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Movable Surface Irrigation System (MSIS) Impact on Spatial and Temporal Distribution of Soil Moisture and salinity

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Abstract: *Movable surface irrigation system (MSIS), was carried out by modification of center pivot irrigation system and depends on replacing the sprayers by polyethylene hoses ending by nozzles. Field experiments were conducted at farm on Alex-Cairo desert road, to assess moving surface irrigation system at 2012 year. The main aims of this research are to study spatial and temporal moisture and salinity distribution patterns under (MSIS), the modification of pivot irrigation system to be more suitable to irrigate some trees, and other high crops under special conditions, to evaluate the modification system and to reduce the investment costs of the modified system. Results show that, operating the (MSIS)at low pressure head (1.5 bar), water amount was saved by (16.8%)(Abdel-Rahman, 2005), the uniformity coefficient was 90.75%, beside, the movable surface system reduced the hazard of chemigation. Finally, High efficiency of applied water distribution, reduce deep-percolation, reducing runoff and having good management without exceed water irrigation by using (MSIS).*
Keywords: *Center pivot, Surface irrigation, movable, Hydraulics, Soil moisture, Salinity distribution, deep-percolation, runoff and uniformity.*

I. Introduction

Irrigation development is a gateway to increased agricultural, water and land productivity, increasedfarmhold and national food security. However, irrigation development has been a major challenge inmany developing countries, including Egypt.**Hanson (1993)** mentioned that efficient furrow irrigation requires reducing deep percolation and surface runoff losses. Water that percolates below the root zone (deep percolation) is lost to crop production, although deep percolation may be necessary to control salinity. Deep percolation can be reduced by improving the evenness of the applied water and preventing over irrigation. **Benham and Eisenhauer (2000)** reported that regardless of whether you dike or block the ends of your furrows, or if you irrigate using every or every-other furrow, soil texture, slope and surface conditions (whether the furrow is smooth or rough, wet or dry) all influence how quickly water advances down the furrow. The speed of advance is directly related to how uniformly irrigation water is distributed within the soil profile. The soil infiltration rate is also affected by soil surface conditions.

Center pivot irrigation systems application and have experienced tremendous growth around the world in recent years due to: 1) their potential for highly efficient and uniform water applications, 2) their high degree of automation requiring less labor than most other irrigation methods, 3) large areas coverage, and 4) their ability to economically apply water and water soluble nutrients over a wide range of soil, crop and topographic conditions. On other side, sprinkler pivot needs high pressure for operating, in order to needs careful assessments whenever it's using chemigation to reduce hazard, also causes some soil compaction, splash erosion, as well as, they for have not the flexibility to irrigate trees, shrubs and vegetables which have been sensitive to water high humidity levels.

LEPA technology has been developed to find the suitable methods of reducing water consumption and energy use in irrigated agriculture. One aspect involved the elimination of the high spray evaporation losses common in Texas. For instance, **Clark and Finley (1975)** found that at a wind speed of 15 miles per hour (which is the annual average for the Texas High Plains) evaporative losses were 17 percent, and at speeds of 20 miles per hour losses were over 30 percent. In the Southern High Plains, losses on a linear-move sprinkler system have been measured as high as 94 percent when wind speed averaged 22 miles per hour with gusts of 34 miles per hour **(Lyle and Bordovsky, 1981 b**). Another aspect involved designing a system to be used in conjunction with micro-basin land preparation or furrow diking which prevents runoff and maximizes the use of rainfall and applied irrigation water. Adouble-ended sock was developed to accomplish both goals. No wind losses result since water is discharged directly into the furrow. Also, the open ends help preserve the dikes. However, this method can be used only for irrigation.**Porter and Marek. (2009).**Center Pivot irrigation systems are used widely where most of the systems are low pressure systems, including Low Energy Precision Application (LEPA); Low Elevation Spray, Application (LESA), Mid-Elevation Spray Application (MESA) and

Low Pressure In-Canopy (LPIC). Low pressure systems offer cost savings due to reduced energy requirements as compared with high pressure systems. They also facilitate increased irrigation application efficiency, due to decreased evaporation losses during application. Considering high energy costs and in many areas limited water capacities, high irrigation efficiency can help to lower overall pumping costs, or at least optimize crop yield/quality return relative to water and energy inputs. **ASAE (1995)** defined low energy precision application(LEPA),asa water, soil, and plant management regime where precision down-in-crop applications of water are made on the soil surface at the point of use. Application devices are located in the crop canopy on drop tubes mounted on low pressure center pivot and linear move sprinkler irrigation systems.

In Egypt, the first farm which depended on pivot at irrigation process was 6 October farms at El-Salihia (Cairo-Ismielia Desert Road),Besides, Dina farm (1978)Typical 6 October farms and more of big farms at Cairo-Alex. Desert Road, and more of a big farms invested pivot irrigation systems, because of low operating cost, low repairs, low maintenance requirements and great results (personal communication).

Many of farmers wish that pivot can irrigate shrubs and some tree according to great economical income of growing under pivot irrigation systems.

The aims of study are concentrated on, 1) to study spatial and temporaldistribution of soil moisture and salts under Movable Surface Irrigation System (MSIS), 2) evaluate the water losses reducing, 3) reducing chemigation hazard, and 4) reducing operating costs. To achieve these aims through:

1. Measuring and analysis soil moisture and salts distribution patterns under (MSIS) Moveable Surface Irrigation System (MSIS),
2. Evaluate the uniformity coefficient of MSIS system, and

II. Materials And Methods

Experimental site:

The applied irrigation system was a pivot located at Farm (kilo 70)on Alex-Cairo desert road, Soil and irrigation water analysis were conduct according to standarad producer and represent in Table (1,2,3).

Table (1): Some physical properties of soil:

Soil depth cm	Partical size distribution				F.C %	W.P %	B.D g/cm3	$CaCo_3$ (%)	Texture class
	C. Sand%	F. Sand%	Silt %	Clay %					
0-30	3.3	53.2	14.2	29.3	28	17	1.37	30.5%	S.C.L
30-60	3.3	52	15.8	28.9	29.5	19	1.40	29.4%	S.C.L
60-100	3.9	49.6	14	32.5	27	18	1.45	33.2%	S.C.L

Table (2): Some chemical properties of soil:

Soil depth cm	PH 1:2.5	EC ds/m	Soluble Cations, meq/L				Soluble Anions, meq/L			
			Ca^{++}	Mg^{++}	Na^{++}	K^{+}	Co_3^{--}	HCo_3	So_4^{--}	CL^{-}
0-30	7.49	3.13	9	5.53	16.38	0.35	-	4.5	16.6	10.16
30-60	7.6	3.07	8.1	6.02	15.96	0.6	-	4.9	15.7	10.08
60-100	7.6	3.02	8.9	4.73	16.17	0.39	-	4	16.14	10.05

Table (3): Some chemical properties of irrigation water:

pH	EC dS/m	SAR	Soluble Cations meq/L				Soluble Anions meq/L		
			Ca^{++}	Mg^{++}	Na^{++}	K^{+}	HCo_3^{-}	So_4^{--}	CL^{-}
6.9	1.59	4.21	2.55	1.61	11.9	0.28	2.25	2.79	11.3

Movable surface irrigation system:

Moveable surface irrigation systemconsists of the following components:

a- Control head:

Control head consists of center-fugal pump 5"/5" (50 m lift and 80m^3/h discharge), derives by diesel engine, sand media filter 48"(tow tanks), back flow prevention device, pressure gauges, control valves, inflow gauge and fertilizer injection pump.

b- Tower of center pivot:

Two towersof center pivot irrigation system 48 m radius, 127 mm in diameter of mainline, thickness of pipe is 3 mm, 75cm spaceing between holes , according to handbook of pivot.

Modification of center pivot:

Sprinkler pivot irrigation system is operated at high pressure with high energy consumptive rate. The basic of modification of pivot system depeneded on replacing the sprinkler heads by P.E. hoses which can be operated at lower pressure. It's crystal clear that pressure head reduces a long pivot span because of friction losses according to dynamic equal, we can see the reserve relationship between velocity of water flow and section area of flow exit.

Determined hoses diameters:

By using the following equation according to **Abdel-Rahman et al. (2005)**, Change of inside diameter hose is very micro,

$$D = 536.3 \frac{\sqrt{Q}}{\sqrt[4]{h}}$$

Where:

D = Inside diameter of nozzles (mm),
Q = Discharge of nozzles (m^3/s), and
h = Nozzles operating head (m).

Where its value between (8.5, 9, 9.5, 10, and 10.5 mm), and the calculated diameters and their changeable are not available at market, which have limited diameters. Therefore, if using available diameter, it's must be design MSIS nozzles. But, to do this, the following two steps must be considered:
1 – Reducing the diameter to be suitable for calculated diameters.
2 – Obtaining micro change of calculated diameters.
The experimental calculated was begun by selecting five diameters of outlets (8.5, 9, 9.5, 10, and 10.5 mm).

Nozzle design of Movable surface irrigation system:

Flow regulars (MSIS nozzles), which design contrasts inside hoses, and hoses contrast at lateral pipe of pivot at sprinkler places by using (barbed). MSIS flow regulars construct from pierced cylinder of delrin (kind of plastics which able to be formed) allow to water inflow pass calculated flow area.

Basic components of modified nozzles:

- Polyethylene hose (20 mm diameter and 200 cm length) connected with barbed,
- Cylinder of delrin stick (was pierced) (20 mm diameter).

Diameter category distribution at pivot main line:

There are five diameters and 45 holes which refer to laterals pivot .So, one diameter category was constructed at nine laterals from beginning of center pivot main line at next.

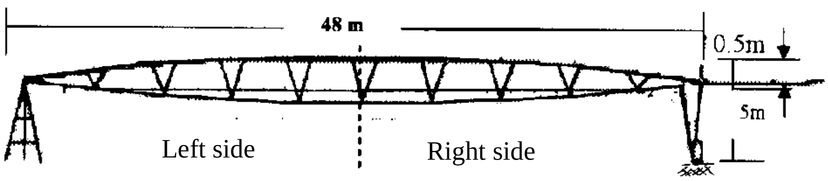

Fig. (1): Two sides of simple tower.

From results, the next type of arrangement of diameters category appear from the following, the pivot main line was rise from middle with 0.5 meter, this is change in elevation of pivot main line affect on the flow of water as mentioned. Fig (1).

$$H_i = H_a + 0.75\, h_{fr} + 0.5\, \Delta Z + h_r + h_{cv}$$
$$H_d = H_i - (h_f + \Delta Z + h_r)$$

Where:

H_i = Pressure head of mainline beginning (m),
H_d = Pressure head of mainline end (m),

H_{fr}	=	Head losses at main line (m),
ΔZ	=	Difference of mainline elevation (m),
H_r	=	Rise of outlet (m), and
H_{cv}	=	Total of secondary losses of connection parts (m).

At left side:
$H_i = 5 + 0.75\ (0.013) - 0.5\ (0.5) + (0.2) + (0.255) = 5.2\text{m}$
$H_d = 5.2 – (0.013 + 0.5 + 0.2) = 4.5\text{ m}$
$H_{aver} = 0.5\ (5.2 + 4.5) = 4.9\text{ m}$

At right side:
$H_i = 5 + 0.75\ (0.013) + 0.5\ (0.5) + (0.2) + (0.255) = 5.7\text{m}$
$H_d = 5.7 – (0.013 + 0.5 + 0.2) = 5\text{ m}$
$H_{aver} = 0.5\ (5 + 5.7) = 5.3\text{ m}.$

At two sides, the discharge must be equal there for,
$Q_L = Q_R$
But $Q = A\ V$
$A_L\ V_L = A_R\ V_R$, and $V = (2\ g\ h_{aver.})^{0.5}$
$A_L(2\ g\ h_{Laver.})^{0.5} = A_R\ (2\ g\ h_{Raver.})^{0.5}$
$A_L\ 4.9 = A_R\ 5.3$

$$A_R / A_L = 0.92$$

That's mean the areas of nozzles at left side of simple tower were be more than right side with 8 % of area, diameters of left side are bigger more than right side diameters with 0.92 mm. and it can be neglected, but although what is could not be neglected is the new arrangement of diameters category, that it were taken the last arrangement of diameters categories, but not on the main line of simple tower, rather on each one side of (left side then right side) simple tower with symmetry distribution, Fig.(1)

Measurements and calculations:

Hydraulic measurements:

Pump discharge, outlets pressure and discharge were determined and samples were taken by selecting 22 from 44 hoses.These samples were taken by received water application at gradual container during period from time according to **(Keller and Karmeli, 1975),** for reduceing experimental mistake, discharge measured four times.

Uniformity coefficient was calculated according to **(Bralts et al.,1987) .**

$$Uf\ \% = 100[1-(\ \Sigma Q_d\ /\ Q_{aver}.)\ ]$$

Where:

Uf %	=	Uniformity coefficient (%),
Q_d	=	Absolute deviation of each ample from the mean (l/s),and
$Q_{avers.}$	=	The mean of outlets discharge (l/s).

Soil measurements:

Soil samples were taken by screw auger before and after irrigation process at three spaces from beginning of mainline center pivot, the space between samples is15 m, and at three depths (20, 40,and 60cm). Sample were analyzed for determining both soil moisture and salt accumulation. Results were drawn by SURFER, ve.11 under windows program, and the "Kriging" regression method was the base model for analysis and contour map developing.

III. Results And Discussion

Evaluation of the water application uniformity of Movable surface irrigation system:

Data showed the deviation of hose discharge from the mean discharge along pivot mainline. Also average pressure head of hoses is equal to 5.25 m and it's nearly constant along pivot beside total dynamic pressure head is 15 m, it deviates ranged from 0.2 to 0.8 meter. Average total discharge is 47.5 m^3/h, beside, average discharge of MSIS nozzles is 0.3 l/s, while pressure head of pivot sprinklers is 50 m, average total discharge for pivot sprinkler is 20 m^3/h, and average discharge of pivot sprinklers is 0.107 l/s according to **(Broner, I. 1991)**.

Data appeared that, water distribution of nozzles is nearly constant for four replicates of measurements. And uniformity coefficient is high, it 90.7 this uniformity is excellent according to **(Merriam and Keller, 1978)**and good according to **(IRYDA, 1983)**for both hoses length.

Regarding the mean total discharge for different replicates, the mean total discharge was 47.5 m3/h and the mean discharge of outlets was 0.3 l/s. The difference between every nozzle discharge (deviation) for all of samples tower (total) and mean total discharge is due to experimental error which result to difference of discharge measurements for both of them. The discharge stability due to the pressure head takes a vibrated line, the constant of plotting head pressure. The deviation from the mean ranged between (0.2, 0.8 meter) (Figs., 2 and 3)

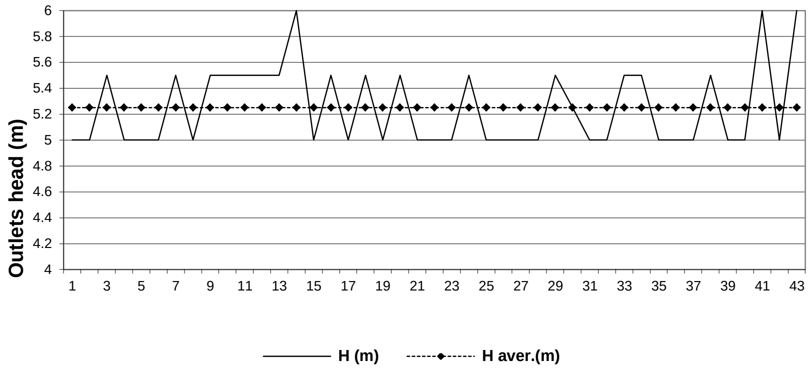

Fig.(2): Deviation of outlets head about the mean head.

Where:

H ——— = Operating head of outlets, (m)
H a. = Average pizeometric head of outlets, (m)

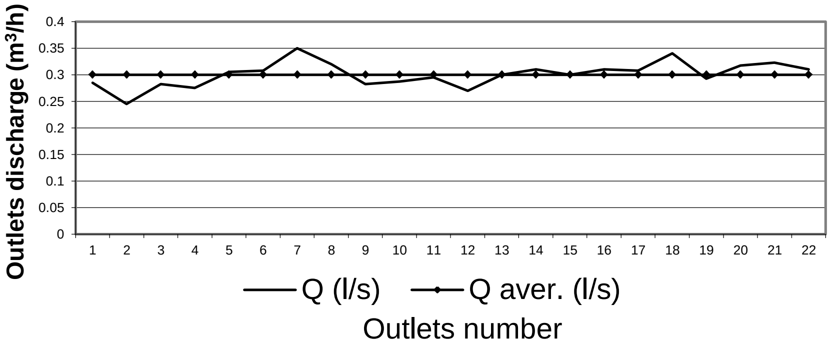

Fig. (3): Deviation of outlets discharge from the mean discharge with long hoses

Where:

Q ——— = Discharge od outlets, (l/s)
Qaver…….. = Average discharge od outlets, (l/s)

The high uniformity coefficient of MSIS nozzle was resulted due to the nozzles design by presenting the graduated diameters according to the changeable piezometeric head for nozzles. Changeable diameters were obtained by using first equation. High water application due to big size of nozzles diameter compared with size of sprinkler hole diameters, sequence irrigation process is operated at low pressure head comparing with the high pressure for sprinklers of pivot system. Work pressure for MSIS nozzle was low because of big size of outfits diameters. Pressure plotting was vibrating along mean pressure line, otherwise, the deviation of pressure plotting was very small, as a sign for the constant outlet pressure, mean results of the total discharge, outlets discharge, total dynamic head, outlets pizeometric head, and uniformity efficiency coefficient of water application

Water distribution:

Water distribution under MSIS is very important indicator to application water. And application efficiency of system which was with 90 %, beside amount of applied irrigation water was (4744 m^3 / ha)**(Abdel-Rahman et al 2005)** while amount of applied irrigation water under sprinkler pivot was (5702 m^3/ha) **(El-Gindy, et al 2003)** that's mean applied water under MSIS lower with 16.8% of applied water under sprinkler pivot. Also, refer to the ratios of water stored in the root zone to the water delivered to the field and is thus influenced by:

a – Evaporation losses from water flowing on the soil surface or in the air from

sprinkler nozzle spray,
b – Deep percolation below the root zone,   c – Runoff,
d – Soil surface evaporation during irrigation.

Movable surface irrigation system aspect involved designing a system to use in conjunction with micro-basin land preparation or furrow diking which prevents runoff and maximizes the use of rainfall and applied irrigation water, nozzles were developed to accomplish both goals. No wind losses result since water is discharged directly into the furrow. Also, protecting plant from water which causes fungal disease beside from pesticide hazard usage and generally chemigation when injection through MSIS**.** Fig: (4).

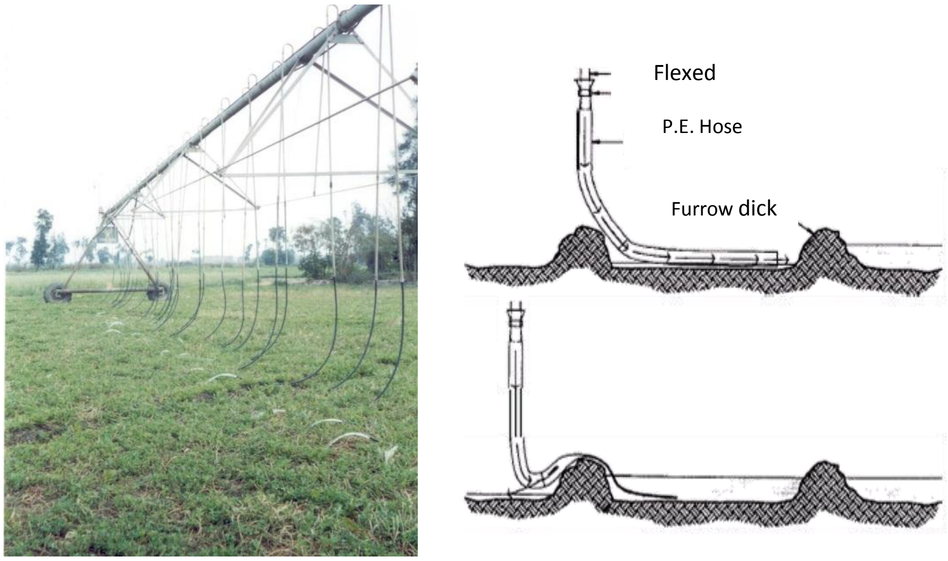

Fig. (4): MSIS nozzles designed to be used in conjunction with furrow dikes.

Soil moisture distribution:

The system efficiency could be evaluated by measured the moisture distribution in the soil profile (three spaces from the center and three depths of the root zone). Soil moisture distribution under movable surface irrigation systems take a same moisture profile of modified surface irrigation. Its mean soil moisture content increased with increment of soil profile depth.

This distribution helps for reducing water losses by evaporation, because water was saved at the root zoon, and the vertical movement of water was more difficult than the horizontal movement of water under sprinkler irrigation, where the greatest saved quantity of irrigation water was at the first layer of the soil profile. Using MSIS, the soil moisture was distributed uniformly and it supported salt leaching, as well as salt appearance, Table (4), and Fig. (5).

Table (4): Soil moisture values before and after irrigation process.

Space / Depth	Before irrigation			After irrigation		
	15m	30m	45m	15m	30 m	45m
20 cm	22.52%	20.60%	22.14%	28.58%	27.07%	28.41%
40 cm	23.77%	22.53%	22.52%	26.84%	28.78%	27.48%
60 cm	23.63%	23.73%	23.45%	29.59%	27.88%	29.52%

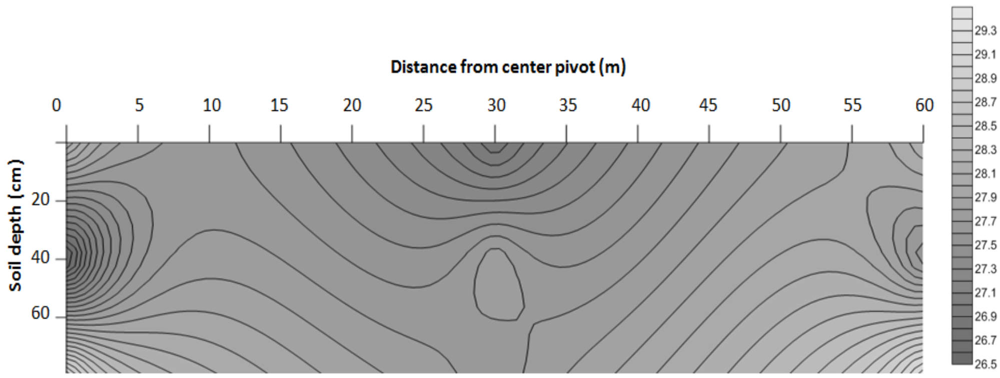

Fig. (5): Spatial and temporal distribution of soil moisture after irrigation under MSIS.

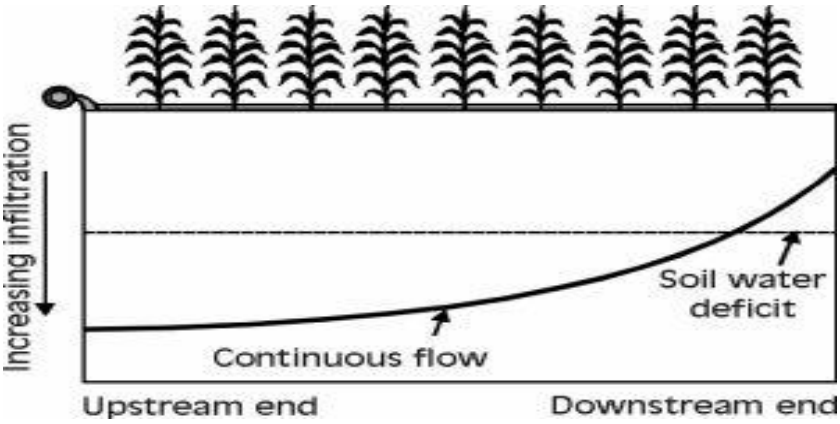

Fig. (6): Poor uniformity and infiltration pattern for traditional furrow irrigation.

The study reveals that furrow irrigation is not the efficient method of irrigation because there is an undesired percolation loss which affects plant water uptake and the growth and yield of the cultivated crop. Generally, there was 4.1 cm percolation loss in the case of furrow treatments, but on the other hand under the drip treatments, there was no percolation.

While under MSIS it can achieve uniform water application and minimize deep percolation and runoff. According to moving of MSIS and applied water at all of land surface by high uniformity distribution which equal 90%.

Counter map for soil moisture distribution before irrigation process as a known that, soil moisture distribution depend on soil texture, slops, and climate. Counter map for soil moisture content after irrigation process, it's clear that the greatest amount of saved water at the third layer of soil (40-60 cm).

MSIS can irrigate crops with the desired amount of water, avoiding excess and runoff, and minimize foliar damage which was common with saline water irrigation, as well as the distribution of water applied is homogenies at all of the two direction of soil depth, Figs. (5 and 7).

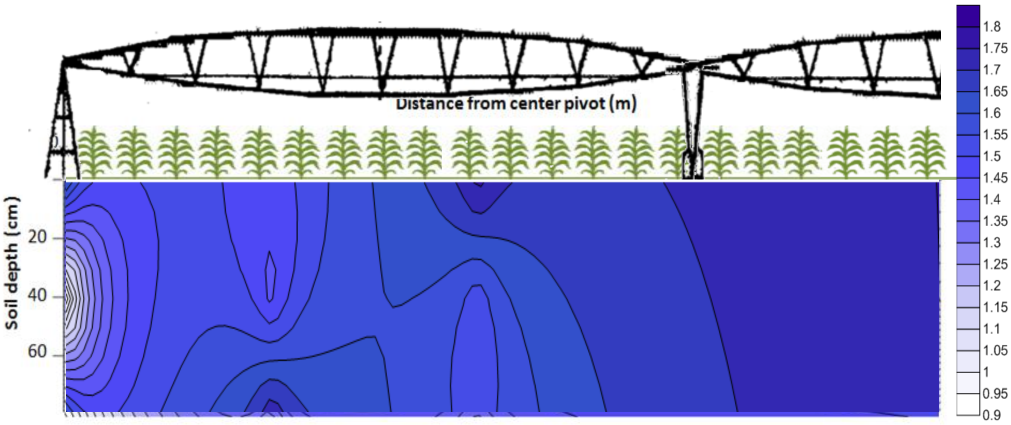

Fig. (7): Map counters of depth of applied water under MSIS.

Counter map for soil moisture distribution before irrigation process as a known that, soil moisture distribution depend on soil texture, slops, and climate. Counter map for soil moisture content after irrigation process, it's clear the greatest amount of saved water at the third layer of soil (40-60 cm).

MSIS can irrigate crops with the right amount of water, avoiding excess and runoff, and minimize foliar damage which was common with saline water irrigation, beside distribution of water applied is homogenies at all of two direct of soil depth vertical and horizontal, Fig. (5 and 7).

- **Salt concentration distribution:**

Movable surface irrigation system obtained advantages compared to both modified surface and pivot system that, water application is at amount prevent the salt appear besides, the water application (0.3 l/s) support the leaching process. But this need agood mangement of nutrient applied in anticaption to nutrients lossses by leaching during irrigation process.

Precision irrigation implies irrigation systems that deliver water to part of the soil surface only. This means that water will move both vertically and laterally from the point of application. Plant roots will remove water from the moving soil solution, concentrating salts as the distance from the nozzles increases. Precision irrigation implies that water sufficient for the plant needs is applied, with little excess for leaching. Any excess water applied through a dripper will leach salts primarily from the zone immediately around the dripper, but will have less impact on salts that have accumulated at greater horizontal distances from the drip line. Rain, on the other hand, falls across the whole soil surface and is the major mechanism through which salts can leach downwards. Fig (8 and 9).

The potential for managing root zone salinity and the application of leaching fractions is increasingly important as precision irrigation is implemented. **Stevens et al. (2004)**

Table (5) : Soil salt concentration (ppm) after and before irrigation process.

Space / Depth	Before irrigation at:			After irrigation at:		
	15 m	30 m	45 m	15 m	30 m	45 m
20 cm	896	960	960	768	1024	768
40 cm	1216	1024	896	896	768	768
60 cm	1280	1280	896	832	896	960

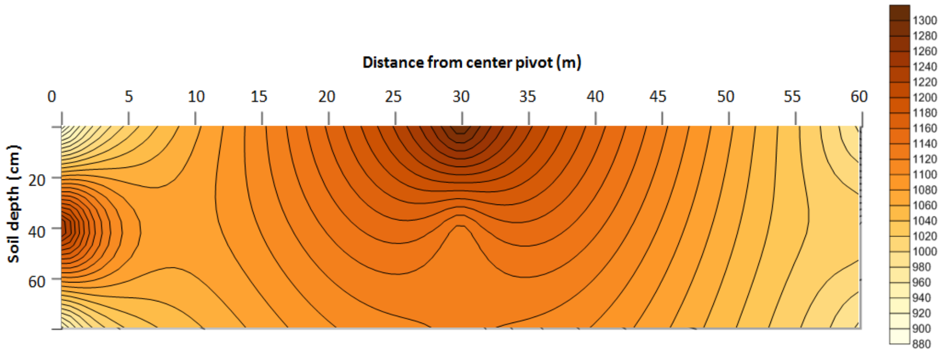

Fig. (8): Spatial and temporal distribution of soil salts before irrigation under MSIS.

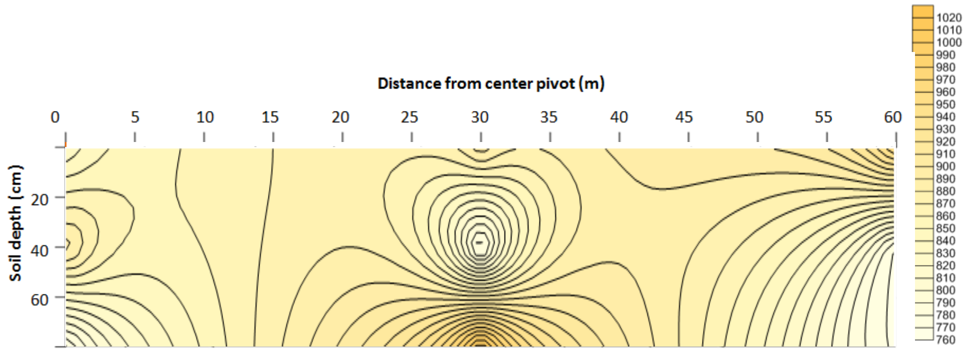

Fig. (9): Spatial and temporal distribution of soil salts after irrigation under MSIS.

Under irrigated conditions in arid and semi-arid climates, the build-up of salinity in soils is inevitable. The severity and rapidity of build-up depends on a number of interacting factors such as the amount of dissolved salt in the irrigation water and the local climate. However, with proper management of soil moisture, irrigation system uniformity and efficiency, local drainage, and the right choice of crops, soil salinity can be managed to prolong field productivity. Salts distribution in the soil profile under MSIS before irrigation process was crystal clear but the application of adequate irrigation water (plus leaching requirements) lead to leached salts from the upper layers without salts appearance on the soil surface (Table, 5) and Figs. (8 and 9).

IV. Conclusion

The basic obtained results of the study are as the following:

Main nozzle flow 0.3 l/s,high uniformity coefficient for MSIS equal 0.7 %,TDH was reduced from (5 bar) for sprinkler pivot system to 1.5 bar for MSIS, Also operating head of nozzoles, at next saving energy requirment and irrigation process costs.

Soil moisture distribution under movable surface irrigation systems take a current of modified surface irrigation. It's mean soil moisture content increased with increment of profile depth. At next, this distribution helps for reducing water losses with evaporation, because water was saved at root zoon, and vertically dynamic of water was more difficult than water dynamic under sprinkler irrigation,

Soil salt concentration distribution under MSIS before irrigation process. It's crystal clear much water inflow leached salt at soil layer, beside, salt were not appear at soil surface. MSIS can irrigate crops with the right amount of water, avoiding excess and runoff, and minimize foliar damage which was common with saline water irrigation.

Movable surface irrigation system obtained advantages compared to both modified surface and pivot system that, water application is at amount prevent the salt appear besides, the water application support the leaching process. But this need agood mangement of nutrient applied in anticaption to nutrients lossses by leaching during irrigation process. Beside flexibility of modified pivot to irrigate shrubs, small trees, and plants which sensitive to water with any fungal disease or flowers fall.

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