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Mangrove ecosystem effect on soil physico-chemical properties at the Red Sea coast

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Abstract

Mangrove forests possess numerous functions as natural ecosystems, offering ecological benefits due to their remarkable capacity to sequester soil organic carbon, and improve soil hydro-physical properties. In this context, the objective of this research is to characterize soil changes induced by mangrove growing. Both modeling and measurements herein performed on five sampling areas at the Western Strand of the Red Sea (plus one control site - beach without plants). The locations (site 1 and 2) of mangrove forest were in El-Gouna village with ages of 10 and 5 years respectively, while (sites 3, 4, and 5) represent mangrove at Hurghada, Abu-Monquar Island, and Safaga, respectively. Soil bulk density (SBD) values varied at El-Gouna1, 2, and Hurghada from 1.63 to 1.75 g/cm³, while the lowest SBD values were observed at Abu-Monquar Island and Safaga with 1.31± 0.02, g/cm³ and 1.53 ± 0.05 g/cm³, respectively. SBD at control site was 1.75± 0.05 g/cm³ which reflect the higher values. Morphological characteristics reveals that tree height results varied from 110-130 cm, 50-70 cm, 150-200 cm, 200-300 cm, and 200-270 cm for ElGouna1, ElGouna2, Hurghada, Abu-Manqar, and Safaga, respectively. Higher values of tree height, size index, and density convenient with the lower values of SBD at Abu-Monquar and Safaga compared to other site locations. Soil-water HYDRUS-1D model revealed that the soil water storage capacity at Abu-Monquar was higher than the other samples. Thus joint use of modeling and measurements enabled deeper insight and a suitable characterization of soil physico-chemical changes induced by Mangrove growing.

Keywords: Mangrove ecosystem, Physical properties, Red Sea, Morphological, HYDRUS-1D code.

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1. Introduction

Mangrove is a multifunctional ecosystem with high ecological and economic value and an extraordinary ability to sequester large amounts of carbon in relatively short period. It has been estimated that mangrove ecosystems can sequester around 25% of soil organic carbon at the soil surface [1,2,3] and only occupy approximately 0.7% of the world coastal zone. Owing to the ecological and economic importance of mangrove forests, there is a need for deeper insight and continuous monitoring to improve their knowledge and also contribute to defining conservation strategies today even more extremely important under changing climatic scenarios. Local conditions, characteristics, and planting practices affect mangrove capabilities to provide ecosystem services, and there is a strong demand to quantify and characterize the multifunctional ability of forests (in general) and mangroves (in particular). In this context, the objective of this paper is to contribute to improve knowledge and characterize the soil physical changes induced by mangrove planting practices to preserve soil quality. To this aim, investigations focused on the original type of the mangrove forest (*Avicennia. Marina.*) that allocated at western strand of the Red Sea for 500 km at the Egyptian coast. There are two main types of mangrove species that thrive in Egypt. The first species is Avicennia marina, which can be predominantly found along the Red Sea coast. Avicennia marina has unique features, including pencil-like pneumatophores that protrude from its roots, which help it to take in oxygen in an environment with a high salt concentration. The second species, *Rhizophora. Mucronata.*, is primarily located at the southern part of the Red Sea coast. Its range spans from the city of Shalatein (Latitude 23° 28′ N) and extends to the city of Mersa Halaib (Latitude 22° 10′ N) as reported by [4]. *Rhizophora. Mucronata.* is characterized by its distinctive stilt roots that provide stability in unstable soil and support the tree's weight. These mangrove species play a vital role in the ecosystem, protecting the shoreline from erosion and providing habitats for various organisms. Recent investigations have assessed the soil carbon sequestration capability of the Avicennia marina located at the northern coast of the Red Sea and highlighted the impact of local conditions. [5] highlighted that the geomorphological and biophysical qualities of mangal locations are important parameters for the maximization of mangrove forest carbon sequestration. Undoubtedly, mangroves have a high efficiency to sequester soil carbon with a rate of approximately 85 Mg C ha^{-1}, which is particularly significant in Egypt, that the estimated mean of the soil carbon sequestration is approximately 0.061 Mg C ha^{-1} $year^{-1}$[6,7]. In addition, [8] investigated the mangrove forests at the Gulf of Aqaba–Egypt at the shoreline, salt plain habitats and intertidal, and for each of them estimated around 41.9, 70.3, 109.3 Mg C ha^{-1} soil carbon stored, respectively. On the Gulf of Aqaba, the mangrove carbon sequestration was estimated at around 2.4 Mg C ha^{-1} $year^{-1}$ for the intertidal, with 1.04 Mg C ha^{-1} $year^{-1}$, while the salt plains with0.545 Mg C ha^{-1} $year^{-1}$, and the shoreline with 0.81 Mg C ha^{-1} $year^{-1}$ for the hypersaline ecosystems, finally at 0.14Mg C ha^{-1} $year^{-1}$ and mudflats [6]. Nevertheless, in comparison with the assessments that presented the mangrove carbon sequestration capability, there is a gap of knowledge related on the impact of mangrove on the soil hydraulic properties. The objective of this paper is to contribute to fill this gap.

1.2. Problem definition

The current study aimed to characterize and analyze in-situ the soil physical changes induced by mangrove planting practices and their benefits in preserving the soil quality. The rate at which soil water infiltrates and subsequently moves within its matrix plays a crucial role for land management practices, favorable plant, and soil health. However, little information exists on the hydraulic properties of soil, because these assessments require accurate soil physical measurements. Laboratory and field methods for investigating the determination of soil hydraulic properties can be both expensive and time-consuming [9], and laboratory methods rely on directly solving Darcy's law for accurate results [10,11], for the determination of hydraulic properties, such as the transient procedures involved and those based on Richards' equation of approximation. In addition, the convenient results that depend on the field-based measurements than on the laboratory measurements because they retain soil continuity versus depth [12]. Infiltration parameter has long been an essential characteristic for the soil and water research due to its important roles in the concept of land management [13]. Several mathematical models during the last decades have been developed to compute infiltration rates. These infiltration-based models are generally classified into empirical, semi-empirical, and physically based models [14,15]. For the empirical and/or the semi-empirical models, as the models of Kostiakov and Horton, are performed in simple equations form and prepared from field, pedo-transfer, and/or laboratory experimental data [16]. Nevertheless, both of the empirical models and the semi-empirical cannot perform detailed clear results on the infiltration process and their impacts on the soil physical properties. Physically-based numerical models, in comparison to semi-empirical and empirical models, offer a more detailed representation of the infiltration process [17,18]. These models utilize the Richards equation as one of the most effective tools for studying water flow. The Richards equation is primarily built upon Darcy's law and the principle of mass conservation [19]. By employing such models, researchers can gain a deeper understanding of the intricate mechanisms involved in water infiltration, allowing for more accurate simulations and predictions. However, due to its strong nonlinearity, the Richards equation proves to be challenging for analytical interpretation and solution, especially when confronted with its boundary conditions and the complex initial [20]. The Hydrus-1D model was performed in this experiment to simulate and analyze two key conditions:

(1) soil water dynamics under Mangrove planting,

(2) soil hydro-physical relations in terms of influence of mangrove on hydraulic conductivity.

2. Materials and Methods

This investigation carried out throughout two successive seasons of 2016 and 2017 seasons on 4 years old of Flame Seedless cv. grapevines grown in sandy soil and cultivated at 2x3 m apart under drip irrigation system and vines were trellised with Y- shape system in a private vineyard at Belbies district, Sharkia Governorate, Egypt. The experiment included 8 treatments as follow: The harvested bunches transported immediately to the fruit laboratory of the Horticulture Department, College of Agriculture, Zagazig University to determine the bunch and berries physical and chemical characteristics as follow:

2.1. Description of the study area

The Red Sea geographically extends from the Bab El Mandab strait at 12° 39′ in the south to Ras Mohammed in the north at 27° 43' and divided into two main gulfs: Suez Gulf to the west and the Aqaba Gulf to the east [21]. The Red Sea coast allocated with 870 Km inside the Egyptian territory. Thus [22] mentioned, the combined length of the Red Sea coastline in Egypt, including both the Aqaba Gulf and Suez Gulf, is approximately 1700 km. The present study primarily concentrates on the mangroves situated and growing along the Egyptian coast (Fig. 1), encompassing various islands into the Red Sea Abu Monquar Island to the Hurghada city (27.216250° N, 33.876288° E). The mangrove sample locations were identified within the designated study area that spanning from the Island of Abu Monquar (27.216250° N, 33.876288° E) and extending northwards towards Hurghada city. A total of five sampling sites were included in this study (plus one control site - beach without plants). The primary objective of the research was to identify and represent the effects of the mangrove pure population of Avicenna Marina type on the soil hydro-physical properties. The mangrove sites at (site 1 and Site 2) located in El-Gouna village, represented mangrove plantations aged 10 and 5 years, respectively. While the mangrove sites 3, 4, and 5 corresponded to mangrove locations in Hurghada, Abu Monquar Island, and Safaga, respectively. The selected areas exhibit specific climatic conditions, characterized by annual temperature with an average of 25 °C, and average annual solar radiation with 28.9 Mj m^{-2}, while the annual mean rainfall presented with 5.9 mm $year^{-1}$ [23].

2.2. In-situ measurements and soil laboratory analysis

The soil profile at each chosen site underwent a comprehensive examination, extending to a depth of 90 cm. Extensive soil samples were collected along three transects, encompassing five distinct locations within each transect. To ensure representative sampling, soil samples were specifically obtained from three different soil layers: 0-30 cm, 30-60 cm, and 60-90 cm. The selected soil samples were subsequently air-dried and subjected to a range of physical and chemical analyses, facilitating a comprehensive evaluation of their properties. In-situ measurements were conducted at field locations to determine the dry bulk density at each soil layer. So, using hammering sample rings with a fixed volume of 100 cm³ into a soil matrix, the soil samples were collected for the dry bulk density. The soil samples in laboratory were air-dried at room temperature and the soil ground to pass through a 2-mm sieve. The pH of the soil was measured using a lab pH meter - model PH211 by extracting the soil with a 1:2.5 ratio of soil to water. Electrical conductivity (EC) was assessed using a conductivity meter to determine the salinity of the soil paste extract. The soil total calcium carbonate content was examined using the method of [24]. The international pipette method [25] was used to analyses the soil particle-size distributions. The soil saturation percentage, field capacity, and wilting points were performed according to [25]. The morphological characteristics of the mangrove forests (Table 2), including tree height, tree size index, trunk circumference, and tree density for each location, were identified to investigate the population growth influences of the mangrove forest on the soil physical properties [26].

2.3. Simulation of one-dimensional water flow

1) To investigate the soil water dynamics under mangrove forests, the HYDRUS-1D model was utilized in this work, that was numerically performed by the method of [27]. The HYDRUS-1D model depended basically on Richards equation that used to simulate the water flows in one-dimensional in media with varying saturation levels.

The Richard flow equation was explained as follows:

$$\frac{\partial\theta(h,t)}{\partial t} = \frac{\partial}{\partial z}\left[k(h)\left(\frac{\partial h}{\partial z}+1\right)\right] \qquad (1)$$

where: θ is volumetric water content; t is time; h is soil water pressure head; z is vertical coordinate at the soil surface (negative downward); and k(h) is unsaturated hydraulic conductivity. The initial boundary condition and the upper boundary condition were:

$$h(0,t)=h0 \qquad\qquad h(z,0)=hi(z)$$

h0 is the water potential at the upper soil surface, while hi (z) is the initial water pressure head. Through the processes into the HYDRUS-1D model, we applied the Van Genuchten-Mualem model for the investigated locations (2):

$$\frac{\theta-\theta r}{\theta s-\theta r} = (1|\alpha h|n)\text{-}m \qquad h>0 \qquad (2)$$

$$\theta = \theta s \qquad h\leq 0$$

where: θ is volumetric soil water content (cm3.cm-3), θs and θr are the saturated and residual water contents (cm3.cm-3), and h is the soil water pressure head (cm). The constants of the Van Genuchten-Mualem model; m, n, and α are the empirical parameters, that the m value is calculated using the van Genuchten-Mualem model with m=1-1/n. As the HYDRUS-1D code connected with a hierarchical computation (ROSETTA model) [28]. the ROSETTA model used to compute the pedo-transfer functions (P.T.F.s), which are used to predict the soil water retention characteristics and the saturated hydraulic conductivity (Ks) of van Genuchten parameters in a hierarchical manner using in sit measured soil textural distribution, soil bulk density, water content at field capacity and water content at wilting point as inputs [29]. For the initial and boundary conditions, we performed the van Genuchten-Mualem model with no-hysteresis to identify the soil hydraulic properties for all the locations. In addition, we implemented the locations upper boundary conditions with pressure head -5 cm, while the locations lower boundary condition presented as free drainage.

3. Results

3.1. Soil physical properties under Mangrove ecosystem

The soil bulk density (SBD) values obtained from the different locations indicated that the soil dry bulk density was higher in the upper soil layers (0-30 cm) than in the lower soil layers. At the control site, the soil dry bulk density values were 1.75 g/cm³, 1.70 g/cm³, and 1.70 g/cm³ at soil depths of 0-30 cm, 30-60 cm, and 60-90 cm, respectively (Table 1). The cultivated locations with the mangrove plants revealed another SBD values in their different layers, where the site S1 in El Gouna location, mangrove had been planted for ten years, the SBD values presented 1.63 g/cm³, 1.60 g/cm³, and 1.50 g/cm³ at soil layers of 0-30 cm, 30-60 cm, and 60-90 cm, respectively. Similarly, for the second site in El Gouna village with the same species of mangrove planted for five years, the SBD values were 1.70 g/cm³, 1.64 g/cm³, and 1.58 g/cm³ at soil layers of 0-30 cm, 30-60 cm, and 60-90 cm, respectively. For Hurghada location (S3), the soil dry bulk density was 1.73 g/cm³, 1.64 g/cm³, and 1.60 g/cm³ at soil layers of 0-30 cm, 30-60 cm, and 60-90 cm, respectively. While for the Island of Abu Monquar (S4), the SBD values represented 1.31 g/cm³ and 1.20 g/cm³ at soil layers of 0-30 cm and 30-60 cm, respectively. In Safaga location (S5), the soil dry bulk density value record 1.53 g/cm³ at a soil layer of 0-30 cm (Table 1). The findings presented in Table 1 indicate notable variations in calcium carbonate ($CaCO_3$) values among the different sites. The highest $CaCO_3$ content was exhibited at Abu Monquar Island with 16.82%. In contrast, for El-Gouna1, El-Gouna2, Hurghada, Safaga, and the control sites had $CaCO_3$ contents of 2.66%, 6.93%, 5.85%, 9.19%, and 2.69%, respectively, for the soil surface (0-30 cm). The obtained soil physical properties for the investigated locations revealed significant differences particularly at the Island of Abu Monquar, which showed increase values in field capacity compared to the other locations mainly in the upper soil layer.

Table 1: The investigated soil physico-chemical properties under the Mangrove planting.

Site	Ec (soil paste) mmhos/cm	Sand (%)	Silt (%)	Clay (%)	Soil Texture	Bulk Density	W.P. (%)	F.C. (%)	CaCO3 (%)
Cont (A)	8.447	92.33	5.40	2.27	Sand	1.75	4.77	9.54	2.69
Cont (B)	9.792	93.00	4.87	2.13	Sand	1.70	4.65	9.29	2.46
Cont (C)	10.458	93.00	4.65	2.35	Sand	1.70	4.71	9.42	2.68
S1 A	17.887	91.00	5.63	3.37	Sand	1.63	6.07	12.14	2.66
S1 B	21.250	92.33	4.60	3.07	Sand	1.60	6.11	12.22	3.09
S1 C	18.167	92.00	4.60	3.40	Sand	1.50	5.65	11.30	2.98
S2 A	13.783	91.33	4.97	3.70	Sand	1.70	6.11	12.22	6.93
S2 B	15.783	91.33	5.04	3.63	Sand	1.64	6.15	12.31	6.55
S2 C	17.467	90.33	5.19	4.48	Sand	1.58	5.69	11.39	8.04
S3 A	16.400	91.50	4.77	3.73	Sand	1.73	5.84	11.68	5.58
S3 B	16.163	91.50	5.25	3.25	Sand	1.64	5.90	11.81	7.41
S3 C	17.213	91.00	5.25	3.75	Sand	1.60	6.03	12.06	7.94
S4 A	88.138	78.50	12.50	9.00	Sandy loam	1.31	8.01	16.01	16.82
S4 B	26.600	89.00	5.50	5.50	Sand	1.20	8.41	16.83	23.61
S5 A	17.680	90.60	5.15	4.25	Sand	1.53	7.74	15.47	9.19

Cont: control, S1: Gouna1, S2:Gouna2, S3: Hurghada, S4: Abu-Manqar, S5: Safaga, A: Soil depth 0-30cm, B: Soil depth 30-60cm, C: Soil depth 60-90cm.

Table 2: The morphological characteristics of the mangrove forests for each location.

Site	Tree height (cm)	Tree size index (cm)	Trunk circumference (cm)	Tree density (individual per 100 m2)
S1	110 -130	90 - 110	20 - 30	3.4 – 15.5
S2	50 - 70	30 - 40	10 - 20	2.5 – 10.5
S3	150 - 200	130 - 170	22 - 35	4.2 – 20.2
S4	200 - 300	150 - 220	25 - 45	5.5 – 27.5
S5	200 - 270	155 - 210	25 - 40	5.1 – 25.5

S1: Gouna1, S2:Gouna2, S3: Hurghada, S4: Abu-Manqar, S5: Safaga.

Table 3: The Hydraulic properties of the investigated soils under Mangrove growing

Sites	Theta r (cm3/cm3)	Theta s (cm3/cm3)	Alpha (1/cm)	n	Ks (cm/day)
C1 (A)	0.046	0.3152	0.0341	2.2038	130.27
C2 (B)	0.0474	0.3292	0.0325	2.313	156.94
C3 (C)	0.0478	0.3295	0.0328	2.3352	164.36
S1A	0.049	0.3501	0.0327	2.2498	171.02
S1B	0.0506	0.3594	0.0327	2.4524	236.63
S1C	0.0519	0.3907	0.033	2.4559	313.32
S2A	0.0467	0.3325	0.0304	1.9766	91.76
S2B	0.048	0.3497	0.0296	2.0469	115.31
S3C	0.051	0.3672	0.0325	2.2231	191.09
S3A	0.0466	0.3239	0.0317	2.0013	94.26
S3B	0.0478	0.3487	0.0301	2.0976	125.16
S3C	0.0491	0.3611	0.0304	2.1191	145.96
S4A	0.0505	0.4424	0.039	1.6818	231.1
S4B	0.0495	0.4794	0.0387	1.6996	449.5
S5A	0.0482	0.3845	0.0259	1.8463	107.73

Theta r (Qr): Residual water content (cm3 cm-3); Theta s (Qs): Saturated water content (cm3 cm-3); Alpha: Sorptivity number (1/cm); n: pore-size distribution index. Ks: Saturated hydraulic conductivity (cm d-1). C: control, S1: Gouna, S2:Gouna2, S3: Hurghada, S4: AbuManqar, S5: Safaga. A: Soil depth 0-30cm, B: Soil depth 30-60cm, C: Soil depth 60-90cm

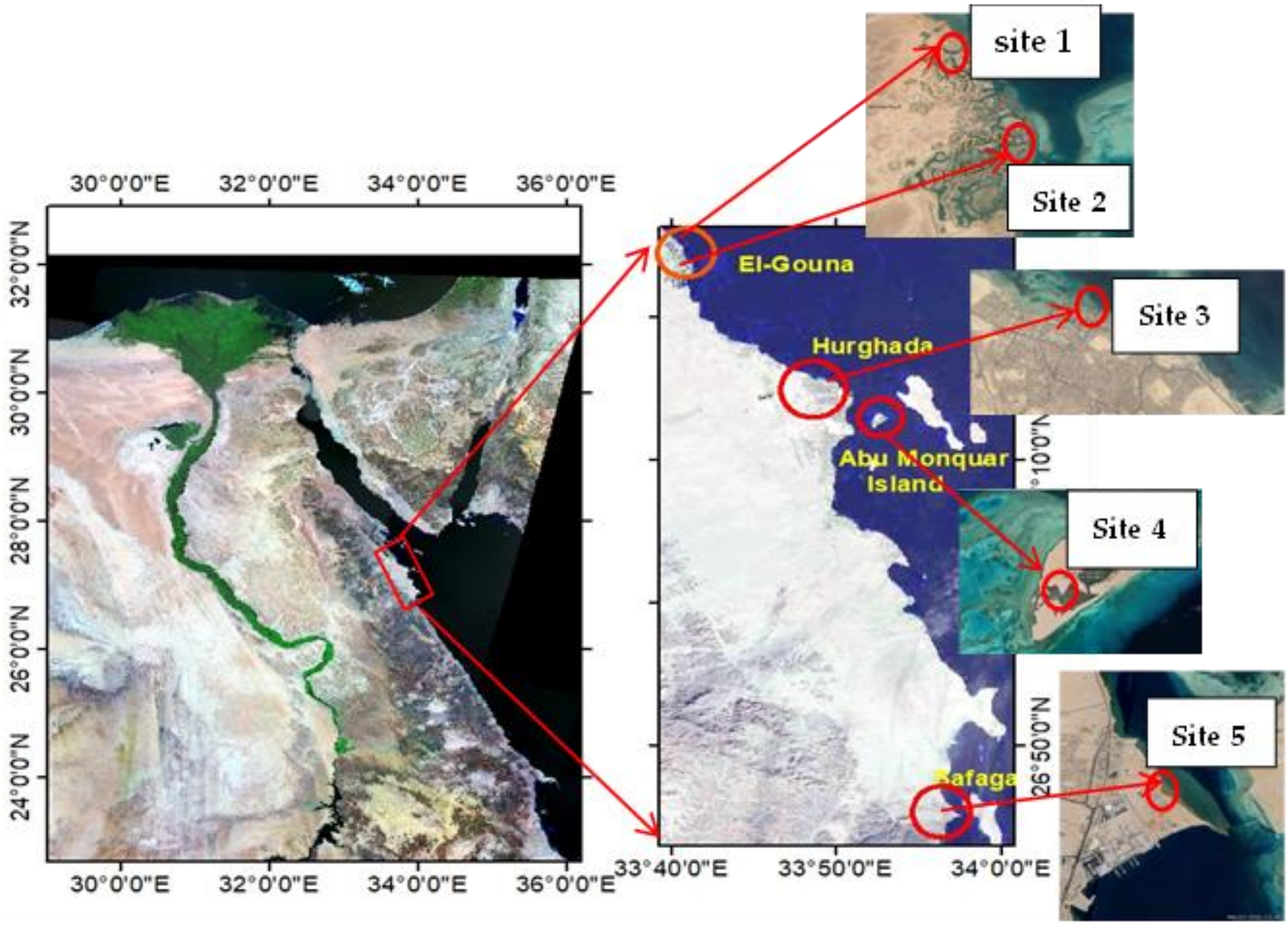

Figure 1: Sample locations of the mangrove sites along the Egyptian Red Sea coast.

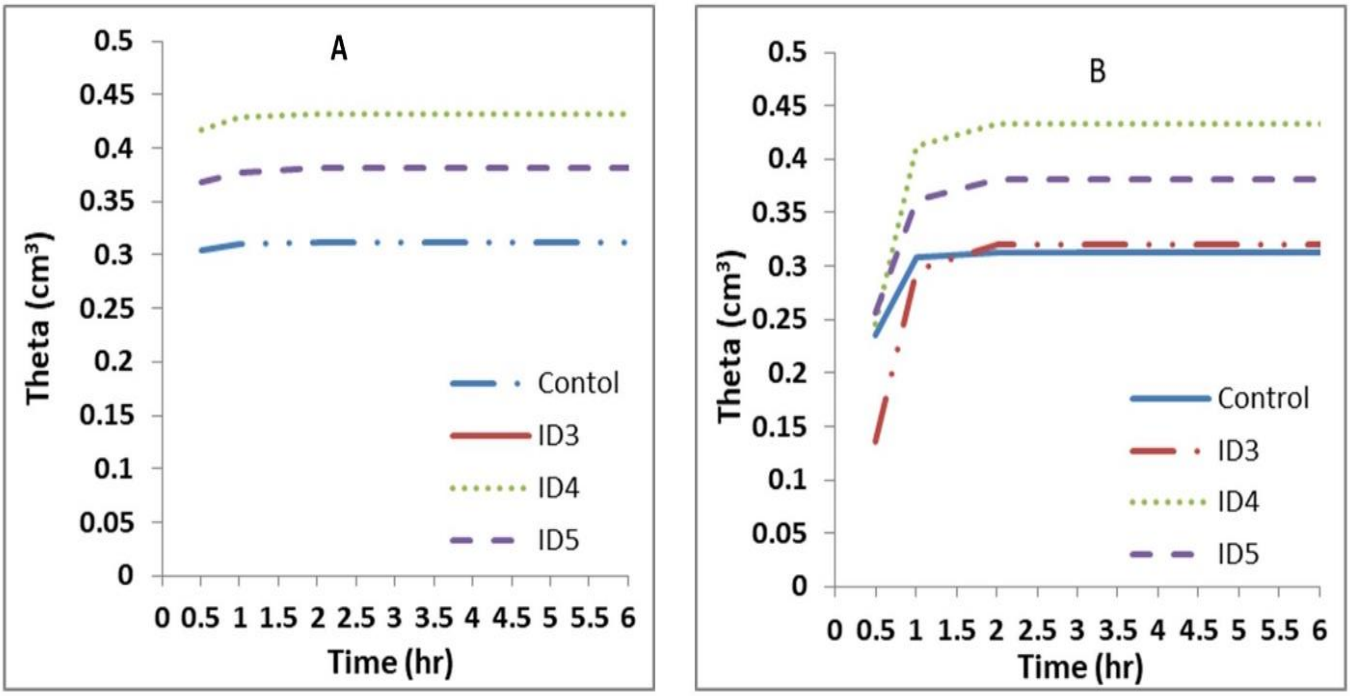

Figure 2: Changes of volumetric water content with time under two different depths (A) at soil depth 10cm and (B) at soil depth 20cm using mangrove growing at the different sites using the numerical model Hydrus-1D. ID3: Hurghada, ID4: Abu Monquar Island, ID5: Safaga.

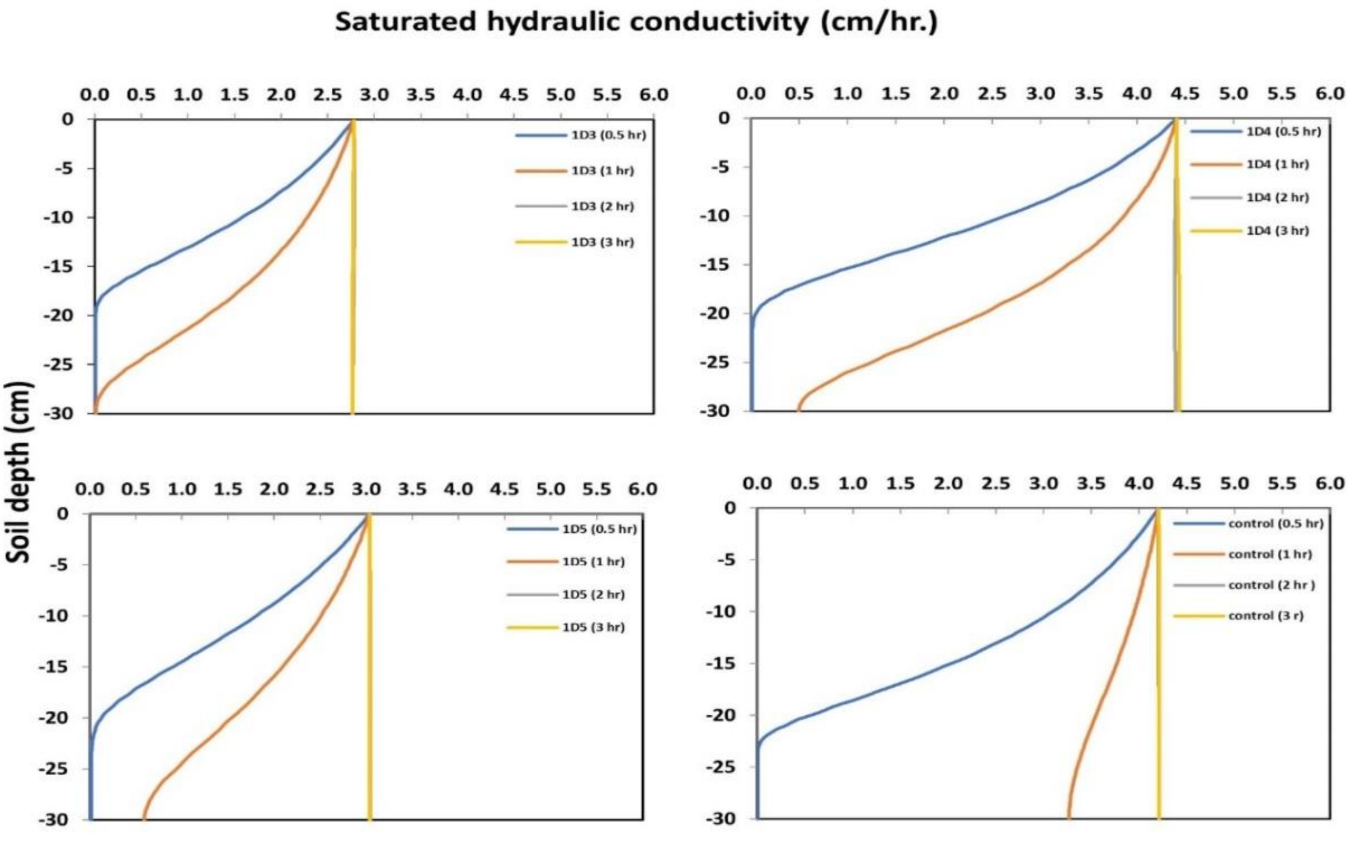

Figure 3: Changes of saturated hydraulic conductivity with depth under Mangrove planting at the different sites using numerical model Hydrus-1D. Control: the control site, ID3: Hurghada, ID4: Abu Monquar Island, ID5: Safaga

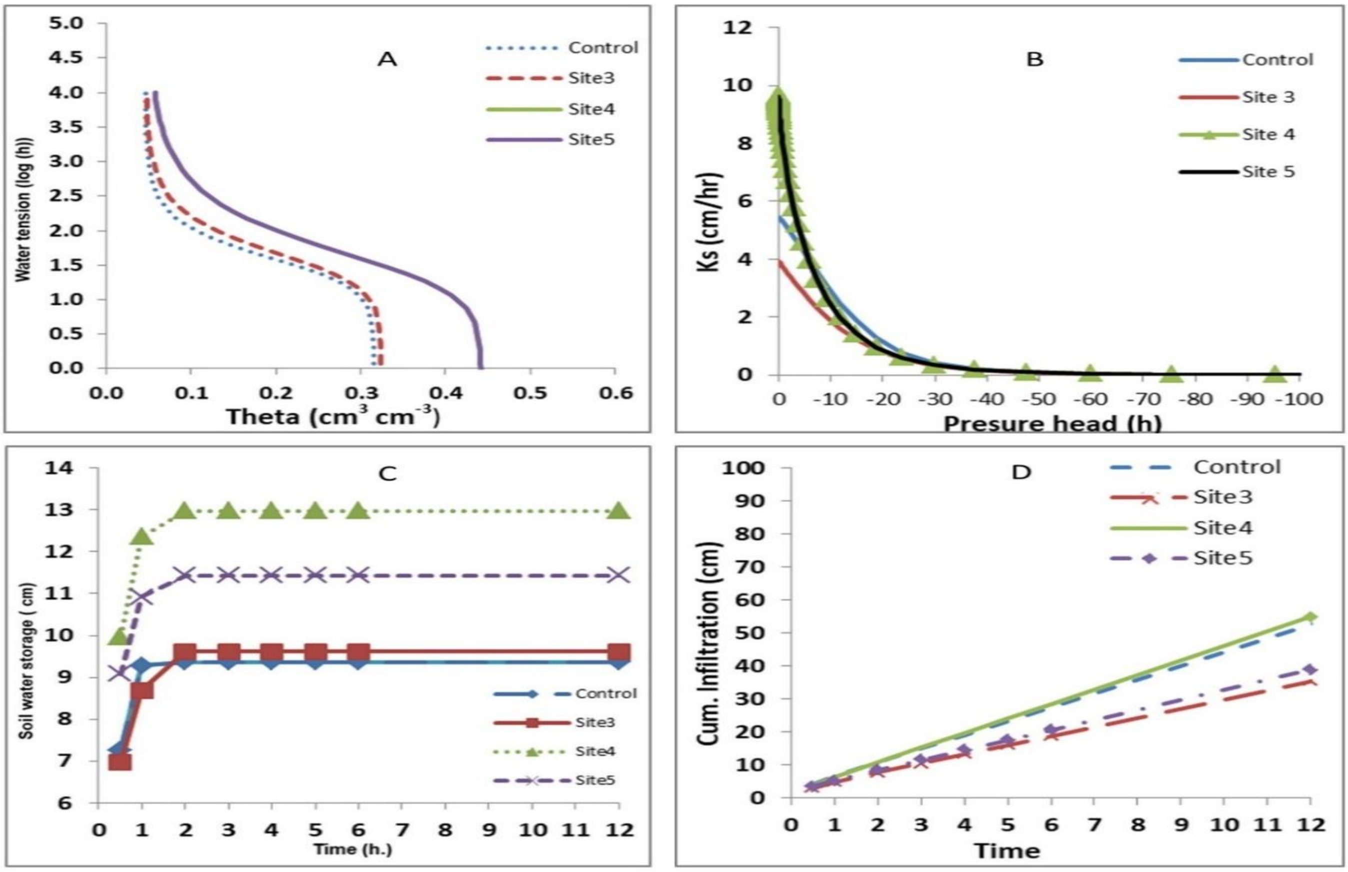

Figure 4: Hydraulic Properties under Mangrove stands at the different sites A: Water retention curves, B: saturated hydraulic conductivity versus pressure head, C: Soil water storage capacity versus time, D: Cumulative inf

At Abu Monquar Island, the field capacity was 16%, while the other sites exhibited values of 9.54%, 12.14%, 12.22%, 11.68%, and 15.47% for the control and Sites 1, 2, 3, and 5, respectively. These findings are consistent with the results reported in [30]. The results of Table 2 revealed the morphological characteristics of the mangrove forests, including the tree height, tree size index, trunk circumference, and tree density for each location. That the tree height results varied from 110-130 cm, 50-70 cm, 150-200 cm, 200-300 cm, and 200-270 cm for El-Gouna1, El-Gouna2, Hurghada, Abu Monquar, and Safaga, respectively. The trunk circumferences were 20 -30 cm, 10-20 cm, 22-35 cm, 25-45 cm, and 25-40 cm for ElGouna1, ElGouna2, Hurghada, Abu Monquar, and Safaga. The results of the morphological characteristics of the mangrove forests for each location were appropriated with the findings of the soil physic-chemical properties (Table 1). That the higher values of the trunk circumference, tree height, tree size index, and tree density convienent with convienent with the lower values of the SBD at the Island of Abu Monquar and Safaga with compared to the other site locations (Figure 1).

3.2. Simulation the soil water flow using one-dimensional model

The soil hydrological parameters of the investigated sites under mangrove planting are shown in Table 3. With implementing the obtained results of the measured particle size distribution, dry bulk density, and in-situ saturated hydraulic conductivity in the van Genuchten-Mualem model into the Hydrus-1D model, the hydrological parameters (Qr, Qs, α, n) were obtained (Table 3). The obtained results were consistence with the obtained results of [14,31] for field experiments that imposed a water pressure head through a disc infiltrometer for the infiltration tests to estimate the hydraulic parameters. Figure 2 shows the relation between the volumetric water content (theta potential), which was solved by the method of [27,28], with the time under mangrove planting of the different investigated sites at two soil depths 10 and 20 cm. The results revealed that the volumetric water content (theta potential) of site 4 (Abu Monquar Island) was higher than the other investigated sites at the same soil depths. This may be attributed to the difference in soil texture and the increase of clay content (Table 1) which have affected the soil water movement and consequently increased the volumetric water content compared with other sites, as shown in Figure 3. The results of Figure 3 revealed that the saturated hydraulic conductivity decreased logarithmically with the pressure head distribution into the soil layer (0-30 cm), in which the impact of the Mangrove planting was predominant. Analysis of the Ks values that estimated by the Hydrus-1D model revealed that the Ks at Abu Monquar Island were two times higher than at the Hurghada site with the same soil pressure. Saturated hydraulic conductivity at a depth of 10 cm under Abu Monquar Island was 4.5 cm/hour, while for the Hurghada site was 2.7 cm/hour (Figure 3). This may be interpreted due to increasing clay content [32,33], higher biological activity, more calcium carbonate in the soil, and hence higher infiltration rate in comparison to the Hurghada site (Table 1). In addition, the soil matrix required 3 hours under each location to be at the constant storage capacity level (Figure 3). Thus, planting Mangroves influences soil hydraulic properties [34]. The results of Figure 4 revealed the impact of the Mangrove stands on soil water flow using the numerical model Hydrus-1D. That Cumulative infiltration curve under Site 4 was more abundant than the other sites (Fig. 5d). The results of Fig. 5a showed the effects of water retention during the infiltration process. While the results of Fig. 5b presented the Ks versus the volumetric water content which reflected the same trend of increasing Ks under Site 4 compared with the other investigated sites with increasing the water in soils which is relevant with the concepts of [14,34]. The soil water storage capacity at Abu Monquar Island (Site 4) was higher than the other sample locations. In addition, the soil cumulative infiltration rate at Abu Monquar Island was higher than the other sample locations. That the soil physical changes induced by Mangrove growing practices at Abu Monquar Island reflect better soil quality which will encourage planting the Mangrove in large spaces compared to the other sites, that is could be interpreted due to increasing the clay content [33,35], higher biological activity, more calcium carbonate in the soil [8,34] , and so higher infiltration capacity [13,36]. These results are relevant well with the finding of [37].

4. Conclusions

The present study indicators at the Red Sea coast showed the mangroves that distributed and grow as discontinuous patches. Mangrove swamps (*Avicennia marina*) have several difficulties that effect the water movement into the soil, leaves, prop roots, and pneumatophores, which could affect sedimentation of the suspended particles in the surrounded areas that could affect the soil hydro-physical properties. The soil clay content reveals the main factor that effect on the different hydro-physical under the different sites. The minimum values of the dry bulk density were noticed at Abu Monquar Island that has the highest clay content compared to the other investigated sites. In addition, the Calcium carbonate values were highest under Abu Monquar Island compared to the other sites. The HYDRUS-1D model results provided reliable simulation of the cumulative infiltration and infiltration rate into the soil. Using the model HYDRUS-1D to investigate the soil hydro-physical properties proved an efficient tool for the mangrove ecosystem assessment on the soil physical properties.

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