Software For Design And Layout Of Drip And Sprinkler Irrigation Systems

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Abstract

A reliable and suitable irrigation water supply can result in vast improvements in agricultural production and assure the economic vitality of the region. Drip and sprinkler irrigation systems are relatively new and very efficient method for placement of water to the crop position. The design and layout of drip and sprinkler irrigation systems consist of the collection of data from different sources with respect to various parameters to arrive at a feasible and practicable design for adoption in the field. It requires tremendous efforts and energy, planning, money to pool the information for the proper design of the systems and also, it is time consuming and cumbersome. Most of the designs require both qualitative and quantitative information to arrive at possible design from the reports and literature. The effort has been made in the developed software to integrate both design procedures and databases. This saves a lot of time and various design options can be prepared and compared before laying the final design in the field. The software for design and layout of drip and sprinkler irrigation systems has been developed using Microsoft Visual Basic 6.0 as front end and Microsoft Access as back end. The user need to provide the basic information regarding drips and sprinklers such as plot size and crop to be grown, soil type, available discharge, differences in topographic height, available pumps, water quality etc to start the design process. The software allows the user to select the various parameters through different screens and finally generate a complete design layout and approximate cost of the system based on the selected parameters.

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1. Introduction

India has 2.4 per cent of land mass and 4 per cent fresh water resources of the world, but supports 17 per cent of the world population. Since independence, therefore, per capita land availability has dwindled from 0.48 ha to 0.15 ha and water availability has been reduced from 5300 cu m to 1500 cu m. In India, 91.6 per cent of the water used for irrigation purpose as compared to 84 per cent in Asia and 71 per cent in the world (Irrigation in Asia in figures, Water Report No. 18, FAO, 1999). The revised National Water Policy, which was formulated in 2002 has also taken cognigence of the necessity of proper irrigation water management. The expected climatic change in the 21st century will have pronounced negative impact on overall water availability and its quality. Thus, the importance of water management and the need to adopt modern techniques of irrigation to increase the yield and water use efficiencies for most of the crops is imperative.

Water is the most vital input in agriculture and has made a significant contribution in providing stability to food grain production and self-sufficiency. As compared to the surface water, greater proportion of additional irrigation water comes from the ground water and this source is increasingly being exploited in an unscientific manner. It is estimated that around 88% of the fresh water resources are currently used for agriculture and remaining water is fulfilling the industrial and domestic requirements in the country. Presently, all the sectors of economy are demanding larger quantities of freshwater. Thus, tremendous amount of pressure lies on agriculture sector to reduce their share of water and at the same time to enhance total production, which could be achieved by enhancing productivity with increased water use efficiency, Heeman et. al [7]. In the global scenario, the demand for water has been on the rise in all water user sectors.

Sufficient efforts were not made in past to adopt efficient water distribution and application method. Many part of the irrigated areas have become water logged and affected by soil salinity problems and this has resulted into low productivity of fertile lands. This was mainly due to traditional flooding irrigation and slow adoption of scientific practices of irrigation water management. Added to these drawbacks, the major and medium irrigation projects also suffered from wide variations in soils, climate and cropping sequence, across the length and breadth of the irrigated command area. The present productivity of irrigated command areas around 2-3 tons per hectare as against 4 to 6 t/ha food grains demonstrated in research farms. The current food gain production of India is stagnating and population of the country is in increasing trend. Anticipating the crisis, the Government of India has always given priority to enhance irrigated area through various major, medium and minor irrigation and multipurpose projects, which were formulated and implemented through successive five-year plans. However, the judicious use of irrigation water for agriculture is equally important, productivity at the same time to save the irrigation water which is costly and limited resource. This can be achieved by introducing advanced methods of irrigation like Micro-irrigation coupled with other improved water management practices, Kumar [2] and Reddy [18].

2. Micro Irrigation Systems

Micro irrigation system applies measured quantity of water slowly and directly above or below the soil surface, usually by discrete or continuous drops, tiny stream or miniature spray through emitters or applicators placed along a water delivery line near the plant.

2.1 Drip Irrigation System

Internationally, drip irrigation was developed originally as a sub-irrigation system and the basic idea underlying drip irrigation can be traced back to experiments in Germany in 1860s. The first work in drip irrigation in the United States was a study carried out by House in Colorado in 1913. An important break-through was made in Germany way back in 1920 when perforated pipe was introduced. During the early 1940s, Symcha Blass, an Israeli Engineer, observed that a big tree near a leaking pipe exhibited a more vigorous growth than other trees in the area, which were not reached by water from tap. This led him to the concept of an irrigation system that would apply water in small quantity literally drop by drop . In Israel, the first extensive research was conducted in the Arava and Negave deserts where adverse conditions of climate, very sandy alkaline soils and saline water had produced good results on crops grown with drip irrigation methods in comparison to conventional methods.

The drip irrigation was practiced in India since time immemorial for irrigating the religious Tulsi plant in many households during summer. With the development of plastic during and after Second World War, the idea of using plastic pipe for irrigation becomes feasible. In the late 1940's in the United Kingdom plastic pipe drip irrigation system was used to irrigate green houseplant. In 1971, the first International drip irrigation meeting was held in Tel Aviv, Israel, where 24 papers were presented. Drip irrigation in modern form was introduced in early 1971 in our country. Significant development has taken place in eighties, Narayanamoorthy [13]. Over the years, different companies developed different type of drippers. A cheap drip irrigation system was designed and fabricated at Tamil Nadu Agricultural University, Coimbatore in 1978, to find out the water used for various vegetables and fruit crops. The result indicated that the water required by crop in drip irrigation system was only 1/3rd to 1/4th of that required by surface irrigation method and the crop yield was to be higher in drip system.

Drip irrigation was practiced in India through indigenous methods such as bamboo pipes, perforated clay pipes and pitcher/ porous cup irrigation. In Bamboo microirrigation systems, long hollow bamboo pipes of varying diameter (50-100 mm) are used for making channels. In Meghalaya, some of the farmers are using bamboo drip irrigation system for beetle, pepper and arecanut crops by diverting hill streams in hill slopes. The discharge at the head varies from 15 to 20 l/min, and is reduced to 10-30 drops/min, at the time of application. These methods can be advantageously used by individual farmers for smaller land holdings. In Maharashtra, perforated earthenware pipes were used and their efficiency and benefit cost ratio have been elaborated for popularizing them. Earthen pitchers and porous cups have also been used for growing vegetable crops in Rajasthan. The technique envisages embedding of earthen cups of 500 ml capacity at the site of seedlings. The cups are filled with water at an interval of 4 to 5 days.

2.2 Sprinkler Irrigation System

Under sprinkler irrigation water is sprinkled under pressure into the air and plant foliage through a set of nozzles attached to network of aluminium or High Density Poly Ethylene (HDPE) pipes in the form of rainfall, Christiansen [5]. These systems are suitable for irrigating crops where the plant density is very high where adoption of drip irrigation systems may not be economical. Sprinkler irrigation is suitable for horticultural crops like vegetables and seed spices. Conventionally, sprinkler irrigation has been widely in use for irrigating cereals, pulses, oil seeds and other field crops.

2.3 Crops Grown Under Drip and Sprinkler Irrigation System

Kumar [2] and Mane et. al. [12] tabulated and described that the following crops can be successfully grown under micro irrigation systems.

Table 1 : Crops Grown Under Drip and Sprinkler Irrigation System

Sl. No.	Varity	Crops
1.	Orchard crops	Grapes, banana, pomegranate, orange, citrus, tamarind, mango, fig, lemon, custard apple, sapota, guava, pineapple, coconut, cashew nut, papaya, aonla, litchi, water melon, musk melon
2.	Vegetables	Tomato, chilly, capsicum, cabbage, cauliflower, onion, okra, brinjal, bitter gourd, ridge gourd, cucumber, gree n peas, spinach, pumkin, guard

3.	Cash crops	Sugarcane, cotton, areca nut, tea, coffee, rubber, strawberry, spices, tomato, turmeric
4.	Flowers	Roses, carnation, gerbera, anthurim, orchids, jasmine, lily, mogra, tulip, dahlia, marigold, cosmos
5.	Oil Seed	Sunflower, oil palm, groundnut, coconut
6.	Forest trees	Teakwood, bamboo, casurina, eucalyptus

2.4 Need of Design Software

The researches have developed the independent software for both drip design and sprinkler design systems, which gives the design parameters but none of these generate the design layout, which is equally important at field level. Andrade et. al. [1] and Hernandez et. al. [8] developed the software for sprinkler design, Rajput et. al. [17] developed the software for design of drip irrigation systems. The design and layout of drip and sprinkler irrigation systems consist of the collection of data from different sources with respect to various parameters to arrive at a feasible and practicable design for adoption in the field. It requires tremendous efforts and energy, planning, money to pool the information for the proper design of the systems and also, it is time consuming and cumbersome. Most of the designs require both qualitative and quantitative information to arrive at possible design from the reports and literature. In the developed software the above points have been addressed to the extent possible for drip and sprinkler design.

3. Overview of the developed software

The developed software has two modules – drip design module and sprinkler design module. The block diagram for the developed software may be shown as below :

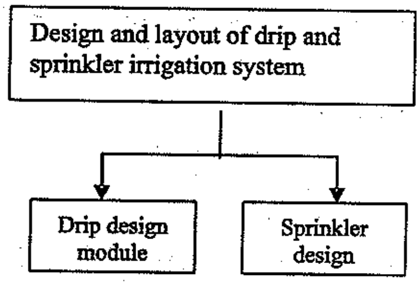

Figure 1 : Block Diagram Of The Developed Software

3.1 Steps in Design of Drip Irrigation System

The design of drip irrigation system differs from crop to crop, soil-to-soil and climatic conditions. The literature is very rich in providing the guidelines and design steps for drip design, [6], [9-12], [14-16]. In general following are the basic steps involved in design:

3.1.1 Selection of Drippers

The selection of dripper types and number of drippers per plant depends on peak water requirement of the crop and the infiltration rate of the soil. The emitter must supply enough water to the plant root zone to meet the crop water requirement. Normally, the emitters are located near the plant or the areas of high root concentration. Drip irrigation emitter can be designed as a point source or line source to supply water into the plant root zone depending on the type of crops.

The required emitter flow can be calculated based on the water requirement of the crop, number of emitters per plant, irrigation application efficiency of drip irrigation system and the duration of irrigation and can be expressed as:

$$q_r = \frac{q_t * l}{T * E_a * e} \qquad (1)$$

Where,

q_r is the required emitter flow rate, l/h

q_t is the water requirement per plant per day, lit/ plant/day

I is the irrigation interval, days

T is the irrigation time per set, hrs

E_a is the irrigation application efficiency

e is the number of emitter per plant

3.1.2 Selection and Design of Lateral

Lateral carries water from submain and feeds to the individual drippers. Generally, one lateral for each row or orchard plant and one lateral for two rows of sugarcane or vegetables are used. The size and length of lateral is decided by the discharge of the drippers and number of drippers on one lateral.

Calculation of lateral flow rate: Flow rate of lateral is the function of emitter discharge and number of emitter along the lateral,

$$Q_l = K * n_e * q_a \tag{2}$$

Where,

Q_l is the total flow rate of one lateral, l/h

n_e is the number of drippers on one lateral

q_a is the average dripper discharge, l/h

K is the constant, 1/3600

3.1.3 Selection and Design of Submain

Submain is generally made up of PVC (poly vinyl chloride) pipes of 32 mm, 40 mm, 50 mm, 63 mm and 75 mm in diameter. The design of submain is based on both capacity and uniformity. Capacity means the submain size should be large enough to deliver the required amount of water to irrigate the subsequent part of the field, Bralts et. al. [3].

Submain supplies water to individual lateral. Design of submain is similar to that of lateral, however it differs in that the spacing between outlets is greater and larger flow rates are involved. The size and length of submain is determined by number of laterals and distance between the laterals. Calculation of frictional head loss :

$$\Delta H_m = K\left(\frac{Q_m}{C}\right)^{1.852} D_{sm}^{-4.871} L_{sm} \times F \tag{3}$$

Where,

ΔH_m is the head loss in submain, m

K is constant, 1.21×10^{10}

Q_m is the flow rate in submain, l/sec

C is friction coefficient for continuous section of pipe depends on pipe material

D_{sm} is the inside diameter of submain, mm

F is the outlet

L_{sm} is the length of submain, m

3.1.4 Selection and Design of Mainline

Generally the size of mainline is one size higher than submain. The size of mainline is decided by flow rate of all submains. The sizes of mainline are 40 mm, 50 mm, 63 mm, 75 mm, 90 mm and 110 mm etc.

The head loss is calculated by (Using C=150),

$$\Delta H_m = 15.27\left(\frac{Q_m^{1.852}}{D_m^{4.871}}\right) L_m \tag{4}$$

Where,

Q_m is the total discharge of mainline, l/sec

D_m is the inside diameter of mainline, cm

L_m is the length of mainline, m

ΔH_m is the head loss in mainline, m

OR

$$\Delta H_m = K\left(\frac{Q_m}{C}\right)^{1.852} D_m^{-4.871} . L_m \tag{5}$$

Where,

K is constant, 1.21×10^{10}

C is the friction coefficient for continuous section of pipe and depends on pipe material

D_m is the inside diameter of mainline, mm

3.1.5 Selection of Pump

Total head of pump = suction head + delivery head + filter losses + mainline losses + Operating pressure + fitting loss + ventury head loss + elevation difference

- Filter losses are assumed to be 2 m for screen filter (disc filter) and 2 m for sand filter
- Operating pressure is about 1 kg/cm² (10 m)
- Fitting loss = 2 m
- Ventury head loss = 5 m

$$H.P. = \left(\frac{Q.H.}{75\ n_{motor}\ n_{pump}} \right) \quad (6)$$

Where,

Q is the maximum flow rate of system, l/sec

H is the total head of the system

n_{motor} is the motor efficiency, generally taken as 80 %

n_{pump} is the pump efficiency, generally taken as 75 %

H.P. is the horse power

3.1.6 Calculation of Irrigation Time

i) Water requirement (l/day/tree)

$$\text{Irrigation time for tree crop (hrs)} = \frac{\text{Water requirement (l/day/tree)}}{\text{Discharge rate of dripper per tree (/tree)}} \quad (7)$$

OR

ii) Water requirement per day (l/day/area)

$$\text{Irrigation time for row crops (hrs)} = \frac{\text{Water requirement per day (l/day/area)}}{\text{Discharge rate of dripper per unit area (l/ha)}} \quad (8)$$

Where, discharge rate per unit area is calculated as lateral line discharge rate divided by row spacing.

3.2 Steps in Design of Sprinkler Irrigation System

Sprinklers, laterals, sub mains and main lines are the primary components of a sprinkler irrigation system. Sprinklers spread water as "rain like" droplets over the land surface uniformly without runoff. Most sprinklers are either rotating or fixed-head type. The design details of sprinkler system components are explained by following steps:

3.2.1 System Capacity Requirement

$$Q_s = K \frac{Ad_{gross}}{f_i\ T} \quad (9)$$

Where,

Q_s = system discharge capacity, l/s

K = conversion constant, 2.78

A = design area, ha

D_{gross} = gross depth of application, mm

fi = irrigation interval, days

T = average actual operating time per day, h/day

3.2.2 Sprinkler Application Rate

$$I = \frac{Kq}{S_e S_l} \quad (11)$$

Where,

I = average application rate

K = conversion constant

Q = sprinkler discharge

S_e = spacing of sprinkler along the lateral, m

S_l = spacing of lateral along the main line, m

3.2.3 Nozzle Discharge and Pressure Relationship

$$q = K_d \sqrt{H} \quad (12)$$

Where,

q = sprinkler discharge, l/min

H = sprinkler operating pressure head, m

K_d = appropriate discharge coefficient for the sprinkler and nozzle combined

3.2.4 Average Instantaneous Application Rate

$$I_i = \frac{K\ q}{\prod(R_j)^2(S_a/360)} \qquad (13)$$

Where,

I_i = average instantaneous application rate, mm/h

K = conversion constant, 60

q = sprinkler discharge, l/min

R_j = radius of wetted area

S_a = angular segment wetted by a stationary sprinkler jet, degrees

3.2.5 Uniformity Coefficient

CU = 100 – 0.63 (100 – DU)

Where,

CU = coefficient of uniformity, %

DU = distribution uniformity, %

$$DU = \frac{\text{Average low-quarter depth of water received}}{\text{Average depth of water received}} \times 100 \qquad (14)$$

3.2.6 Fertigation Unit

India is the third largest fertilizer producing and consuming country in the world. The nutrient consumption per hectare and fertilizer use efficiency is very low in India. The main reason for the low efficiency is the type of fertilizer used and its method of application adopted by Indian farmers. Fertigation is the process of application of water-soluble solid fertilizer or liquid fertilizers through drip irrigation system. Through drip irrigation fertigation nutrients are applied directly into the wetted volume of soil immediately below the emitter where root activity is concentrated. Fertigation is possible in drip irrigation. Commonly used fertigation equipments are: venturi pumps (injector), fertilizer tank with flow by pass, pressure by pass tank and injection pumps.

3.2.7 Filtration Unit

Clogging of emitters is the most difficult problem encountered in drip irrigation system. The most common agents of clogging are the mineral and organic particles in the water source. Filtration of the water to check the contaminants entering the system is the best way against these occurrences. Clogged emitters are difficult to detect and expensive to clean or replace. The process of removing solid particles from liquid or gas by forcing through a porous medium is called as filtration. Setting basins, sand or media filters, screens, cartridge filter and centrifugal separators are the primary devices used to remove suspended material.

There are several types of commercially available filters, each based on different working principle and technologies and performs different filtration tasks according to water quality such as Gravel filters, Screen filters, Disc filters, Cartridge filters, Hydro cyclone filters.

4. Developed Design Software

As stated the developed software has two modules: 1) Design of drip irrigation system and 2) design of sprinkler irrigation system.

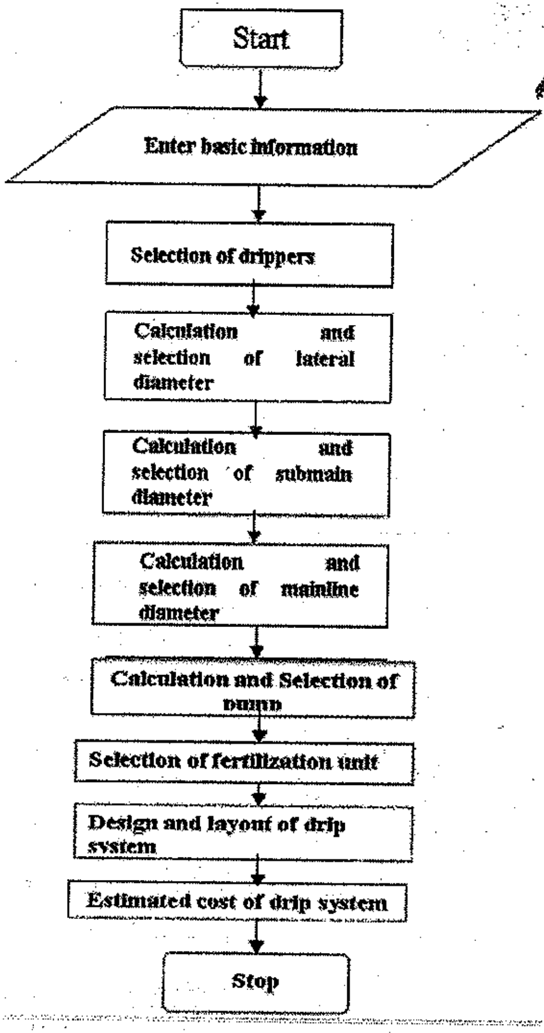

Figure 2 : Flow Diagram For Drip Design Module

The steps for design of drip and sprinkler irrigation systems have been followed in chronological order, which are explained in previous pages. The final design is generated based on the input values and values entered or selected from various databases and respective boxes on the screens.

The two softwares used for developing of the design software are: Visual Basic as front end and Microsoft Access as back end. The developed software has many screens as per the steps followed for design of drip and sprinkler irrigation systems. The software starts with Splash screen followed by main screen, which gives the option for module selection.

4.1 Drip Design And Layout Module

The step by step flow diagram for the drip design module is shown in figure 2 and the Splash screen of the software is shown in Figure3.

Main Screen of the Developed Software

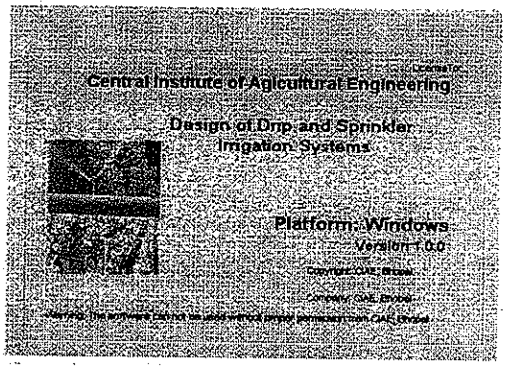

Figure 3 : Splash Screen Of The Developed Software

The main screen of the software is shown in figure 4. There are two options for selection of required type of system - drip irrigation system and sprinkler irrigation system. One can select any of the system to proceed further based on requirement.

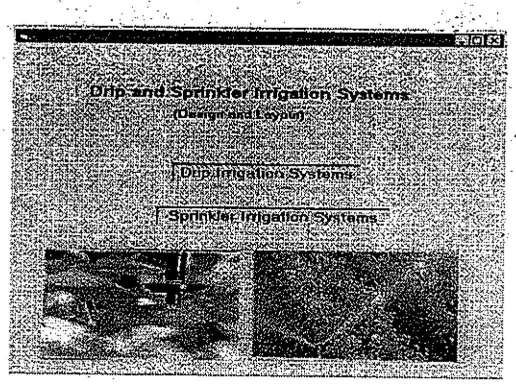

Figure 4 : Main Screen Of The Developed Software

Basic Information for Drip Design

The design process starts with entering the basic information such as length and width of the plot, type of soil, slope of land, type of crop, water quality, type of shape of the plot etc. Just after entering and selection of values, next button is to be pressed to reach on the next screen.

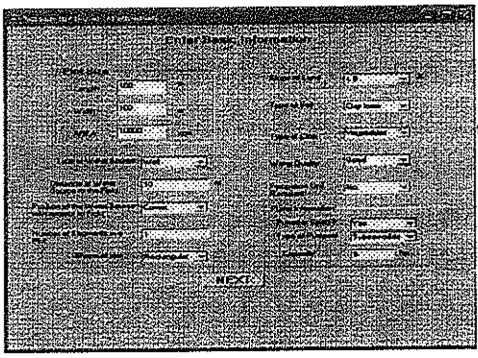

Figure 5 : Basic Information For Drip Design

Calculation of Crop Water Requirement

The next screen is for calculating the water requirement of the crop as described earlier. The input values on this screen are – name of crop, age of crop, crop coefficient, pan coefficient, row to row and plant-to-plant spacing etc. After selection and entering the values in various text and combo boxes, water requirement of the crop can be calculated by clicking on 'Calculate' button. The screen is shown in figure 6

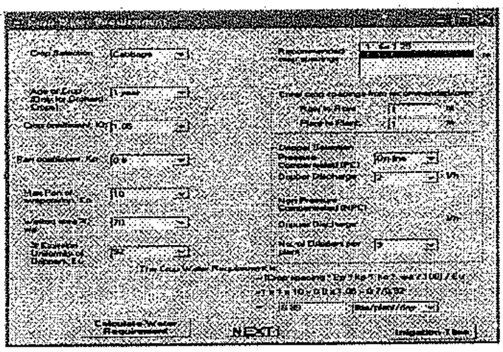

Figure 6 : Calculation Of Crop Water Requirement

Calculation And Selection Of Lateral

Once the crop water requirement is calculated, next screen is for calculation and selection of diameter for lateral. Any diameter is selected from the dia list box and based on this, the head loss is calculated using Hizen and William equation. If head loss comes within the permissible limit i.e. 10% pressure variation then the lateral dia is acceptable. If not then next higher dia is selected and again the head loss is calculated, the same process is repeated till the calculated head loss is under permissible limit. The screen is shown in figure 7.

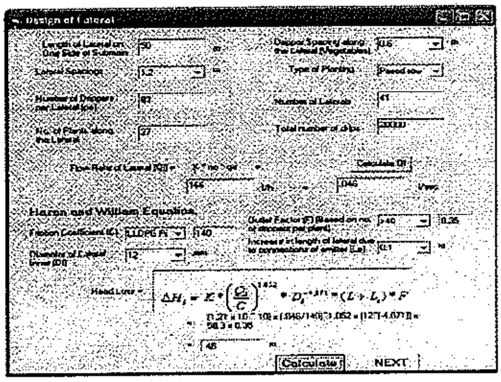

Figure 7 : Calculation And Selection Of Lateral

The same process is repeated in case of submain and mainline where we need to select the diameter and calculate the head loss, which should come under permissible limit to get the appropriate size of diameter to carry the required amount of water.

Design Layout Of Drip System

The design layout is generated based on the values selected or calculated in various screens. The design layout shows the information about the length, width, size and capacity of laterals, submain and mainline, distance and position of power source, capacity of the drippers, number of segments in the field, details of fertigation and filtration units required/selected etc. The screen is shown in figure 8.

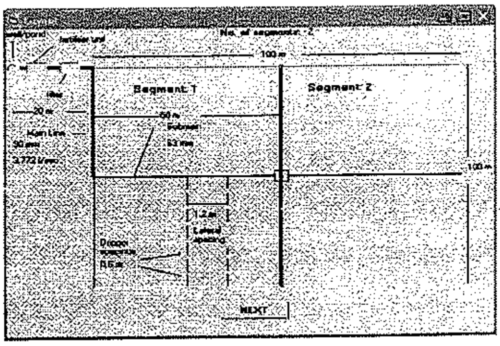

Figure 8 : Design Layout Of Drip System

Calculation Of Material Requirement

Finally, on the basis of generated design and layout, approximate cost of the complete drip system is calculated, which can be printed or output can be stored in a file. Before calculating the final system cost the filtration and fertigation equipment need be selected, otherwise software reminds that these units are to be selected before final cost of the is calculated. The screen is shown in figure 9.

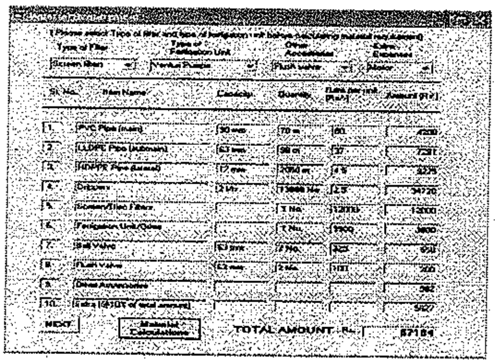

Figure 9. Calculation Of Material Requirement

4.2. Sprinkler Design And Layout Module

Sprinkler design is also based on the sequential steps starting from basic information to the final layout and cost estimates. The flow diagram for design of sprinkler irrigation system is shown in the figure 10

Screen For Basic Information For Sprinkler Design

Design starts with selection and entry of parameters from this screen. The basic information like plot size, crop type, overlap percentage, wind speed etc is entered or selected in this screen. The screen is shown in figure 11.

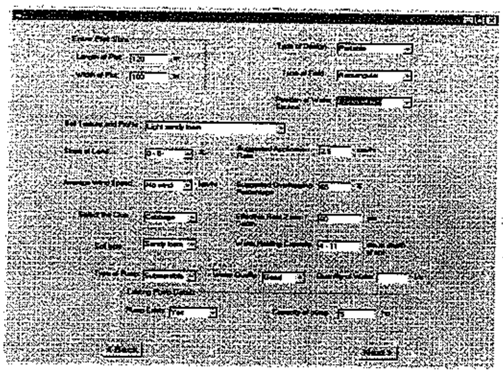

Figure 11 : Basic Screen For Sprinkler Information

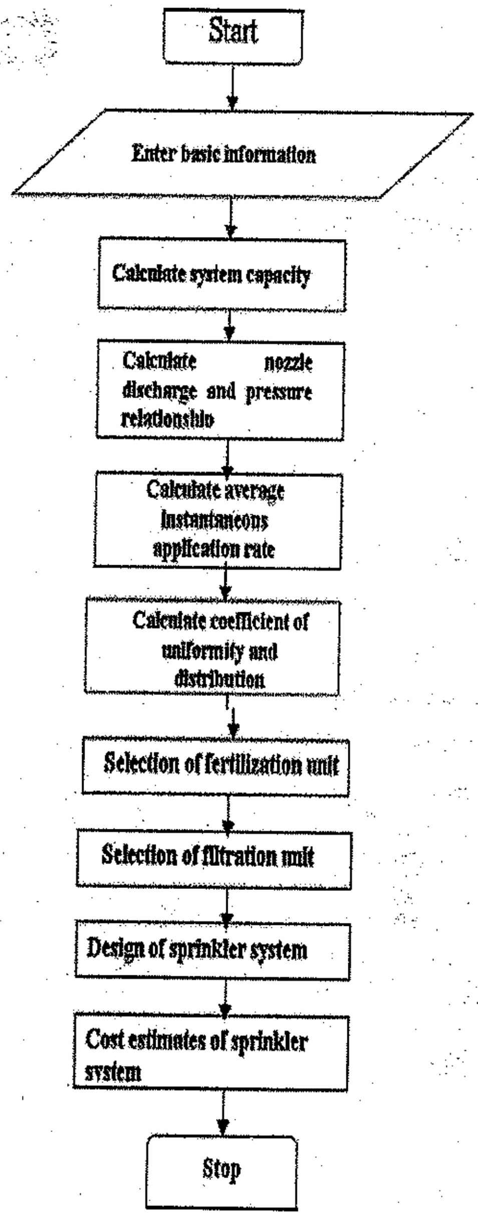

Figure 10 : Flow Diagram For Sprinkler Design Module

Screen For Sprinkler Spacing And Size Of Sprinkler

The capacity of sprinkler and nozzle is calculated. If the required size of sprinkler is available then it is selected from the list provided in the combo box, if not then next higher capacity sprinkler is selected. The screen is shown in figure 12.

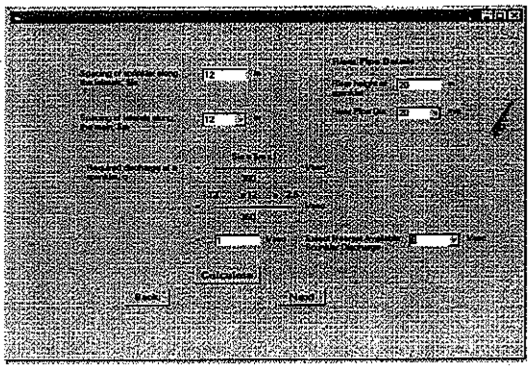

Figure 12 : Screen For Sprinkler Spacing And Size

Screen For Capacity Of Sprinkler System

Based on the sprinkler size and water requirement, capacity of sprinkler system is calculated. Number of sprinklers is also calculated on this screen, the number is required for calculation of estimated cost. The screen is shown in figure 13.

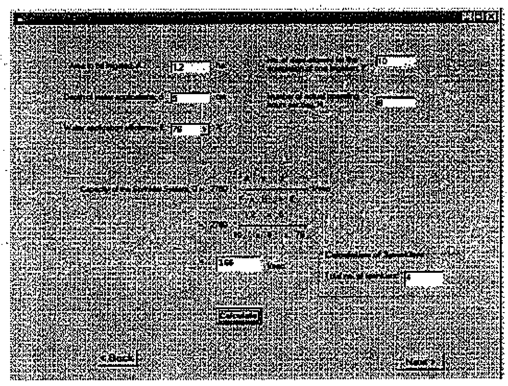

Figure 13 : Capacity Of Sprinkler System

Screen For Sprinkler Diameter Selection

The diameter of sprinkler pipe is selected based on the calculation for flow rate in the pipe. The screen is shown in figure 14.

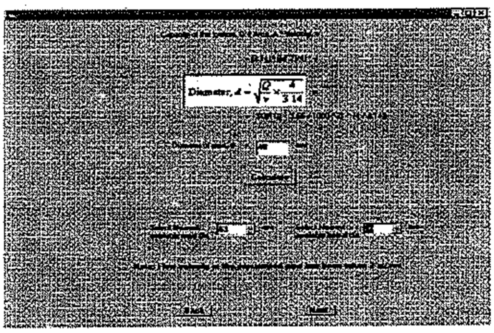

Figure 14 : Selection Of Sprinkler Diameter

Screen For The Generated Sprinkler Layout

Sprinkler layout is generated based on the values selected, entered or calculated on the previous screens. The generated design layout is shown in figure 15.

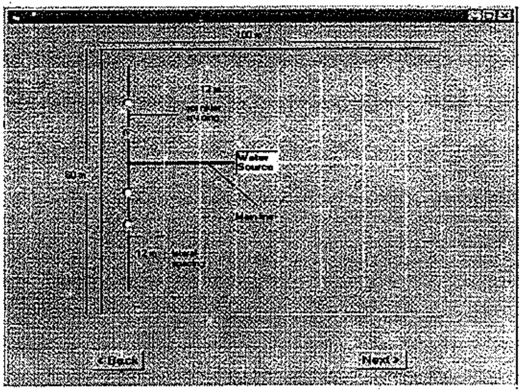

Figure 15 : Generated Sprinkler Layout

Screen For The Cost Estimate Of The Sprinkler System

After selection of filtration and fertiligation units, cost estimate of the complete sprinkler system is calculated. The cost estimates can be viewed on the screen or a print

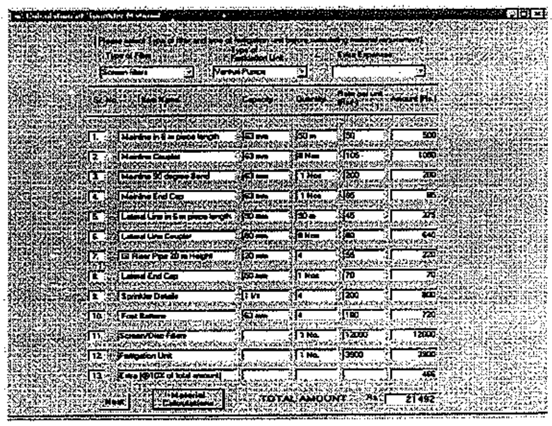

Figure 16 : Cost Estimates Of Sprinkler System

out can be taken for future use. The screen is shown in figure 16.

5. Conclusion

The software has been developed keeping in view the actual requirement of the farmers, which has following features:

1. Provides the design of drip and sprinkler irrigation systems based on the selected parameters.
2. Material required and approximate cost estimate of the system is known in advance before installation the actual system in the field.
3. Various combinations of values can be tried as per the requirement of the user to get the suitable design.

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