EFFECT OF SEPARATE CLAYEY PATCHES IN LOAMY SAND SOIL ON BOTH OF SOLUTE TRANSPORT AND SALINITY DISTRIBUTIOIN

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ABSTRACT

Soil permeability and soil salinity are considered the most important elements affecting agriculture in arid areas. To analyze and visualize solute transport and soil salinity distribution mechanisms, dye tracer and an electromagnetic device (W.E.T Probe) were used. The purpose of this study is to investigate the effect of separate clayey patches (spots) exist in loamy sand soil on both of soil permeability and salinity distribution. Two sites at Sahl El-Tina area in El-Salam Canal project service area, eastern of Suez Canal, Egypt were chosen. The soil type at the first site is loamy sand with separate clayey spots while the type is sandy soil at the second. Two experimental plots, one plot in each sit (1mx1m), were prepared for the infiltration of dye by leveling the surface. Each plot was irrigated with solution containing dye tracer for three days. On the day following the last day of irrigation, a trench was dug and ten centimeter thick vertical slices were excavated and photographed. Soil bulk salinity measurements through a grid of 1 meter width and 0.5 meter depth and 10 cm interval were taken. The dye photographs showed that solute transport is very poor at the site contained clayey spots. Small preferential flow is obvious within the same site. When matching the photos of the sections with the corresponding contour maps of soil salinity, it was found that points of high level of salinity coincides well with points of clayey spots. In general, the existence of clayey spots within loamy sand soil decreases solute transport. Furthermore, points of high salinity through the soil which coincide with these spots were not affected by continuous washing during irrigation. These high salinity patches will have its effect on plant growth.

Keywords: Salinity, Solute transport, Clay, Egypt

INTRODUCTION

Saline clayey soil is considered a major problem for the cultivation. Due to the low permeability of the clayey soil, salt leaching is very weak. This will affect the period required for washing saline soil. This problem does not exist in sandy or loamy soil due to their high permeability. However, if some clayey patches exist in loamy sand soil; their effect on both of permeability and soil salinity distribution among the soil matrix will be investigated.

In order to investigate this effect, permeability and solute transport should be studied. Dye will be used to visualize solute transport and hence the permeability.

While soil salinity measurements will be measured by a new electromagnetic device called the WET Probe (the new modified version of the Sigma Probe).

Almost 35% of the agricultural lands in Egypt suffer from salinity, wherein the electrical conductivity of the extract from saturated soil is higher than 4 dS/m (GARE, 1992 [7]). FAO (1986) [4] indicated that the decline of productivity in Egypt is attributed to the increase in primary and secondary salinization.

An early soil survey for the Nile delta indicated that the percentages of salt-affected soils relative to total cultivated lands was 60% in the Lower Delta, 25% in the Middle Delta, 20% in the Upper Delta and Middle Egypt, and 25% in the Upper Egypt (Aboukhaled et al., 1975 [1]). In the Mediterranean coastal plains and lower Delta, excessive rates of groundwater withdrawal have resulted in a large drop in the water table and, as a consequence, seawater intruded into the aquifers (GARE, 1992 [7]). The main reasons for soil salinity in these areas include seawater intrusion, irrigation with low quality (saline) water as they are located at the downstream regions of the system, and an inadequate field drainage (Kotb et al. 2005 [8]).

Öhrström et al., 2003 [11] used two electromagnetic devices for measuring soil salinity. Both of Sigma Probe and Time domain reflectometry TDR were used for measuring soil salinity and water content in a sandy loam soil. They used combined tracers of dye and bromide in order to investigate solute transport. They concluded that most of the water and bromide transport occurred already after one or two hours after irrigation event.

Dye, as a tracer, is a useful tool for revealing spatial flow patterns, and has been used by soil scientists for years (Ewing and Horton 1999 [3]). They are valuable tracers to study the movement of water and solutes in soils and aquifers. The advantages of the dye are: 1- that dye is relatively cheap; 2- the experiments are made on undisturbed soil and in a rather large soil volume; 3- the spatial flow patterns are revealed with a high resolution. The disadvantages are that the results are instantaneous and the experiments can only be done once on the same site.

A dye experiment in loamy sand conducted by Kung (1990) [10] showed that water moved downwards as vertical plumes in the upper soil layers. Deeper down the water started to funnel into preferential flow paths mainly due to textural discontinuities.

Flury and Flühler (1994) [5] studied the toxicity of Brillian Blue FCF. They made a literature review and found that Brillian Blue FCF is a useful dye tracer to stain the flow paths of water in soil media. It doesn't accumulate in plants or animals, but degrades slowly in the environment. From the toxicological point of view the dye can be considered as suitable and environmentally acceptable tracer for studying solute transport in soil, especially in the field.

In Tunisia, dye experiments in clayey soil showed that the dye moved along ped faces and along distinct cracks (Yasuda, 1996 [12]).

The dye Brilliant Blue FCF has been used in several investigations. Experiments conducted by Flury and Flühler (1995) [6] showed that the mobility of the dye is almost as large as the one of water.

An investigation conducted by Ketelsen and Meyer-Windel (1999) [9] shows that the adsorption of the dye differs between soil types; soils with high clay content and low content of organic carbon tend to adsorb more dye than others.

The main objective of this paper is to investigate the effect of existence of some clayey patches through a loamy sand matrix on both of soil salinity distribution and solute transport. A comparison between loamy sand site with pure sand site was conducted. The clayey patches were originally had high value of salinity.

MATERIALS AND METHODS

1. Area description

The experiments were carried out in early October 2004 at two sites in Sinai eastern north of Egypt. Both of the two field sites are located within the El-Salam Canal project territory. They are located in Sahl El-Tina area eastern of Suez Canal, 50 Km south of Port-Said City (Fig. (1)). The field sites were used for agriculture since year 2001. The common cultivated crops are wheat, barley, melon and maize. The soil at the first site is loamy sand with some clayey patches while it is sandy at the second site. Soil properties are described in Tables (1, 2). The precipitation in this area is only 10 mm per year. The main problem of this area is the very limited irrigation water amount and its high salinity level in comparison with the soil salinity. Many farmers tried to cultivate rice but they failed due to the lack of irrigation water.

One plot (1x1m) was chosen at a middle position in every site. The soil was dry before the experiments at the two sites (Tables 1, 2). The water table is located at depth 1.00 m at the first site (loamy sand) while it is not detected through the shallow depths (up to 2.0m) at the second site (sandy soil). Iron frame (1m x 1m x 0.25 m) was used to bound the study area in order to prevent dye leakage from the sides.

The first field has been filled to a very deep depth (at least more than 70 cm). The tillage maybe contributes for mixing the original soil (loamy sand) at the upper layer with clayey soil located underneath. This is probably the reason of the clayey patches existence.

Table (1) Soil properties for the first site (loamy sand soil)

Sample Label	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Bulk density (gm/cm^3)	Water Content %
A	0-10	79.75	12.25	8.00	1,381	15.74
B	10-30	80.25	13.50	6.25	1,372	16.1
C	30-50	80.80	9.30	9.90	1,379	17.3
Clayey Patches	-	4.00	28.45	67.55	1.81	-

Table (2) Soil properties for the second site (sandy soil)

Sample Label	Depth (cm)	Fine sand (%)	Silt (%)	Clay (%)	Bulk density (gm/cm^3)	Water Content %
A	10	90.50	5.50	5.00	1,68	3.56
B	30	90.75	4.75	4.75	1,66	4.1
C	50	92	3.60	4.40	1,649	4.66

2. Experimental set-up

All the vegetation was removed from the measurements area (plot 1x1m) and the surface was leveled. An iron box (1 x 1 x 0.25 m) was impeded at the soil to 25 cm depth. Local irrigation water was used for the experiments. The irrigation water had an average electrical conductivity EC_P of 3.5, 3.2 dS/m for the loamy sand and sandy soil respectively. The irrigation water was mixed with dye (5g/l). Manual irrigation was used to irrigate the soil surface by fourteen liter of the mixture for three successive days. The amount of 14-16 liters is typically used in the area as daily irrigation volume. An area extending 0.25 m in all directions was irrigated in order to avoid boundary effects. Between irrigation events, the site was covered with plastic sheet in order to prevent evaporative losses. At both sites flooding irrigation is common to irrigate wheat, Mice and other crops.

The dye tracer used was the food-grade dye pigment Vitasyn-Blau AE 90 (Swedish Hoechst Ltd.). This dye has the same chemical composition as the dye Brilliant Blue

FCF, which has been used frequently in several field experiments (e.g., Flury and Flühler, 1994 [5]; Aeby et al., 1997 [2]).

The fourth day after irrigating the mixture of water and dye, a trench was dug and eight vertical sections were excavated at 10 cm intervals. In general, soil sections were excavated until no dye traces were seen. This meant in all cases down to a depth of 50 cm. Each section was photographed by a digital camera. The Wet Probe was used to measure EC_b for depths between 0.05 and 0.45 m and through a grid 10x10cm. The probe (7 cm long) was inserted horizontally into the soil.

Soil Samples were collected at each site at depths 0-10, 10-30, 30-50 cm.

3. Image analysis

Vertical soil sections were photographed with a digital camera from approximately the same horizontal distance from each section (1.5m). The pictures were taken with resolution of 2592*1944 pixels (5 Mega pixels). The digitized images were analyzed using Adobe Photoshop CS. The investigated sections of 100 * 50 cm were scaled to 2000*1000 pixels. Consequently, a resolution of 0.5 mm in both of horizontal and vertical direction was created at the pictures. The dyed area were chosen by the Photoshop toolbox and filled with black color while the left soil matrix was transferred into white color. Then the back and white pictures were imported as matrices in Mathworks Matlab v6.5, where they were analyzed using different calculations determining dye coverage and maximum depth.

RESULTS AND DISCUSSION

1. Dye and tracer analysis

Figure (2) shows five black and white images each representing the area of the plot 1x1m for both sites. The images represent the first five vertical soil sections separated in the horizontal by 10 cm. The total depth of each image is 50 cm.

Dye patterns with depth at each of the two sites have approximately the same shape. Also plums are not existed. This reveals that the flow is mainly vertical and the three dimensional flow is very weak.

Dye patterns also reveal that the dye moves much deeper and wider in sandy soil than in loamy sand. The average dye depths were 19 and 9 cm where the percentages of dye areas in a vertical section (with respect to the total area of the section) are 20% and 4% in sandy and loamy sand soil respectively. The narrow dye area in loamy sand (few centimeters depth) reveals poor solute transport through the soil matrix in this site in spit of deep tillage (1.2 m). This is probably due to the existence of clayey patches together with some silt.

The dye pattern reveals also small preferential flow through the loamy sand soil while the flow is fairly homogeneous in sandy soil.

Figure (3) shows the maximum, minimum and mean values of horizontal dye coverage for both of the soil types. The horizontally dye coverage can be very useful to study since it gives an overview of how the dye is distributed in the soil profile. The dye cover with depth at each of the two sites decreases downwards. In sandy soil the dye coverage decrease from 100% at the surface to approximately 50% at 10 cm depth and to 20% at 15 cm depth. In the other hand, in loamy sand soil the dye coverage decrease rapidly from 100% at the surface to only 5% at 7 cm depth. The dye cover value in sandy soil is much bigger than for loamy sand soil by many times. The average dye depth for sandy soil is twice for the loamy sand.

2. Soil salinity distribution maps

Figure (4) shows the bulk soil salinity distribution contour maps for the first four sections for the sandy soil. The salinity range is from 0.06 to 0.18 dS/m. These low salinity levels are probably due to the nature of sand which has a very high permeability and helps for rapid salt leaching. The maps show also that the salinity distribution is not uniform and decreasing downwards. This decrease is probably due to the deep rapid salt leaching downwards.

Figure (5) shows the bulk soil salinity distribution for the first four sections for the loamy sand soil. The salinity range is from 0.5 to 2.6 dS/m. This relatively high level of salinity is probably due to the poor permeability of the soil which slows the salt leaching process. The maps show many plums with high salinity levels. Due to the existence of these plums, salinity distribution is generally heterogeneous through the soil matrix. For the rest of the soil matrix, salinity value increases downwards. The downwards increase of salinity is probably due to the accumulation of salt downwards at the layers near the surface due to the slow salt leaching which results from the low permeability.

Figure (6) shows a representative vertical section photo and the corresponding bulk soil salinity contour map. The clayey patches have transferred into white color by using Photoshop toolbox. This figure shows the effect of clayey patches on soil salinity distribution. From the figure, it is obvious that there is a reasonable matching between points of high salinity (plums) and clayey patches allover the soil section. Figure (7) show a similar comparison between vertical photo and the corresponding bulk soil salinity contour map for the sandy soil. The salinity values are much less and the distribution of salinity is much uniform than the loamy sand soil. Figure (8) shows a relation between the location of the clayey patches and their bulk salinity with respect to the average bulk salinity allover the soil matrix. This graph proves that the clayey patches have a higher salinity values than the soil matrix since most of their salinity values located higher than the overall average salinity of the vertical section. Most likely that patches originally have a high degrees of salinity which were not affected by continuous washing/irrigating for more than three years.

SUMMARY AND CONCLUSIONS

Two sites at Sahl El-Tina area in El-Salam Canal project service area, eastern of Suez Canal, Egypt were investigated. The soil type at the first site is loamy sand with separate clayey patches while the type is sandy soil at the second. The objective of the paper is to investigate the effect of clayey patches in loamy sand soil on both of permeability and soil salinity distribution compared with sandy soil type. A plot 1x1m in each site was prepared. An amount of irrigation water equal 14 liter mixed with 5 gm/l dye (Vitasyn-Blau AE 90 (Swedish Hoechst Ltd.)) was added to the plot each day for three successive days. The day after the last day of adding the solution a trench was dug and a total of 8 vertical 10 cm thick slices were excavated. Each section was photographed and measurements of bulk soil salinity by the WET Probe were taken. The measurements were taken through a grid 10x10 cm from depth 0.05 to depth 0.45m.

Dye pattern reveals that the flow mainly vertical at the two sites. Dye moves only a few centimeters from the surface in case of loamy sand with clayey patches while it moves a relatively deep and wide in sandy soil. The poor solute transport in loamy sand is probably due to the existence of both of clayey patches and some silt content. The existence of clayey patches may contribute for blocking the movements of the dye due to its cohesive force. Consequently, the existence of clayey patches contributes for decreasing solute transport downward the soil matrix.

Bulk soil salinity contour maps shows that salinity ranges are much smaller than in sandy soil than in loamy sand soil. This is probably due to the rapid salt leaching in sandy soil due to its bigger particle size. Moreover, the existence of clayey patches in loamy sand soil which may cause slow salt leaching and accommodation of salt at the upper layers of the soil.

For the upper layers of the soil (up to 50 cm), due to the rapid salt leaching in sandy soil, salinity decrease downwards while it increase at the same directions for the loamy sand due to its slow salt leaching.

When matching the vertical sections with the corresponding salinity contour maps, it is found that points of high salinity coincide with the positions of clayey patches. It is probably due to the high salinity levels of these patches which were not affected by the continuous washing/irrigating due to its cohesive force. These points of high salinity act like plumes within the soil matrix and contribute for the overall heterogeneity of the salinity distribution. The existence of high saline clayey patches contributes for existence of point of high salinity and cause heterogeneity of salinity distribution within the soil matrix. This indeed will affect the plant growth.

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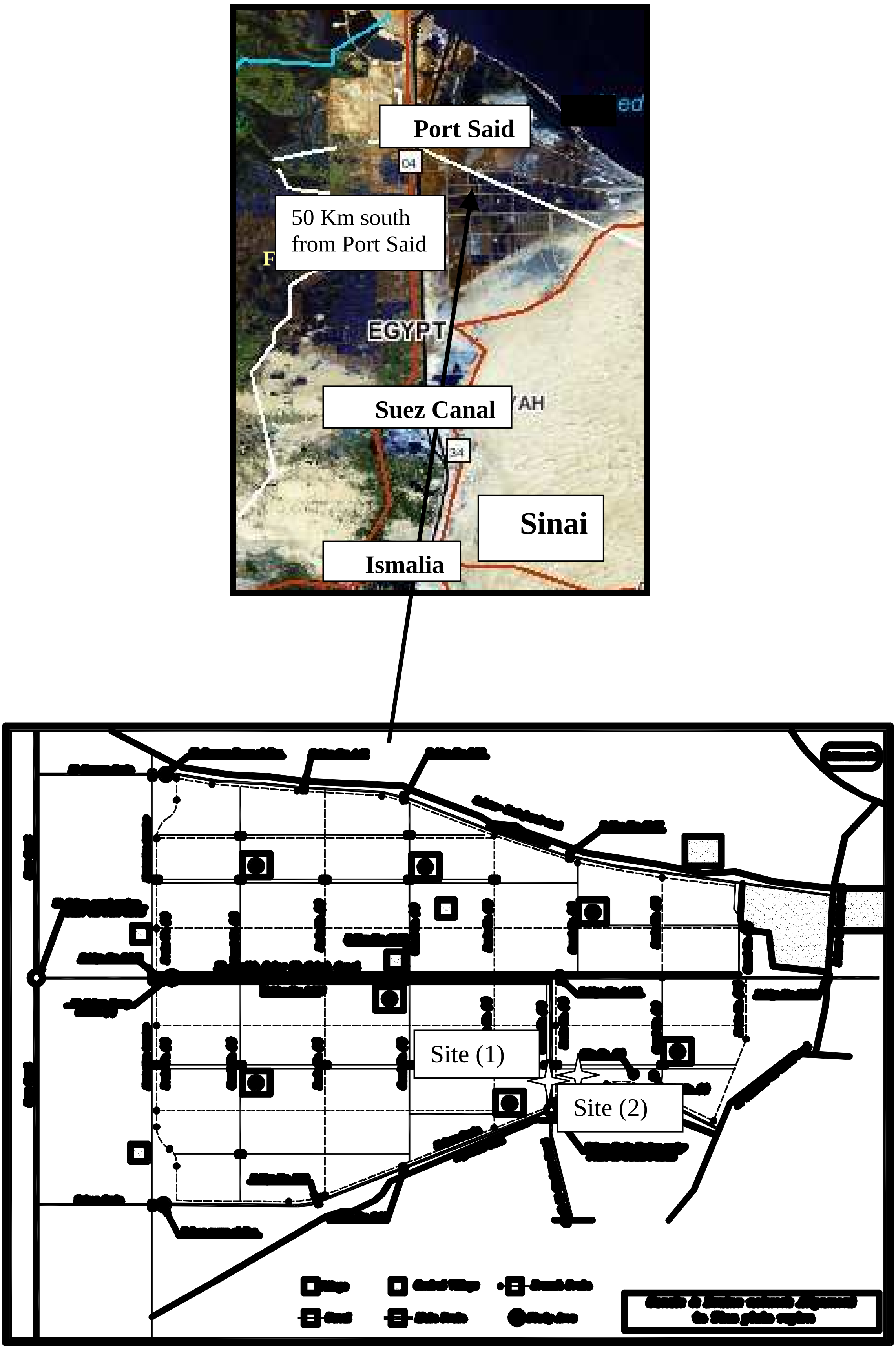
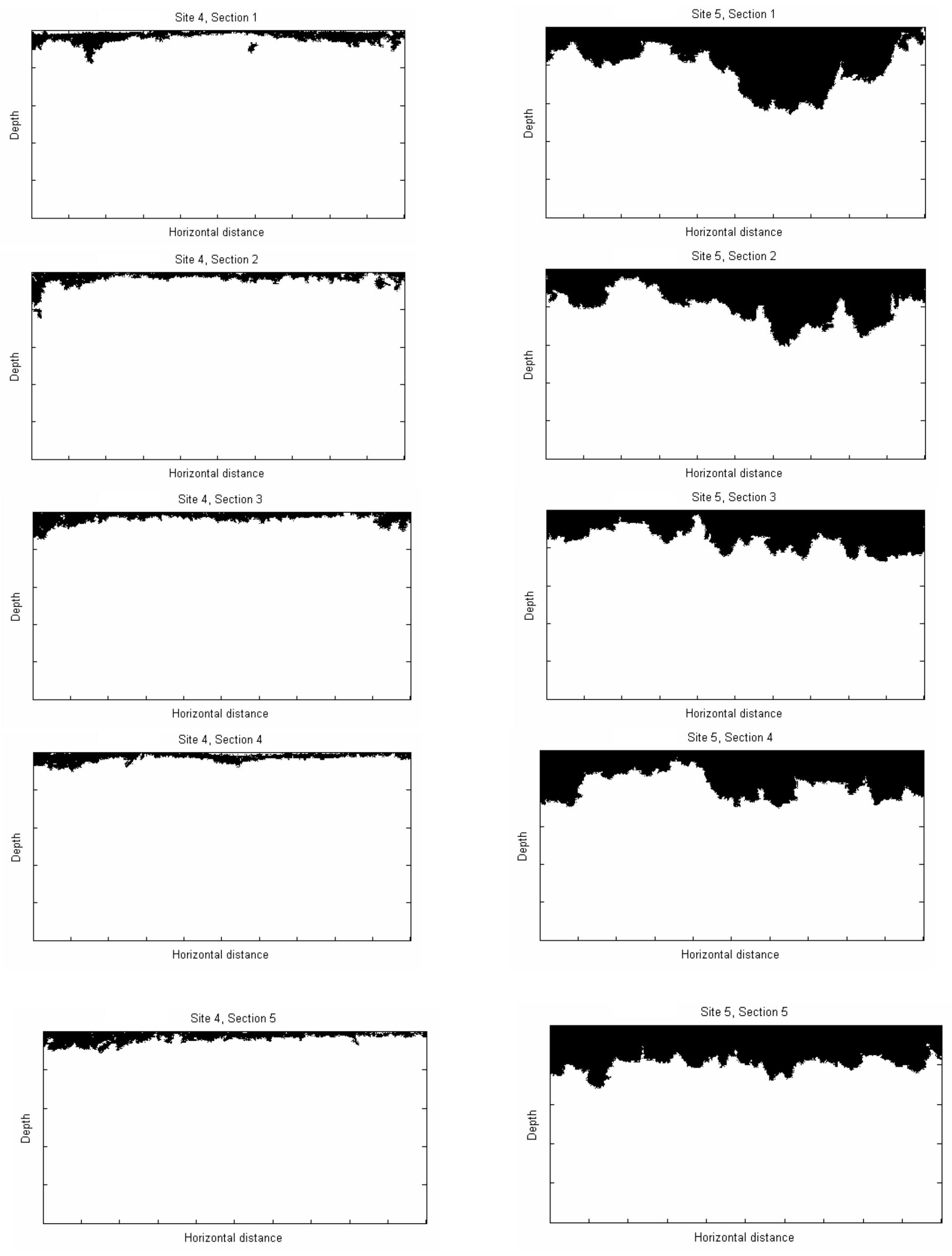


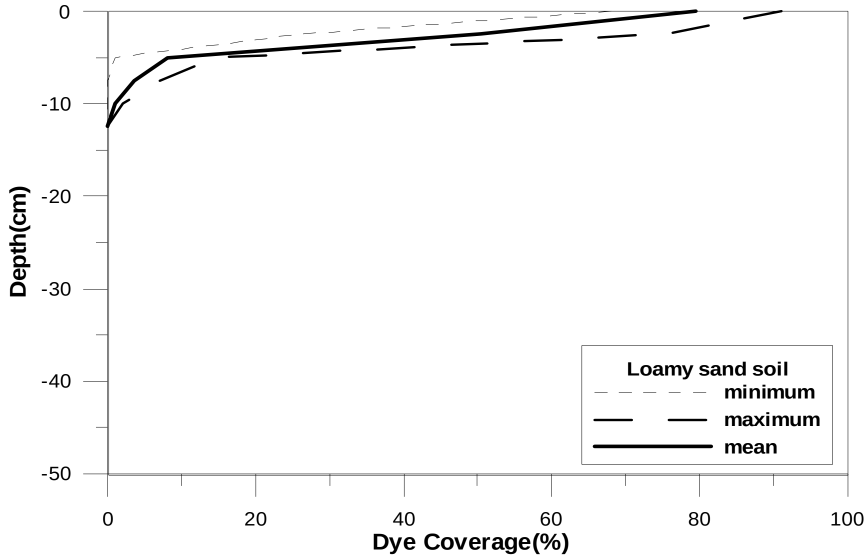
Fig. (1) Location of the field sites

Loamy Sand soil **Sandy soil**



Loamy Sand soil **Sandy soil**

Fig. (2) Dye patterns for the first five successive sections for the two sites



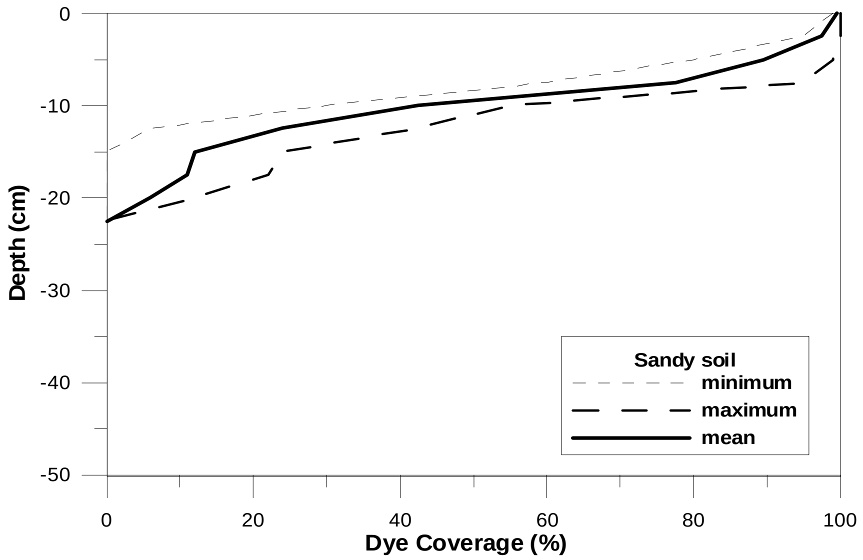


Fig. (3) Maximum, minimum and mean dye coverage for the two sites

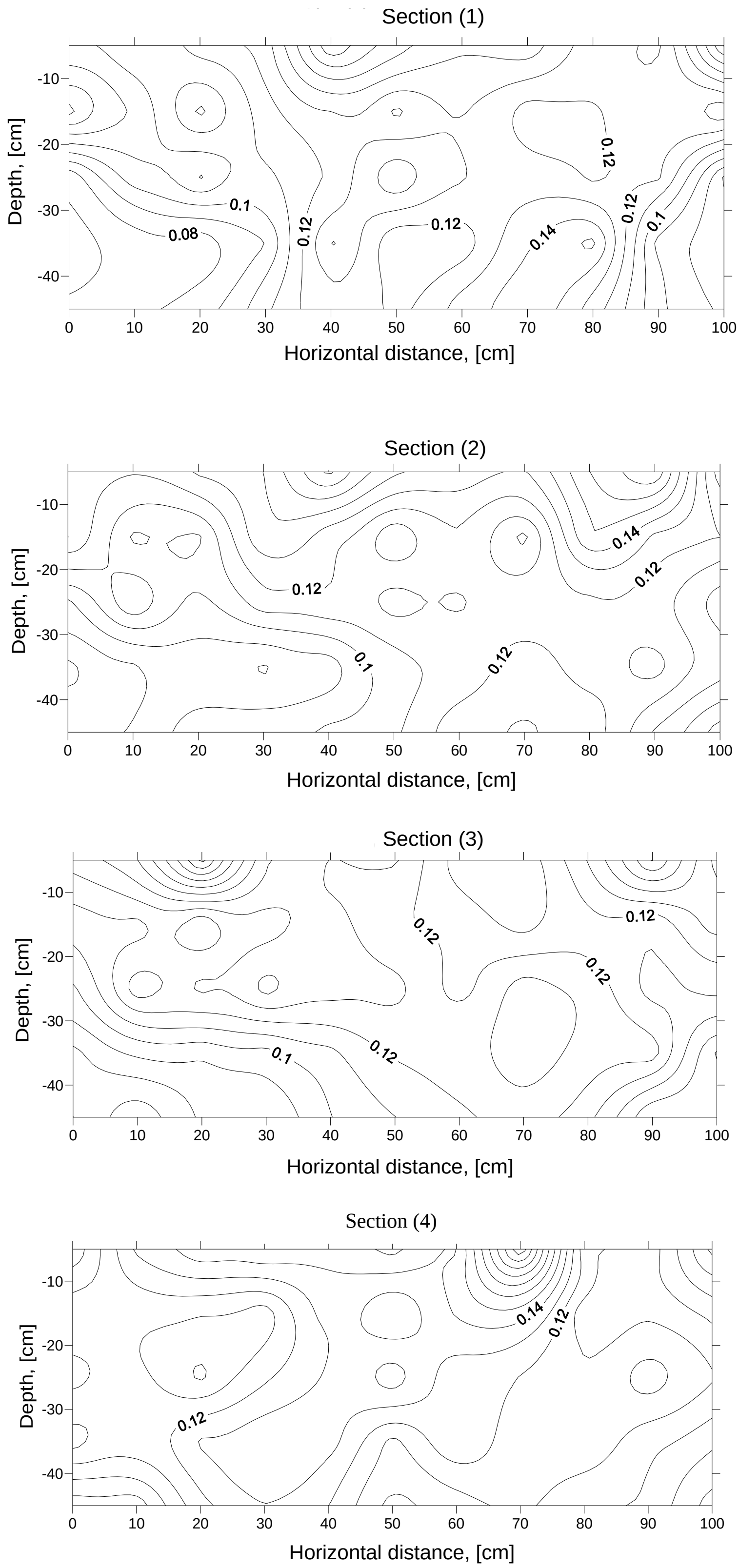


Fig. (4) Bulk soil salinity distribution for the first four sections for the sandy soil

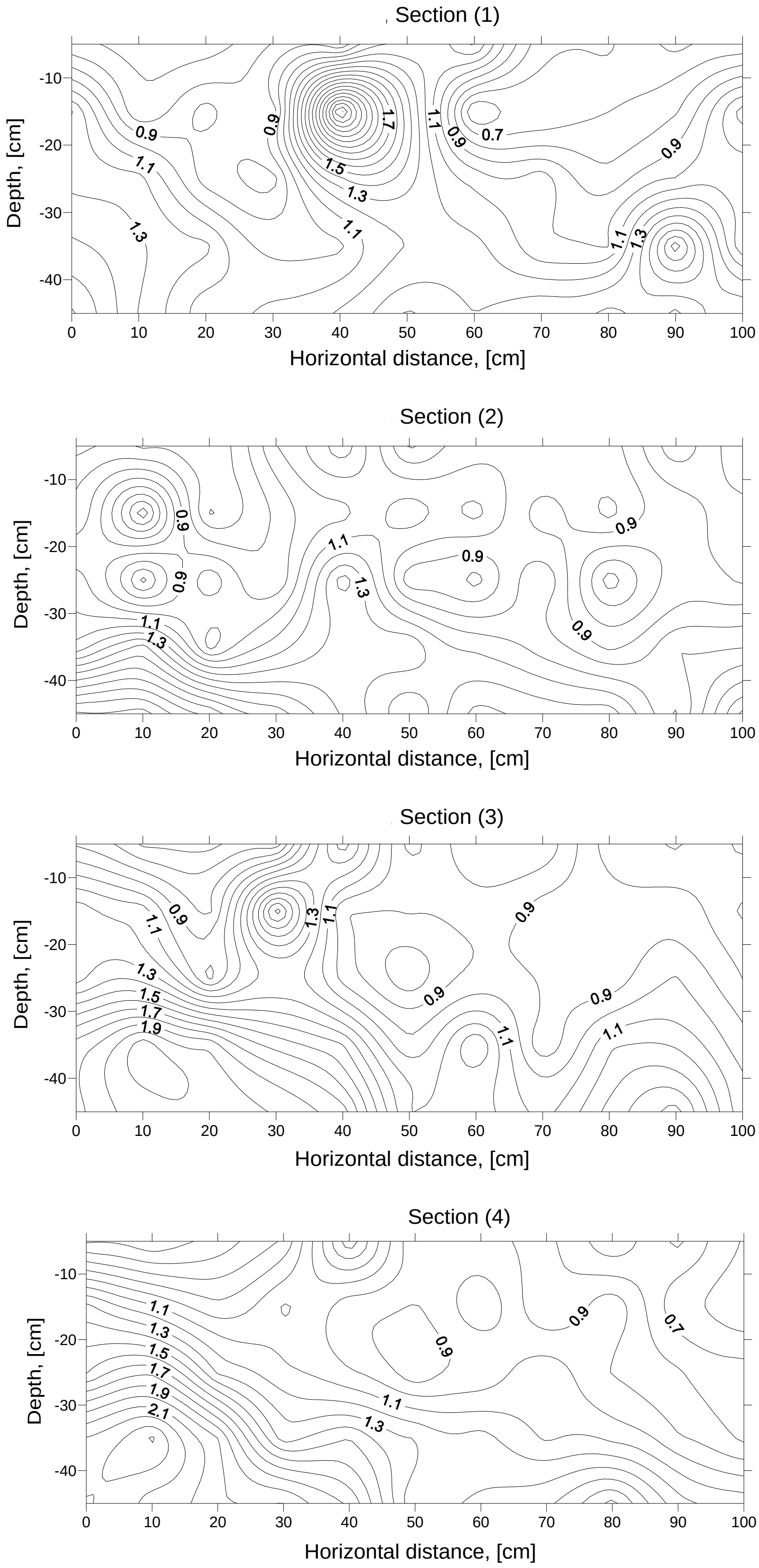


Fig. (5) Bulk soil salinity distribution for the first four sections for the loamy sand soil

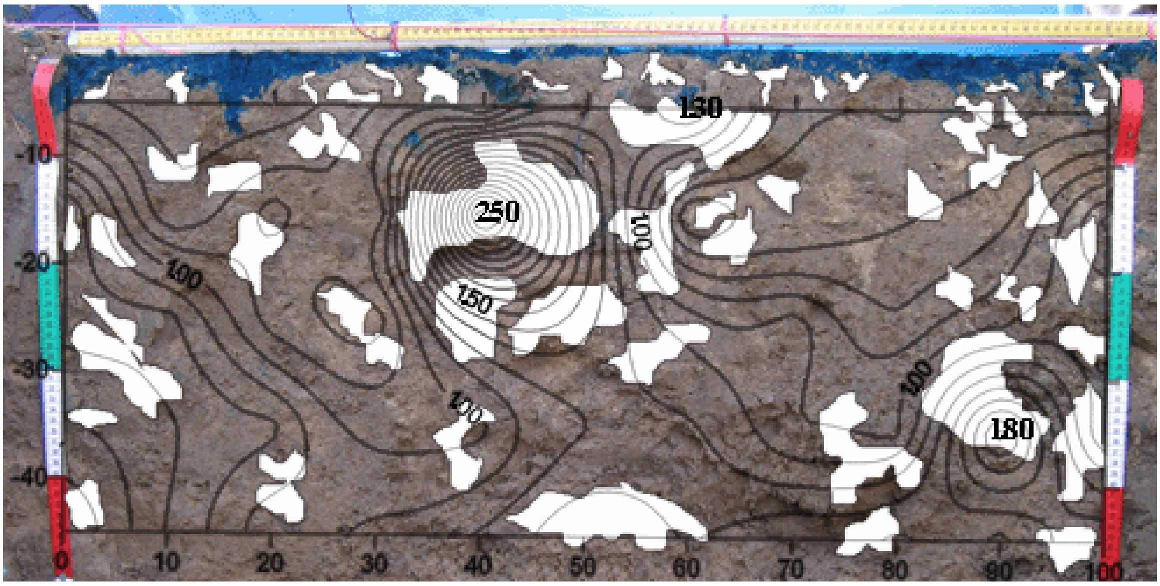


Fig. (6) Comparison between clayey patches positions and salinity distribution map for the loamy sand soil

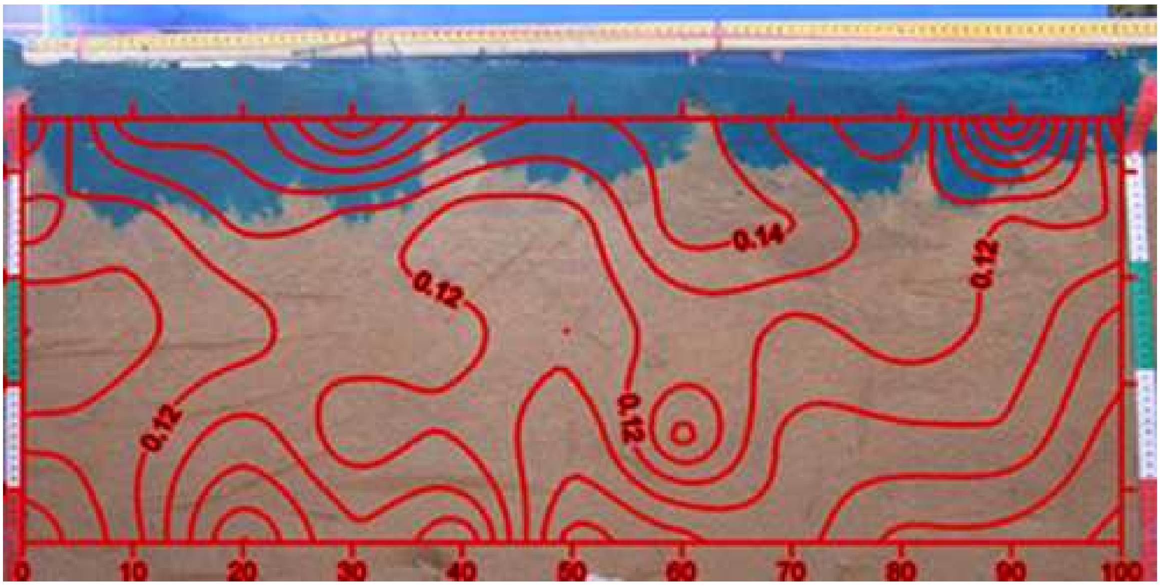


Fig. (7) Salinity distribution map and the corresponding vertical section for the sandy soil

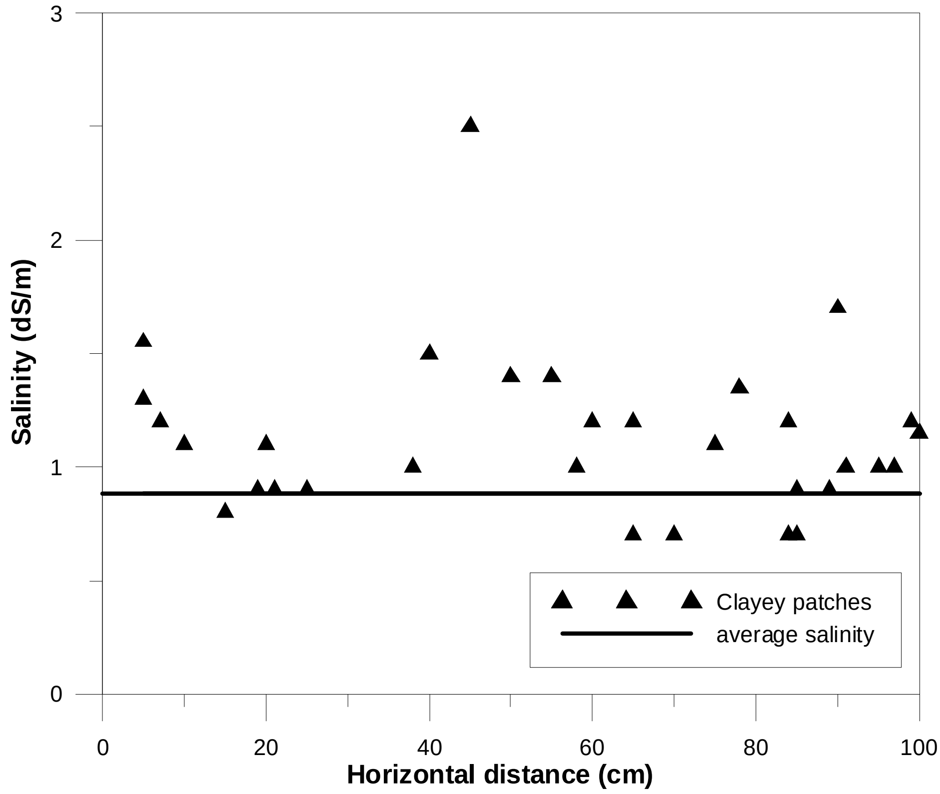


Fig. (8) Bulk soil salinity of the clayey patches with respect to the overall average bulk salinity