MODELING FIELD GEOMETRY OF MICRO-IRRIGATION SYSTEMS

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ABSTRACT

The purpose of planning an irrigation network is to achieve suitable water distribution and to satisfy the hydraulics and economic rules. A model was developed to design, plan and manage an irrigation system subject to a number of constraints according to field geometry, soil properties, plant characteristics and irrigation system parameters. As a result, management criteria may be achieved by selecting a layout pattern and the appropriate number of shifts. The Microsoft Excel Solver tool was used to solve the partitioning part. The model divides the field into subunits. The decision variables are: 1) pipe lengths and diameters (lateral, riser, manifold, auxiliary, submain and main). 2) The total number of subunits, number of sets (subunit parallel to the main line). 3) Number of submain lines perpendicular to the main line. 4) Possible numbers of shifts and shift time. 5) List of system equipment. 6) Pump total dynamic head, system capacity and pump power. 7) Cost analysis of the system and total capital cost. The model was successfully solved the problem of partitioning the field and specifies the dimension of different parts of the micro irrigation system network. The planning of the irrigation field layout accomplished among five patterns (A through E). The validity of the model was extended to select the economic pipe sizes and estimate the system total costs in case of one shift operation policy or at a higher number of shifts to reduce the cost. Throughout a case study to plan design and management of 20 fed. (300 m length and 280 m width) to irrigate trees 5mx5m spacing, results indicated that pattern E was the most economic option either in operating the system in one shift (the cost is 7348 LE.fed) or to reduce further cost to be 3861 L.E./fed.) in case of operate the system in four shifts. Investigating the effect of system area ranged between 5 to 50 feddan on system total cost indicated that the cost increased linearly proportional to

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the increasing of the system area. The effect of number of shifts on total cost was also studied. The results showed that the relationship is power function where the total cost is inversely proportional to increasing the number of shifts.

INTRODUCTION

Planning an irrigation network is to put a suitable layout of the piping system depending on the field shape and topography. This process has no predefine steps and depends mainly of the designer experience and sense while some economic and hydraulic considerations must be achieved. In this research the uniformity and hydraulic balance is an essential target and were considered. In the research the design criteria for flow variation within the subunit depends on distribute 20% of nominal operating pressure as recommended by Keller and Karmeli (1975), to design lateral diameter by 55% of the allowable pressure and manifold diameter by the rest of the allowable pressure, then round up the calculated diameters to the next commercial diameters.

The largest diameters confirm that the allowable pressure differences within the subunit not exceed the 20% allowable pressure and insure flow variation less than 10%. The diameter of riser auxiliary, submain and main lines were estimated based on limiting velocity rule; water velocity was less than 1.5 m/s.

A few studies have been reported on the optimization of pressurized irrigation systems considering field geometry ; **Abdel Wahed, (2002)** proposed a method to plan drip irrigation network, his method depends on dividing the field area into similar sections which must be irrigated by the total discharge of the pump. Each section subdivided into number of subunits. The subunits could be double or single lateral.

El- Awady and Osama (1996), investigated the effective factors geometrical proportion of the plot and the economical considerations for planning of trickle irrigation networks.. In their study, they considered the subplot is square with area ranging from 5 to 10 fed., lateral length equal half of the subplot length and the submain length is equal to the subplot length. The results are the optimum planning, number of subplot, number of laterals, submain and main.

Ismail *et al*., (2001) developed MicroCAD computer package for design and planning micro irrigation systems. The planning approach depends on categorizing the planning layouts into eighteen general cases. By default, MicroCAD set maximum manifold length to 100 m and the maximum lateral length to 50 m. The MicroCAD offers the option to automatically or manually modify the previous values. Beside the ability of selecting the planning category by number, any layout differ from the suggested could be applied and any modification to the suggested layout could be applied too.

Oron and Walker (1981) presented design model for sprinkler irrigation systems. Their model was based on the work of **Oron and Karmeli (1979)**. The aims of the work were to compute the number of subunits in both directions of the field, the optimum size of subunits, and the associated diameter of the system components. The system capital and operating costs, was examined as a function of field geometry, consumptive use and pressure head at the water source. They showed that the optimum division of the field into subunits is greatly affected by the field geometry. It depends not only on the area of the field, but also on its width/length ratio and most economical size of the subunit is the square type.

Oron (1982) suggested that fields to be irrigated with permanent pressurized systems should be divided into subunits. The subunit array permits one to irrigate part of the field at a time, achieve a more uniform emitter discharge, increase flexibility in irrigation practices, select smaller pipe sizes throughout the system, and allow one to use an increasing number of emitters per plant during the growing stages.

Hassanli and Dandy (1995), proposed design model for design and operation of drip irrigation system on flat terrain. The model minimizes the sum of the capital cost of the system and the present value of operating cost. In the model, the field was divided to subunits with an assumed layout and configuration of piping system

A few studies have been reported on planning the pressurized irrigation systems considering the field geometry and subunit size.

The main objective of the work was to develop model for design, plan and manage an irrigation system subject to a number of constraints according to field geometry, soil properties, plant characteristics and irrigation system parameters.

Model Development

System components:

This model plans a flat rectangular micro irrigation system, design the network for minimum total cost. The different layout patterns considered in the research are shown in Fig. (1). They consist of a pump and control head at the edge of the field for patterns A,B,C and at the center for patterns D,E. The piping system consists of one main line parallel to one edge of the field in the first category patterns, and two mainlines at both sides of the pump in the other pattern. The mainline deliver water from the pump to the submain pipes. The submain lines are perpendicular to mainline. Auxiliary pipes receive water from submain to manifold and then to the laterals throughout risers. Summary of these variables describing the field geometry and various constants are illustrated as follows:

Integer variables:

ne = number of emitters on lateral on both sides of lateral.

nl = number of laterals along the manifold ion both sides of the manifold

NsX = number of submains applying subunits parallel to the main line

NsY = number of subunits parallel to the submain.

Ns = number of subunits on the system

Constants:

SX = field length in X direction (m)

SY = field length in Y direction (m)

se = spacing between emitters (m)

sl = spacing between laterals (m)

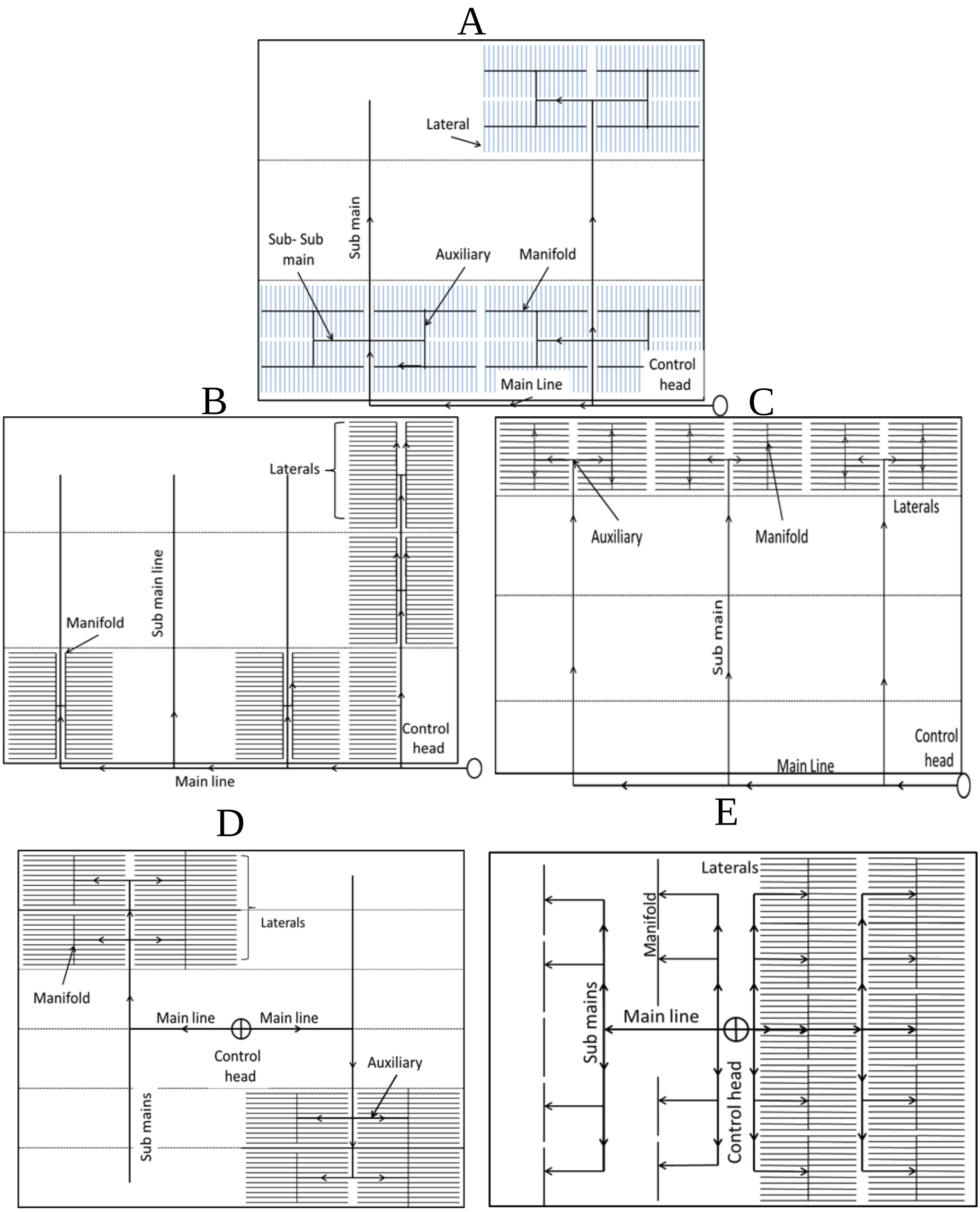


Fig (1): Layout pattern from “A” to “E” that the model investigated.

<u>Planning the micro irrigation system:</u>

The partitioning of the field geometry has been carried out using the principles of operation research as:

Equalize: $$\frac{(ne.se).(nl.sl).(2NsX).NsY}{Sx.Sy} = 1 \qquad (1)$$

Subject to:

1- Limiting lateral length

$$50 \leq int\{se\ (ne-1)\} \leq 100 \qquad (2)$$

2- Limiting manifold length

$$50 \leq int\ \{sl(nl-1)\} \leq 100 \qquad (3)$$

3- Defined the number of subunits in y direction: $NsY = \frac{SY}{nl*sl}$

4- Defined the number of subunit in x direction: $2.NsX = \frac{LX}{ne*se}$ or $NsX = \frac{LX}{ne*se}$ depends on layout pattern (2 in case of two subunits on both sides of the sub main line)

5- Defined the number of subunits on the system: $\frac{2\ NsX\ .NsY}{Ns} = 1$ or $\frac{NsX\ .NsY}{Ns} = 1$ depends on layout pattern

Based on the above criteria of planning micro irrigation system, the total number and / or total length of the field components of the distribution network can be expressed with the previous variable and constants given in Table (1).

Irrigation interval, irrigation time and number of shifts:

Irrigation interval is the time in days between the commencement of one irrigation cycle and the next. The irrigation time or duration is the length of irrigation event (The period of time during which water is being released from one set of emitters). The irrigation shifts (N_{sh}) refers to the number of different sets of submains which are irrigated simultaneously; one shift means irrigating the entire field simultaneously. Two shifts operation involves irrigating half of the field at the same time of one shift. The model allows the number of shifts to be chosen as decision variable. Initial estimate of number of shifts is essential for specific crop, soil and irrigation system.

1- **Irrigation intervals** determined by identifying the depth of water which can be stored in the soil and the consumptive use of the crop as:

$$RAW = 10(fc - wp).R.dr.P_W \qquad (4)$$

Where:

RAW = depth of water available to the crop in soil (mm)

Fc = soil field capacity moisture content(%)

Wp = soil wilting point moisture content (%)

R = root depth (m)

Dr = fraction of available moisture depletion allowed (decimal)

P_W = wetted area as a percentage of total area of irrigation (%)

The maximum irrigation interval (*Iv*) is estimated so that the average daily transpiration (ET_C) during the beak use period in each irrigation cycle is less than or equal to the depth of water which can be stored in the root zone

$$Iv \leq \frac{RAW}{ET_C} \qquad (5)$$

2- **Gross irrigation requirements (G_{IR}).**

$$G_{IR} = \frac{ET_C}{E_a} \times \frac{1}{(1-LR)} \qquad (6)$$

Where:

Ea = irrigation system application efficiency (decimal).

LR = leaching requirements (decimal).

3- **Irrigation duration (Id).**

$$Id = \frac{G_{IR} .Iv .se.sl}{q .n_p} \qquad (7)$$

Where:

q = emitter flow rate (l/h)

n_p = number of emitter per plant.

4- Number of shifts per irrigation cycle (N_{sf}).

$$N_{sf} \leq \frac{Iv.Dl}{Id} \qquad (8)$$

Where:

Dl = day length, taken as (20 h/day)

Piping system diameters and lengths:

The irrigation system network consists of two types of pipes, conveyance and distribution. Lateral were considered distribution pipes, therefore; 20% of emitter operating pressure distributed as 55% on lateral and 45% on manifold. Auxiliary, riser, sub-submain, submain and mainline were considered conveyance pipes, Therefore; a limiting maximum velocity of water inside the pipe as 1.5 m/sec was considered as the design criteria to find conveyance pipe diameters. After the pipe diameter is calculated it rounded up the next commercial pipe diameter and cost estimation based on its price.

System Hydraulic Losses

Darcy-Weisbach formula and Blassius equation were applied to determine the friction head loss within the piping system as follows:

$$Hf(i) = 79844.75\,.L(i)\,.\;Q(i)^{1.75}D(i)^{-4.75}F(i) \qquad (9)$$

Where:

i =subscript the pipe

Hf = friction loss along the pipe, (m)

F = reduction factor of the pipe as a function of outlets.

L = pipe length (m)

Q = pipe discharge (m^3/h)

D = pipe diameter (mm)

F = reduction factor

The reduction factor F depends on the discharge exponent of friction loss formula (m) and the number of outlet "*no*" in the line under consideration as:

$$F1 = \frac{1}{m-2} + \frac{1}{no} + \frac{\sqrt{m-4}}{6.no^2} \qquad (10)$$

In this study, the first outlet (emitter or lateral) was half the others spacing; therefore, the F1 has to be readjusted to another factor F as:

$$F = \frac{2no}{2no-1} * F1 - \frac{1}{2no-1} \qquad (11)$$

Table(1): Number or length of all the field components in the distribution network of all layout patterns considered in the study

Items	Patten A	Pattern B	Pattern C	Pattern D	Pattern E
Total No of emitters on the system	$\frac{Sx\ Sy}{se.sl}$	The same	The same	The same	The same
Total lateral lengths on the system	$Sx\ Sy\left\{\frac{ne-1}{sl\ .ne}\right\}$	The same	The same	The same	The same
End plugs for laterals	$2\left\{\frac{Sx.Sy}{se.ne.sl}\right\}$	The same	The same	The same	The same
Total Tees connecting lateral to riser	$\frac{Sx.Sy}{se.ne.sl}$	The same	The same	The same	The same
Total length of risers on the system	$Sx.Sy\left\{\frac{hr}{se.ne.sl}\right\}$	The same	The same	The same	The same
Total Tees connecting riser to manifold	$\frac{Sx.Sy}{se.ne.sl}$	The same	The same	The same	The same
Total length of Maifolds pipes	$Sx.Sy\left\{\frac{nl-1}{ne.se.nl}\right\}$	The same	The same	The same	The same
Tees connecting auxiliary to manifold	$\frac{Sx.Sy}{(se.ne)(nl.sl)}$	-	The same	The same	The same
Auxiliary pipe lengths	$Sx.Sy\left\{\frac{0.5}{nl.sl}\right\}$	-	The same	The same	The same
Tees connecting auxiliary to sub-submain	-	-	-	$2\ NsX.NsY$	-
Tees connecting Sub-submain to submain	-	-	-	$NsX.NsY$	-
sub -Submain total length	-	-	-	$\frac{Sx.Sy}{ne.se}$	-
Submain total length	$NsX\left\{Sy-\frac{nl.sl}{2}\right\}$	The same	$\{Sy.(nl.sl)\}NsX$	$NsX\left\{Sy-\frac{nl.sl}{2}\right\}$	$(Nsy-1)Nsx(sl.nl)$
Tees connecting auxiliary to submain	$2NsX.NsY$	-	-	-	$NsX.NsY$
Main line total length	$Sx-(ne.se)$	The same	$Sx-2(ne.se)$	$Sx-(nl.sl)$	$Sx-(ne.sl)$
Tees connecting submain to main	NsX	The same	The same	The same	The same
Total No of subunits on the system	$2NsX.NsY$	The same	The same	The same	$NsX.NsY$
Total No of subunit valves	$2NsX.NsY$	The same	The same	The same	$NsX.NsY$
Total No of subunit pressure regulators	$2NsX.NsY$	The same	The same	The same	$NsX.NsY$

Table (2): Definitions of system piping (*i*), system length (*L*), discharge (*Q*), and number of outlets (*no*) .

Pipe(i)	L, (m)	Q, (m^3/h)	Outlet No. no
Lateral (A,C,E,D) Lateral (B)	$0.5(ne-1).se$ $(ne-1).se$	$0.5\,(ne.kH^x)$ $(ne.kH^x)$	int. (0.5 ne) (ne)
Manifold	$0.5(nl-1).sl$	$0.5\,(nl.ne).kH^x$	int. (0.5 nl)
Riser	0.6	$ne.kH^x$	-
Auxiliary (A,C.D,E)	$0.5(ne.se)$	$(nl.ne).kH^x$	-
Sub-sub main (A)	$sl.nl/2$	$2.(nl.ne).kH^x$	-
Submain (A,B,C) Submain (D) Submain (E)	$Sy-0.5(nl.sl)$ $0.5\,Sy-0.5(nl.sl)$ $0.5\,Sy-0.5(nl.sl)$	$2.NsY.(nl.ne).kH^x$ $NsY.(nl.ne).kH^x$ $0.5.NsY.(nl.ne).kH^x$	$2.NsY$ NsY $int(0.5.NsY)$)
Main (A,B,C) Main (D) Main (E)	$Sx-(ne.se)$ $0.5.Sx-(ne.se)$ $0.5.Sx-(ne.se)$	$2.NsY.NsX.(nl.ne).kH^x$ $NsY.NsX.(nl.ne).kH^x$ $0.5.NsY.NsX.(nl.ne).kH^x$	NsX $int.(0.5.NsX)$ $int.(0.5.NsX)$

Minor loss due to emitter connection barb on lateral was estimated by additional length method according to **SCS, (1984)** by:

$$f_e = 1 + \frac{18.91}{se\;.\;Dl^{1.87}} \qquad (12)$$

Then lateral length (L) changed by (L . $\frac{se+fe}{se}$) where *D* is lateral diameter, (mm). and *se* is the distance between emitters.

Tee head loss due to connecting the network pipes was estimated according to **Keller and Bliesner, (1990)** by the following equation:

$$Hf_T = K_T\frac{V^2}{2g} \quad or \quad 6375.5\;K_T.Q_T^{\;2}\;.D_T^{\;-4} \qquad (13)$$

Where:

V = water velocity (m/s)

g = acceleration of gravity (m^2/s)

K_T = tee loss coefficient (1.2 from line to branch flow and 0.8 from branch to line flow)

D_T = diameter of the tee, (mm)

Q_T = discharge across the tee (m^3/h).

In large areas where the field is divided into subunit, it may be essential to install pressure regulator next to auxiliary to insure uniformity of water application. The friction loss across the pressure regulator is a function of the water discharged to the subunit. The head loss across the pressure regulator estimated according to **Goehring (1976)** as;

$$HF_{PR} = 0.13\, Q^2{}_{SU} + 0.67\, Q_{SU} + 1.56 \tag{14}$$

Where:

Q_{SU} = flow rate submitted to subunit (m^3/h)

Head loss across the control head was estimated according to **Holzapfel et al., (1990)** by;

$$HF_{CH} = 0.02\, Q^{1.474}{}_{CH} \tag{15}$$

Where:

Q_{CH} = flow rate submitted to the system (m^3/h).

<u>Cost of the irrigation system</u>

The cost of the irrigation system include the capital cost of piping system, pump, emitters, valves, accessories and the operating cost;

$$Z = C_{pi} + C_{pu} + C_{em} + C_{ac} + C_{op} \tag{16}$$

Where:

Z = system total cost

C_{pi} = cost of piping system

C_{pu} = cost of pump

C_{em} = cost of emitters

C_{ac} = cost of accessories and fittings

C_{op} = operating cost

The cost of pipes can be expressed as:

$$C_{pi} = C_l + C_m + C_r + C_a + C_{sub} + C_{ma} \tag{17}$$

Where:

C_{pi} = total cost of the piping system

C_l = cost of laterals
C_m = cost of manifolds
C_r = cost of riser
C_a = cost of auxiliary
C_{sub} = cost of submain lines
C_{ma} = cost of the main line

The system assumed to be semi automated, thus; the labor cost is small compared to the capital and energy cost.

The model subunit pipes, laterals were assumed to be laid on ground while the rest of the piping system, manifold, riser, auxiliary, submain and main are assumed to be buried. Therefore; installation cost is added to the pipe cost as 10% for laterals and 20% for the buried pipes.

The cost of pumping system (C_{pu}) is a function of its power and discharge (**Holzapfel *et al*., 1990**) as follows:

$$C_{pu} = K_P \left\{ \frac{Q_{pu} \cdot H_{pu}}{270. \ \eta_p} \right\} \qquad (18)$$

Q_{pu} = discharge of the pump (m^3/sec), system total number of emitters/
number of shift x emitter flow rate

H_{pu} = Total dynamic head at the pump (m)

K_P = constant found by fitting a set data include the cost of various pumps
and their design head and discharge

The cost of accessories include filter unit, chemical injection tank and cost of valve for each subunit, one for each submain line and one for each main line.

The power of electric motor expressed as:

$$P_m = \frac{\gamma \ Q_{pu} \ H_{pu}}{\eta_m \ \eta_p} \qquad (19)$$

Where:

P_m = electric motor power (Kw)

γ = specific weight of water (N/m^3)

$\eta_m \ \eta_p$ = efficiency of motor and pump respectively.

The annual energy requirements (kWh) based on annual irrigation requirements and annual operating hours of pump :

$$A_{en} = 2.78\, X\, 10^{-7}\, P_m \frac{A_{ir}\, Sx\, SY}{E_a\, Q_{pu}} \qquad (20)$$

Where:

A_{en} = annual energy requirements (kWh)

A_{ir} = net annual irrigation requirements (mm)

E_a = irrigation system application efficiency

<u>Basic inputs to the model:</u>

The model was run using the Microsoft Excel Solver tool. The input variables are:

1- field dimension Sx, Sy.
2- potential evapotranspiration ETo and crop coefficient, Kc or the crop consumptive use ETc.
3- percent of the wetted area Pw by the emission devices
4- emitter characteristics and flow function q, k, x, Ho.
5- application of the irrigation efficiency Ea.
6- annual irrigation requirements for the crop, A_{ir}
7- field capacity Fc and permanent wilting point wp of the soil.
8- effective depth of the root, Rz.
9- allowable depletion ratio, dr.
10- spacing between emitters, se and lateral spacing, sl.
11- hours per day for irrigation, Tr.
12- efficiency of the electric motor η_m and the pump efficiency η_m.
13- available diameters for PVC and PE pipes, accessories and their price lists.
14- energy cost (C-kWh)
15- cost functions of the system component.
16- length of irrigation season, LSI (days)

<u>Model assumptions:</u>

The general configuration of pipes within the field (main and sub main lines) and within the subunit (lateral, manifold, auxiliary and riser) were layed out as given in Fig.(1) by patterns from A to E. The model was developed for a field with unknown area and unknown dimensions for which the water source is located at the edge of the area or at the center. The model can be easily applied to any size and field dimensions.

RESULTS AND DISCUSSION

The main objective of the study is to develop model to plan, design and manage micro irrigation system characterized by economic cost with acceptable flow variation. The model was based on multiple subunit system. The influence of system area, number of shifts and layout pattern on total cost will be investigated and discussed among case study to find an optimum solution among various operating conditions.

Case study and analysis of the model results:

To validate the model; a micro-irrigation system of 20 fed. level rectangular field cultivated by trees 300m x 280m need to be planed, designed and managed for minimum total cost taken in to account acceptable number of shifts and flow variation using data given in Table(3).

Table. (3): Constants and input data for the case study

Variable	value	Variable	value
Se	5 m	X	0.5
Sl	5 m	C_{em}	14.42 L.E/unit
LSI	180 day	Ho	20 m
Tr	20 hr	Kp	1050
FC	20%	PE	60%
Pw	10%	C-kWh	0.4
Wr	50%	C-EP[1]	0.5 L.E./UNIT
R	1m	C-PR[2]	180 L.E./UNIT
dr	50%	ET_{crop}	8 mm/day
K	0.008		

1 C-EP: Cost of end plug.

2 C-DR Cost of pressure regulator.

Five main runs were achieved for each of the layout patterns, A thtough E. For each run the model specifies the number of the sub main lines (Nsx) attached to the main line and number of subunit normal to the main line attached to the sub main line (NsY). Also, the number of emitters on laterals, the number of the laterals on the manifolds and the system total number of subunits were determined. The results of layout parameters from A to E patterns presented in Table (4). Secondary runs were archived after each main run based on the available number of shifts. For instance, according to the given input data of soil, plant, and irrigation system characteristics, the irrigation interval was 4 days and the irrigation time/shift was 5 hours. Therefore., the system could be operated just one time each 4 days as one shift or on two shifts in 10 hours or for four shifts in 20 hours continually to irrigate the whole area in one day. Another option could be in two sifts day by day or shift per day and so on. The selection of management policy depends on the available water source, labors and the cost of investment. The results of the secondary runs of each layout pattern according to the available number of shifts were given in Table (4,5 and 6) either for the management and design parameters or the cost analyses for each item of the network. Pipes, emitters, accessories and energy relative costs to the system total cost increased by increasing the number of shifts. The relative cost of the control head and pumping have a different behavior, where the relative cost decreased by increasing the number of shifts. Summarized results are given in Table (8), showed the total cost for different number of shifts at each layout pattern and the expected flow variation. Pattern E was the most economic option either in operating the system in one shift (the cost is 7348 LE. fed) or to reduce further cost to be 3861 L.E./fed.) in case of operate the system in four shifts.

To show the effect of area and number of shifts on total cost. Pattern ”E” was considered for the available number of shifts. Areas ranged between 5 to 50 feddan were selected. The output results were presented in Table (7). Analyzing the results indicated that the cost increased linearly proportional to the increasing of the system area as shown in Fig. (2 a). The effect of number of shifts on total cost showed that the relationship is power function where the total cost is inversely proportional to increasing the number of shifts as given in Fig. (2 b).

Table(4): Different layout patterns of model.

Layout parameters							
Input		Output					
			Pattern A	Pattern B	Pattern C	Pattern D	Pattern E
Field total area	20 fed.	No. of sub main lines NsX	2	2	2	2	4
Field length in X direction Sx	300 m	No. of subunit parallel to main line NsY	4	4	4	2	4
Field length in Y direction SY	280 M	Total No. of subunit on system NS	16	16	16	16	16
Distance between emitters se	5 m	No. of emitters on lateral (ne)	15	15	15	15	15
Distance between laterals ne	5 m	No. of laterals on manifold (sl)	14	14	14	14	14

Table(5): Results of model output for management and design parameters.

	Management and design parameters													
Items	Pattern													
	A			B			C			D		E		
	1 shifts	2 shifts	4 shifts	1 shifts	2 shifts	4 shifts	1 shifts	2 shifts	4 shifts	1 shifts	2 shifts	1 shifts	2 shifts	4 shifts
Lateral diameter (mm)	13.6	13.6	13.6	15.6	15.6	15.6	13.6	13.6	13.6	13.60	13.6	13.6	13.6	13.6
Manifold diameter(mm)	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.40	28.40	36.4	36.4	36.4
Riser diameter(mm)	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
Auxiliary diameter(mm)	46.4	46.4	46.4	-	-	-	46.4	46.4	46.4	46.40	46.6	59.2	59.2	59.2
Sub submain line diameter	-	-	-	-	-	-	-	-	-	70.6	70.60	-	-	-
Sub maim diameter(mm)	131.8	84.6	70.6	131.8	84.6	70.6	84.6	84.6	59.2	131.8	84.6	103.6	70.6	59.2
Main line diameter(mm)	188.2	131.8	84.6	188.2	131.8	84.6	84.6	84.6	84.6	188.2	131.8	131.8	103.6	103.6
Total system capacity m^3/h	120.1	60.1	30.05	120.2	60.11	30.53	120.21	60.11	30.05	120.2	60.11	120.21	60.11	30.06
Total dynamic head m	55.4	41.8	39.63	55.09	41.90	36.70	33.36	33.17	23.00	56.62	44.45	41.47	34.58	34.12
Pump power kW	30.7	11.9	5.49	30.50	11.60	5.22	18.48	9.18	4.43	31.34	12.30	22.95	10.14	4.73
Flow variation on subunit %	7.67			7.15			9.40			9.2		6.48		

Table(6): Results of model output for cost analyses parameters.

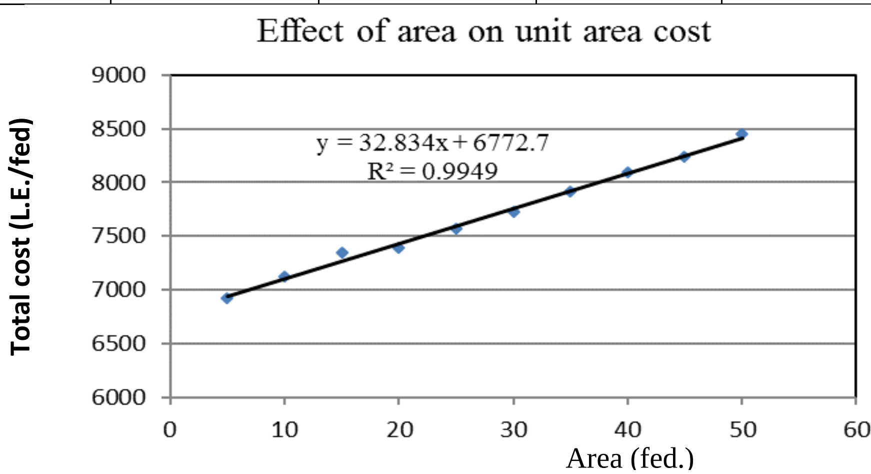
Items	Cost analyses parameters													
	A			B			C			D		E		
	1 shifts	2 shifts	4 shifts	1 shifts	2 shifts	4 shifts	1 shifts	2 shifts	4 shifts	1 shifts	2 shifts	1 shifts	2 shifts	4 shifts
Total cost LE.fed	9604	6765	2556	9938	7068	5871	8587	6536	5472	9641	6670	7348	4977	3861
Piping cost (%)	19.11	26.1	31.28	22.63	30.71	36.59	21.94	27.95	33.17	19.56	26.78	19.85	28.81	36.77
Emitters cost (%)	24.90	35.5	43.28	24.07	33.85	40.75	27.86	36.6	43.42	24.81	35.33	16.01	23.63	30.46
Accessories cost (%)	2.10	2.95	3.57	1.38	1.90	2.27	1.58	2.06	2.45	1.46	2.05	1.53	2.21	2.83
Head cost (%)	21.1	15.4	9.31	20.93	14.68	8.8	24.22	15.87	9.44	21.57	15.33	28.3	20.85	13.38
Pumping cost (%)	30.6	18.2	10.48	29.44	17.06	9.57	24.23	15.85	9.26	30.96	18.55	32.59	22.17	13.67
Energy cost (%)	1.61	1.93	2.22	1.56	1.81	2.03	1.28	1.68	1.96	1.64	1.96	1.73	2.35	2.90

Table (7): Output results of pattern “E” for different areas.

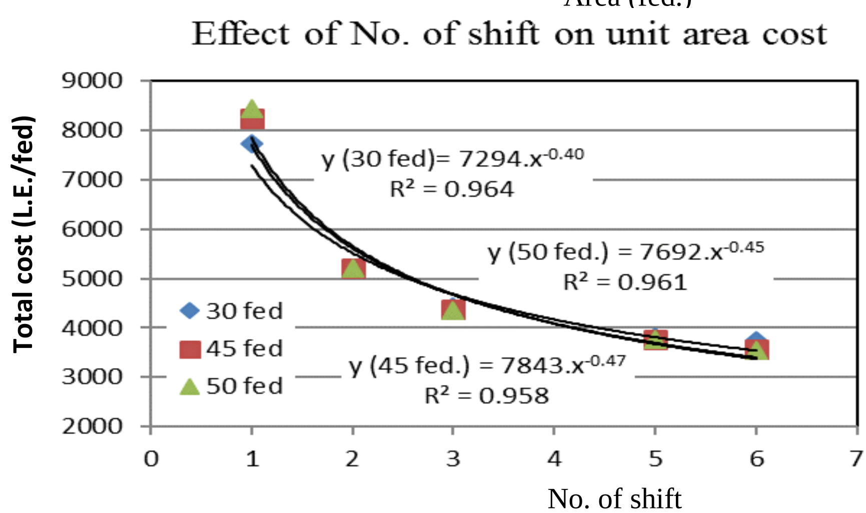
Area (fed.)	X	Y	NsX	NsY	Cost per unit area (LE./.fed.)							Flow variation %	No. of units	Unit area m^2	Lateral length m	Manifold length m
					1 shift	2 shifts	3 shifts	4 shifts	5 shifts	6 shifts	7 shifts					
5	150	140	2	2	6918	4836						7.67	4	5250	35.0	32.5
10	225	200	3	2	7121	4916	4116					5.7	6	7500	35.0	47.5
15	315	200	3	2	7342	4966	4249					6.49	6	10500	50.0	47.5
20	340	255	4	3	7391	5017	4249	3922				5.78	12	7225	40.0	40.0
25	350	300	5	4	7565	5099		3974	3797			7.47	20	5250	32.5	35.0
30	390	325	6	5	7724	5192	4438		3826	3729		4.83	30	4225	30.0	30.0
35	420	350	7	5	7915				3858		3664	4.63	35	4200	27.5	32.5
40	420	400	4	5	8091	5173		3956	3671			8.73	20	8400	50.0	37.5
45	450	420	5	6	8240	5206	4372		3773	3576		8.52	30	6400	42.5	43.5
50	500	420	5	6	8449	5219	4355		3769	3551		6.48	30	7000	47.5	32.5

Table. (8):Total cost (L.E./fed.) and flow variation of different pattern of layout and number of shift.

Pattern	One shift	Two shifts	Four shifts	Flow variation %
A	9604	6765	5546	7.67
B	9938	7068	5871	7.15
C	8587	6536	5472	9.40
D	9441	-	6670	9.20
E	7348	4977	3861	6.48



(A)



(B)

Fig. (2): Effect of system area and number of shifts on system total cost.

SUMMARY AND CONCLUSION

Planning an irrigation network is to achieve suitable distribution of water and satisfy the hydraulics and economic rules. The objective of this research is to develop model to design, plane and manage an irrigation system subject to field geometry, soil, plant and irrigation system parameters. Planning or partitioning of the micro irrigation system was archived by solving equality subject to field area, dimensions, distance between lateral and emitters, constraints to limit lateral and manifold lengths and two other integer variables describes the arrangement of subunits around the main and submain lines. The Microsoft Excel Solver tool that applies the Generalized Reduced Gradient code was used to solve this part of the model. The model divides the field into subunits. The output variables are pipe lengths and diameters (lateral, riser, manifold, auxiliary, submain and main), the total number of subunits, number of sets (subunit parallel to the main line), and number of submain lines normal to the main line. Diameters of Lateral and manifold determined based on dividing 20% of the emitter nominal operating as allowable friction loss divided to 55% on lateral and 45% for manifold. Other network pipe diameters were designed based on water velocity limit to 1.5 m/sec. According to the soil and plant characteristics, the irrigation interval, duration and the possible number of shifts were determined. Based on the number of shifts the system was divided to number of subunits operate simultaneously. Base on the shift number the conveyance pipe diameters (main and submain), system water capacity, total dynamic head, pump power were re-estimated, therefore, the system total cost. The validity of the model was confirmed throughout two case studies. The first is to plan design and manage of 20 fed. (300 m length and 280 m width) to irrigate trees 5mx5m spacing. The selection of the layout was among 5 patterns. Pattern No. E was the most economic option either in operating the system in one shift (the cost is 7343 LE.fed) or to reduce further cost to be 3861 L.E./fed.) in case of operate the system in four shifts. The other case study was to investigate the effect of system area (between 5 to 50 fed.) on system total cost. The results indicated that the cost increased linearly proportional to the increasing of the system area. The effect of number of shifts on total cost

was also studied. Results showed that the relationship is power function where the total cost is inversely proportional to increasing the number of shifts.

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الملخص العربي

نمذجة التخطيط الحقلي لنظم الري المصغرة

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الهدف من هذا البحث هو إنشاء نموذج رياضي قادر على تخطيط وتصميم وإدارة نظم الري المصغر مراعيا في ذلك القواعد الأساسية للتصميم الهيدروليكي لشبكة الري مع الحفاظ على انتظام توزيع المياه وتقليل التكاليف الاقتصادية من ناحية الإنشاء والتشغيل. وللوصول إلى هذا الهدف فقد تم تطوير نموذج قادر على حل خمسة نماذج للتخطيط (A, B, C, D, E)، ثلاثة منها يكون مدخل مصدر المياه من على أطراف الحقل (A, B, C) واثنان من مركز الحقل (D, E). كما يمكن إضافة العديد من النماذج الأخرى وحلها بنفس الطريقة. ويعتمد ذلك على حل متساوية لبعض الثوابت والمتغيرات. والثوابت هي طول وعرض الحقل والمسافة بين المنقطات على خطوط التنقيط والمسافة بين خطوط التنقيط على طول المشعب. ومتغيرات توزيع وحدات الري على الخطوط التحت رئيسة (على الجانبين أو على جانب واحد) وعدد الخطوط التحت رئيسة الممكنة على امتداد طول الحقل. وكذلك عدد وحدات الري الممكنة على امتداد عرض الحقل، الحدود المسموح بها لخطوط التنقيط والمشعبات. تكون المخرجات عبارة عن عدد المنقطات على طول خط التنقيط (طوله) وعدد خطوط التنقيط على المشعب (طوله) وكذلك عدد الخطوط التحت رئيسة وأطوالها وعدد وحدات الري العمودية على الخط الرئيس وعدد الوحدات الكلية للنظام وطول الخط الرئيس وأطوال الخطوط الأخرى هذا بالإضافة إلى بيان بإجمالي المهمات المطلوبة. وقد تم تصميم أقطار خط التنقيط والمشعب على أساس تقسيم ٢٠% من ضغط التشغيل الأسمى للمنقط المستخدم كفاقد مسموح به بنسبة ٥٥% لتصميم قطر خط التنقيط و٤٥% لتصميم قطر المشعب. أما باقي الأقطار على شبكة الري فتم تقديرها على أساس قاعدة عدم تجاوز سرعة المياه بها ١,٥ م/ث. ويلي هذه الخطوة تعديل الأقطار المحسوبة إلى الأقطار الأكبر المتاحة في الأسواق.

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وبذلك يتم تقدير فواقد الضغط الكلية داخل وحدة الري وبالتالي الاختلاف الفعلي في التصرف. وبناء على بيانات التربة وقدرتها على الاحتفاظ بالمياه وخواص النبات (عمق الجذور، نسبة الاستنفاذ والبخر نتح) يتم تقدير فترة الري ومدة الري وعدد المناوبات الممكنة والتي يمكن من خلالها تقسيم الحقل إلى قطاعات تعمل بها عدد من حدات الري سويا. ويلي هذه الخطوة إعادة حساب أقطار شبكة الري الموصلة للمياه إلى وحدات الري (الخطوط التحت رئيسة والخطوط الرئيسة) حسب الوحدات العاملة معا وترتيبها وبالتالي ضاغط التشغيل الكلى وسعة الطلمبة المائية وقدرتها. ثم يتم تقدير تكاليف الإنشاء والتشغيل عند كل من المناوبات المتاحة. وللتأكد من صلاحية هذا النموذج في تخطيط وتصميم وإدارة نظم الري المصغرة، فقد تم تقديم دراسة حالة لري ٢٠ فدان أشجار بوحدة ري مصغرة لأقل تكاليف إنشاء وتشغيل. فأظهرت النتائج أن النموذج E هو الأنسب من الناحية الاقتصادية سواء مع تشغيل النظام في مناوبة واحدة وذلك بتكاليف كلية سنوية مقداره ٧٣٤٣ جنيه أو عند التشغيل على أربعة مناوبات بتكلفة كليه سنوية مقدارها ٣٨٦١ جنيه. وبدراسة تأثير مساحة النظام على التكلفة الكلية، أظهرت النتائج أن العلاقة خطية. ودراسة عدد المناوبات على التكلفة الكلية، أظهرت النتائج أن العلاقة عكسية تناقصية.