler and micro-sprinkler. The field layout can be taken as a print-out for system installation. The design specification of the lateral, sub main and main pipes, decided based on the water requirement of crop and agro-climate data are also displayed by the DSS along with the system layout plan.

Cost calculation

Besides a suitable layout plan and its design details, the DSS also provides a cost estimate based on the prevailing normal prices and different components of the irrigation system (Figures 6 and 7). The actual cost of installing the system may however be obtained from the different system suppliers approved by the concerned State Government. The DOMIS prepares a final table consisting of user-inserted inputs, data suggested by DOMIS and approved by the user and the complete design specifications of the system along with its likely cost.

Conclusion

The web based system (http://domis.iari.res.in) uses scientifically accepted algorithms and agricultural formulae with large knowledge-base and expert opinions. It is

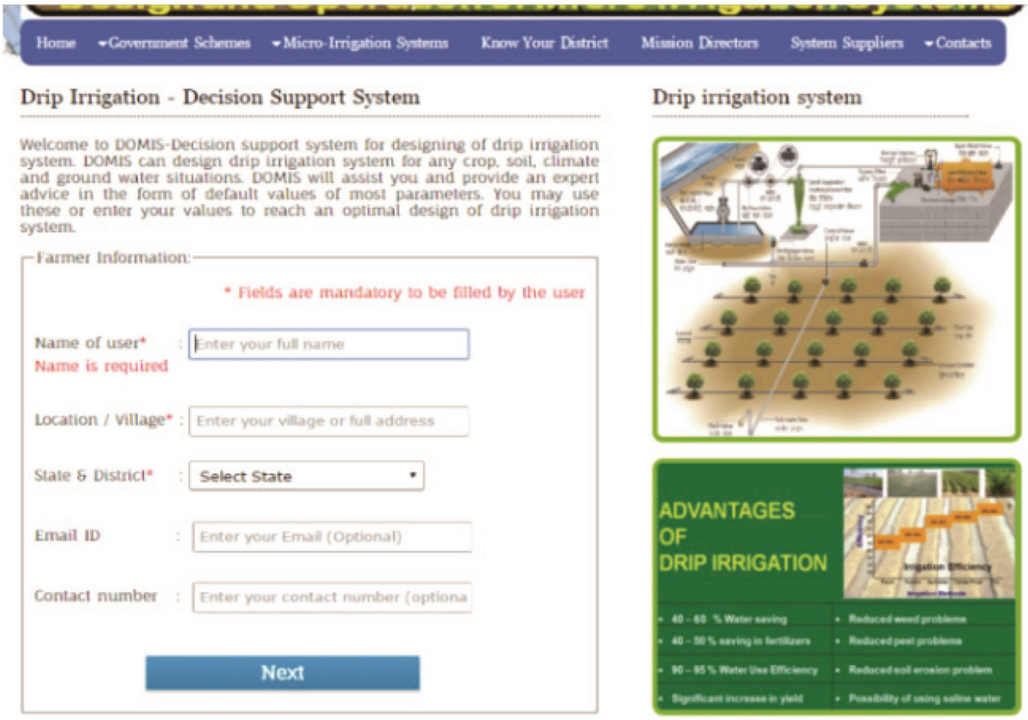
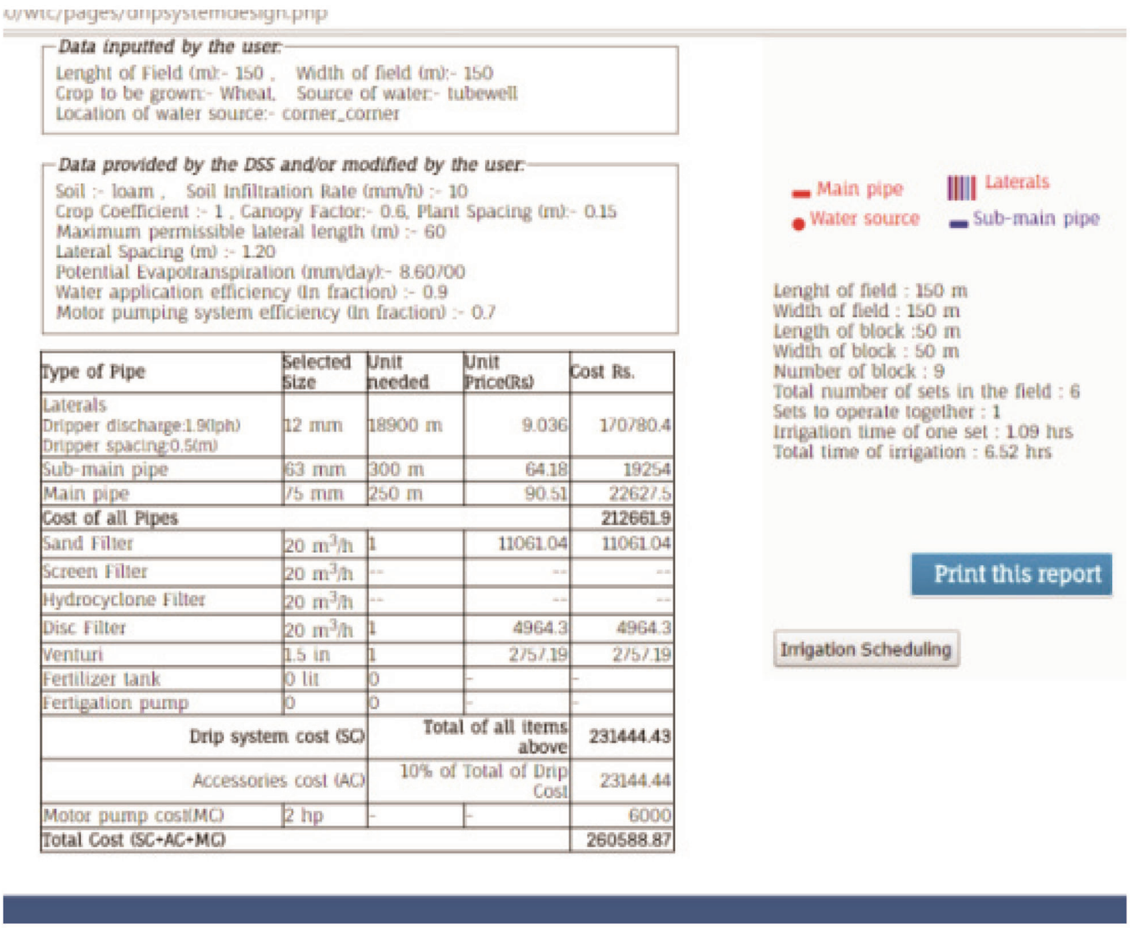


Figure 5. Input screen of DOMIS.



Type of Pipe	Selected Size	Unit needed	Unit Price(Rs)	Cost Rs.
Laterals Dripper discharge:1.9(lph) Dripper spacing:0.5(m)	12 mm	18900 m	9.036	170780.4
Sub-main pipe	63 mm	300 m	64.18	19254
Main pipe	75 mm	250 m	90.51	22627.5
Cost of all Pipes				212661.9
Sand Filter	20 m^3/h	1	11061.04	11061.04
Screen Filter	20 m^3/h	--	--	--
Hydrocyclone Filter	20 m^3/h	--	--	--
Disc Filter	20 m^3/h	1	4964.3	4964.3
Venturi	1.5 in	1	2757.19	2757.19
Fertilizer tank	0 lit	0	-	-
Fertigation pump	0	0		
Drip system cost (SC)		Total of all items above		231444.43
Accessories cost (AC)		10% of Total of Drip Cost		23144.44
Motor pump cost(MC)	2 hp	-	-	6000
Total Cost (SC+AC+MC)				260588.87

Figure 6. Report with equipment details and cost estimation.

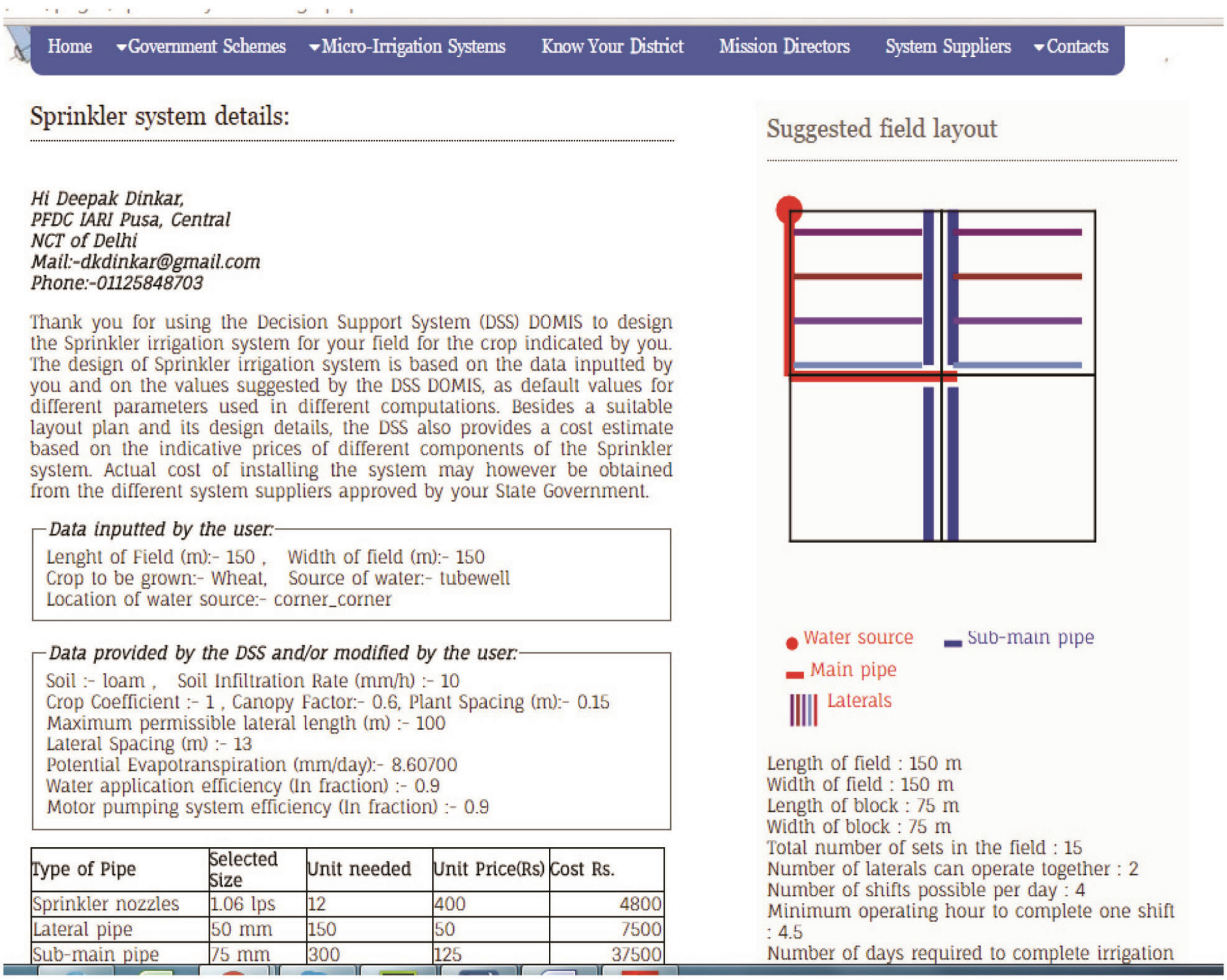


Figure 7. Report page with system layout and irrigation timing.

flexible and easy to use which makes the DSS-DOMIS an advanced tool for designing micro-irrigation systems to enhance water efficiency in crop production. It provides all the information related to design of systems as well as cost estimation for drip, sprinkler and micro-sprinkler systems. It evaluates the economic feasibility with detail cost calculation of the suggested layout in the given agro-climate details. Besides providing support in designing the appropriate micro-irrigation systems, DOMIS also provides other necessary general information about schemes of the Government of India, agencies promoting micro irrigation, implementing agencies in different states of India, approved system suppliers in different states and general information about different districts in the country. The developed DSS has been tested and appreciated by 22 Precision Farming Development Centres, State Micro Irrigation Mission Directors and several micro-irrigation industries. This software is considered to be useful to farmers, industry, researchers and policy makers in agriculture and allied sectors.

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