A REVIEW OF DRAINAGE MANAGEMENT AND SUSTAINABILITY OF EGYPTIAN HEAVY CLAY SOILS

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ABSTRACT

Reclamation and cultivation of heavy clay soils in Egypt are increased last decades due to high demand for food production. They are very attractive for agricultural expansion in the North of the Nile valley due to their high capacity of water holding and high fertility. High water table, high salinity and low permeability affect the productivity of heavy clay soils. The land drainage is required to improve the productivity these soils. Improvement of soil properties, suitable drainage systems, suitable drainage design, accurate drainage installation and maintenance are required to have feasible drainage system with good performance. The purpose of this paper is to summarize past and present drainage management practices and future challenges and technology to sustainability the agricultural expansion in the heavy clay soils of northern part of the Nile Delta.

KEYWORDS: Drainage; Management; Sustainability; Heavy Clay Soil

1) IMPORTANCE

In Egypt, the heavy clay soils are always threatened by a shallow saline groundwater (Antar et al., 2008). An increased attention has been given to reclaim, improve and manage the Egyptian heavy clay soils to solve problems of saline and sodic for optimal crop production. The saline and sodic problems are in many instances associated with heavy clay soils. Establish of the limits for sustainable farming on heavy clay soils is needed to devise economical types of drainage systems (FAO, 1970). Drainage is an essential tool to combat waterlogging and salinity. Subsurface drainage improves the productivity of poorly drained soils by lowering the water table, creating a deeper aerobic zone (Smedema et al., 2004) and enabling faster soil drying and improving root zone soil layer condition (Jung et al., 2010). (Gehan et al.; 2003) mentioned that the drainage management for problematic heavy clay soils is a multi-disciplinary process concern crop variety, water management, soil improvement, drainage management and socio-economic aspects. Hence, the management of problematic heavy clay areas should be a multi-disciplinary strategy and joint efforts between key persons who involved in this process. (Hamed et al., 2010) were optimistic about the future of the productivity and land reclamation in heavy clay areas. They suggested careful and continuous monitoring of the salinity status in the future. (Qadir et al., 2015) believed that the investments in salt-affected irrigated zones could make a significant contribution to poverty reduction, economic and social development as well as efforts for achieving food security. They predicted that the enhancing soil carbon sequestration will improve the environment by mitigate the climate change impacts.

2) HEAVY CLAY SOIL DEFINITION

(FAO, 2006-a) described the heavy clay soils as vertisols or vertic intergrades that easily to recognize because of their clay texture, cracking structure and their dark colors. (USDA, 1999) defined that

Vertisols as churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years. Heavy clay soils have high plasticity and shiny surfaces with clay content more than 60%. It has cracks that open and close periodically. (FAO, 1995) considered the soils with 50-80% clay in the topsoil heavy clay soils. (FAO, 2006-b) reported that the vertic horizon is a clayey subsurface horizon that, because of shrinking and swelling, has slickensides and wedge-shaped structural aggregates. It contains 30 percent or more clay throughout a thickness of 15 cm or more. It has wedge-shaped structural aggregates with a longitudinal axis tilted between 10° and 60° from the horizontal. It has slickensides. (USDA, 1999) defined the Vertisols as clayey soils that have deep, wide cracks for some time during the year and have slickensides within 100 cm of the mineral soil surface. (FAO, 1995) mentioned that They shrink when dry and swell when moistened. It defined the heavy clay vertisols as soils having a vertic horizon within 100 cm from the soil surface. The heavy clay soils often have less well-developed structure and a permeability of less than 0.1 m/day. (DRI, 2001) defined the problematic Egyptian heavy clay soil as a clay soil with more than 40% clay, low hydraulic conductivity less than 0.1 m/d and with problems such as salinity, alkalinity, difficult installation of subsurface pipe drains in sticky clays, hard pans, and underlain by saline groundwater with possibly upward seepage.

3) HEAVY CLAY SOIL LOCATIONS

(Dudal and Eswaran, 1988) estimated that 78 Million ha of the dark clay soils in Africa. 69% occur in semi-arid zones and the rest in sub-humid zones. He estimated that 1 Million hectare is found in Nile delta of Egypt. (DRI, 2001) concluded that problematic heavy clay soils represent approximately 260,000 feddan (1 feddan=0.42 ha) in the Nile Delta. Hamul and Zawia (Kafr El Sheikh), El Robh El Sharq (Fayoum), Damietta Dairy Drainage Project (Damietta), El Rowad Area of South El-Hossania (Sharqia); Tina Plain area (North Sinai), Edco area (Beheira) and Integrated Soil and Water

Improvement Project (ISAWIP), El-Serw, and El Halafy (Dakahlia) were identified as heavy clay soils as shown in Figure (1).

4) HEAVY CLAY SOIL PROPERTIES

(Wahab et al.; 2010) concluded that a significant area in the northern Nile Delta is subjected to a high risk of physical and chemical degradation. Moreover, processes of water logging, soil compaction, soil salinity and alkalinity are slight, medium and high in different land units. (Abu Zaid, 1991) concluded that problematic heavy clay soils in the Nile Delta consist of Marine clays, which are highly saline and have poor internal drainage properties.

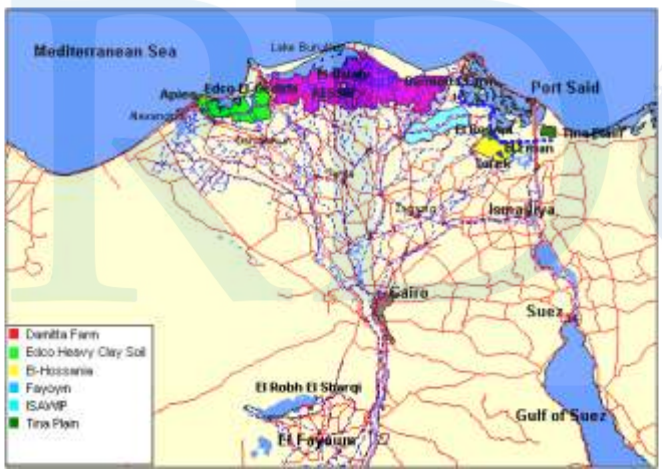

Figure 1. Problematic heavy clay soils in Egypt (DRI, 2001)

The sodicity hazard in these soils is high, their permeability is very low, and reclamation is very difficult and expensive. (Kubota et al., 2017) identified many factors that are affecting soil salinity, including the use of drain water or mixed water as irrigation water and the fluctuation in the water table level, which is related with the efficiency of the subsurface drainage systems. (Stewart et al., 2016) proposed a framework to describe the porosity distribution in shrink–swell clay soils, focusing on three porosity domains (aggregate, shrinkage cracks and subsidence). The behavior of the aggregate domain can be understood through application of the soil shrinkage curve, for which we proposed a new expression that, when presented in normalized terms, requires only water content and two fitting parameters (or, alternatively, soil suction and four fitting parameters). This new soil shrinkage function is flexible and capable of describing many different shrinkage behaviors; it can also be readily integrated and differentiated, thus allowing estimations of shrinkage phase transitions. (El-Araby et al., 1987), (Boulos et al., 2008), (Hamed et al., 2010), (Selim, 2011), (Mohamedin et al., 2011) and (El-Gammal et al., 2015) investigated the heavy clay soils at 1.0 m depth from the surface of clay content (43-70.5%) in North Delta. The areas were in E1-Zawia (Kafre E1-Shiekh), South El-Husseinia plain of El-Salam canal project (Sharqiah), south of Port Said, El-Hamoul area (Kafr El-sheikh) and Damietta. They found that the bulk density of soils ranged between (1.35-2.15 gm/cm^3), the soil salinity EC was (5.58-58.4 dS/m) and the soil alkalinity pH (7.35-8.40). The average water content was (29-51%) and the infiltration rate was (12-60 mm/h). (Abdeldayem et al., 2000) found the soil salinity at 60 cm below surface was more than 100 dS/m before leaching of 22,000 ha of Tina plain in Sinai in North East of river Nile Delta and the soil hydraulic conductivity was 55 mm/day. After leaching, the soil salinity dropped to (9.8-16.1 dS/m) through the soil profile. (Diane Bulot et al., 2017) highlighted the importance of soil hydrodynamic properties on water table drawdown and cranberry yield and showed that nearly 50% of the variance of water table drawdown and crop yield is explained by soil hydrodynamic properties. (Dudal and Eswaran, 1988) mentioned that with rainfall or irrigation, cracks have bigger depth and width and the wedge-shaped soil structure is more distinct. (Kodikara et al., 2002) mentioned that the basic patterns of cracking were identified as orthogonal and non-orthogonal cracking. It was highlighted that the development and response of cracks are dependent on the restraint conditions placed on the soil, severity of the drying cycles and initial state of the soil. The crusting of surface is more frequent. Organic matter is higher in the topsoil and the color becomes darker. (Hussein, 2002) used two criteria to characterize the extensibility of heavy clay at the site, namely the coefficient of linear extensibility (COLE) and the potential of linear extensibility (PLE). COLE gives an indication of the reversible shrink–swell capacity of a soil. It is calculated from the dry bulk density and the bulk density at 33.3 kPa water suction. PLE is the potential for soil swelling and shrinking in field conditions. It considers swelling and shrinking properties of the individual soil horizons in the studied soil profile. (Reeve et al., 1980) mentioned that the COLE is more than 0.06 in vertic horizons. Soil with COLE > 0.09 m is classified by the US, Department of Agriculture, Natural Resources Conservation Service as having Very High shrink–swell potential, and it is frequently assumed in modeling that this class of soil would have a ratio of change in thickness relative to change in depth of water stored of 1:3. PLE is more than 14 cm for high shrinkage heavy clay soils. (Hussein, 2002) found that the Egyptian heavy clay soils in Kafr El-Sheikh have high extensibility. The Value of (COLE) was (0.043-0.168) and the (PLE) value was (7.20-15.03 cm). He mentioned that infiltration, internal drainage, salt movement, root development, and evaporation are important factors that affect soil cracking and soil structure. He found the average crack depth under cultivated lands in Kafr El-Sheikh was (3.30-6.50 cm) while in the bare lands the crack depth was (2.00-6.20 cm). In the harvested cultivated lands 40 to 50 days after irrigation, it was (18.20-21.00 cm). The average crack width in the cultivated lands was (0.8 and 1.8 cm), while in the bare land the crack width was (0.6-2 cm). The crack width in the harvested cultivated lands 40 to 50 days after irrigation was (2.1-3.2 cm). The crack volume per unit surface area was (10.40-52.16 m^3/feddan) in the cultivated lands while it was (16.00-120.40 m^3/feddan) in the bare lands. The crack volume per unit surface area in the harvested cultivated and bare lands 40 to 50 days after irrigation was (178.70-204.60 m^3/feddan).

5) HEAVY CLAY SOIL DEVELOPMENT APPROACH

(Ritzema, 2009) recommended the (Croon, 1997) a three-step development approach for the low-lying areas in the North Delta areas of Egypt. In the first three years after reclamation, surface drainage is installed and salt-tolerate crops are cultivated. Gypsum or other amendments are applied to improve of the top (10-20 cm) of the soil profile. After 3 to 5 years, mole drains are installed and salt resistant/tolerant crops are cultivated to improve soil structure and fertility by nitrogen fixation. If required, more gypsum is applied; Finally, after the heavy clay soils have ripened and reached a hydraulic conductivity greater than 0.1 m/day, subsurface drains can be installed at economical spacing. Subsurface drainage, in combination with the existing surface drainage, enables the cultivation of more profitable, i.e. less salt-tolerant crops. (El-Sanat et al., 2017) recommended that the application of 50% from gypsum requirements (5 Mg compost per Feddan) combined with plowing depth at 60 cm achieved economic production of wheat and maize without adverse effect under salt affected soils at North Delta, Egypt.

6) CROPPING PATTERN AND LAND USE

Water and salt movement in the fields of the Nile Delta are critical factors determining the ability of soils to sustain reasonable production of different crops (Kubota et al., 2017). The impact of human activity on the ecosystem on southeastern part of Burullus Lake in Kafr El-sheikh governorate and the surrounding bare areas is obvious. (Belal, 2006) determined land use and land cover systems as agriculture, bare soil, sabkhas, swamps, fish farms, water bodies and village areas. Barley, Sugar beets and sunflowers are salt tolerant crops usually cultivated in saline and sodic heavy clay soils. (Arafat et al., 2010) stated that due to the intrusion of seawater, most of agricultural lands in the northern Nile delta are affected by different degrees of salinity. (Henkel, 2015) mentioned that rain or irrigation, in the absence of leaching, can bring salts to the surface by capillary action. (USDA, 2010) recommended growing salt tolerant plants which can tolerate the soil salinity. For example, germinating sugar beets die when the salinity level is high, but mature plants are very tolerant of the same salinity level. (Sherif, 2003) proposed to increase the area of rice cultivation in the southern parts of the Delta and reducing the rice cultivation in the northern parts. This will help mitigate the seawater intrusion on the long term. (Hefny and Shata; 1995) showed that the presence of heavy clay soils and salty groundwater made growing rice inevitable in parts of the northern delta of Egypt despite attributed high rates of water diversion. (Hoang et al., 2016) reviewed the challenges that hinder the improvement of salinity stress tolerance in rice as well as potential opportunities for enhancing salinity stress tolerance in rice crop. (Abdou, 2003) summarized the actual of crops area percent to the total cultivated area in Behera and Kafr El-sheikh of north Egypt as shown in table (1).

Table 1. Actual crops area percentage of total cultivated area in North Delta

Region	Winter Season		Summer Season	
	Crops	%Cultivation Area	Crops	%Cultivation Area
Behera	Wheat	40.8	Rice	36.9
	B.beans	11.5	Cotton	21.5
	Potatoes	13.1	Maize	21.4
	Tomatoes	10.4	Potatoes	11.4
	Clover	24.5	French harricots	8.8
Kafr	Wheat	40. 4	Rice	64.4

ElShiekh	B.beans	4.8	Cotton	27.3
	Sugar Beet	33. 9	Maize	8.1
	Clove	20. 8		

7) DRAINAGE SYSTEMS

Surface drainage considered as an option where ever circumstances cause the watertable to rise to the surface during a critical time of the year. The types of surface drainage are bedding, furrow and ditch systems. If the hydraulic conductivity of the soil is so low (<0.01 m/day) that no subsurface drainage with economically justifiable is possible, one should use a surface drainage system of furrows and small ditches of 40-45 cm, possible combined with bedding of the soil. When the hydraulic conductivity is more than 0.1 m/day, the soils are highly responsive to conventional pipe drainage. The spacing is often determined using local experience, and it varies between 10 and 20m in heavy clay soils. The vertical drainage could be solved if the layer with higher hydraulic conductivity is at depth greater than 2m and the top layer is of very law hydraulic conductivity (Abdulhamid , 2017). (Boulos et al., 2008) recommended to use open drains with an auxiliary tile drainage system for reclaiming the soil salinity. He recommended to use open drain ditches in combination with tile drainage to overcome the slow water movement and accelerate the leaching process. (Smith and Rycroft, 1986) and (Antar et al., 2012) investigated a network of mole drains in northern Nile Delta. They reported that mole drains have great potential for reclamation purposes, but this is not used widely in Egypt. (DRI, 2001) observed that when saturated hydraulic conductivity of the soil is greater than 0.1 m/d; Mole drains at (50-70 cm) depth and (1-3 m) spacing in combination with a subsurface lateral system at (1.0-1.5 m) depth and (20-40 m) spacing are worked satisfactorily. (Moukhtar et al., 2003) concluded that tile drains combined subsoiling type treatments in heavy clay soils are efficient in lowering the total soluble salts.

8) DRAINAGE DESIGN

(Skaggs, 2016) proposed that technical papers on drainage research studies and engineered design projects should report standard coefficients/parameters that characterize the hydraulics of the system. The following coefficients define key subsurface drainage rates that could be used to quantify the hydraulics of a drainage system. First, the steady subsurface drainage rate (cm/d) corresponding to a saturated profile with a shallow ponded surface. Second, the Drainage Intensity (DI), which represents the drainage rate (cm/d) when the water table midway between parallel drains is coincident with the surface. Third, the hydraulic capacity of the system, often called the drainage coefficient (DC). This value is the rate (cm/d) that the outlet works can remove water from the site. Routine inclusion of these three coefficients in the documentation of research and design projects would be very useful to readers as they compare results of different studies. (Ritzema, 2009) considered the upward seepage in the design criteria of the subsurface drainage system in the northern part of the Nile Delta. He used the design discharge of 1.2 mm/day to maintain the soil salinity below the critical levels for crop production in the northern parts of the Nile Delta. He considered 30m as the minimum spacing between laterals and the average drain depth varied between 1.3 and 1.4 m. For rice and non-rice areas, He used the design drainage rate of 2 mm/day to calculate pipe diameters. He designed the collector pipe drains for a peak discharge of 4 mm/day in rice areas and 3 mm/day for non-rice areas. He took a safety factor of 25% in the design of the collector drains due to sedimentation, irregularities and misalignment. A maximum collector drain depth of 2.5 m is used. The lateral length of 200 m is used for a slope between 0.1 and 0.2%. Collector drains are spaced at 400 m and consisted of pipes with increasing diameter. The diameters are based on the Manning equation for transporting pipes using a roughness coefficient derived by Visser. (Hussein, 2002) proposed modified drainage design criteria in cracking heavy clay soils in Egypt. Shallower drain depth is proposed to be a maximum of 1.20 m depth instead of 1.50 m. The permissible head loss to be increased from 0.40 to 0.65 m. The drainage rate to be increased from 1.5 to 2.0 mm/day. This will allow a lower drainage resistance, better drainage function. It is and more economic installation by keeping the current practice (20 m spacing). (Pali, 2013) investigated variability in drainable porosity and hydraulic conductivity of saline soils of Haryana state in India. He found that modified Glover equation was the most superior equation for drainage design followed by Integrated Hooghoudt equation and then Van Schilfgaarde equation. (Maged, 2015) considered the effect of cracking depth on the drainage of Egyptian heavy clay soils. He developed drainage design equation for subsurface field drains. He considered the influence of cracking top layer as well as bottom layer and the drainable pore space on the drainage of the soil profile. The unsteady state equation for design spacing between subsurface field drains is developed for use in cracking Vertisols. The drain spacing computed by the new equation has wider spacing compared with the Glover-Dumm equation of unsteady state condition (38-54%) according to crack depth.

9) DRAINAGE INSTALLATION

(Hussein et al., 2000) investigated many problems of the subsurface drainage installation in the heavy clay soils in the northern of the Nile Delta. Poor pipe connections, misalignment and depth fluctuations of collectors and laterals during installation, pipe sedimentation and lack of envelope materials affect are related to lack of planning before construction work and need for good distribution of responsibilities, bad conditions of transporting, storage and handling of material and need to improve inspection techniques. (Croon, 1997) reported that the installation problems were aggravated with the presence of high water table or upward artesian pressure. The investigated problems were high draught requirements and sticky clay not loosening from the digging chain of the trencher. Egyptian Public Authority for

Drainage Projects (EPADP) applied the technique of spraying the trencher box with water to reduce friction with the soil and thus reduce draught requirements as shown in Figure (2). EPADP suggested altering the shape of the digging chain elements to enhance release of the excavated soil.

Figure 2. Spraying the trencher box with water to reduce friction with the soil

(DRI, 2001) suggested using the V-plough drainage trenchless machine shown in Figure (3) for construction in heavy clay soils. Trenchless drainage was a good solution in heavy soils, since the chains and knives of a digging chain of trencher machine are subjected to excessive wear and tear. The installation capacity of collector drainage machines in Egypt decreases from 100 m/h for new machines to 55 m/h for machines older than 15 years. For field drainage machines, the figures are respectively 380 m/h and 90 m/h.

Figure 3. V-plough trenchless drainage machine

10) DRAINAGE MATERIALS

(Ritzema, 2007) adapted that the drainage envelope materials increase the efficiency of subsurface drainage systems by protecting drainpipes against soil particles invasion and facilitating the flow of water into drainpipes by creating a more permeable zone around drains. The application of gravel around the drain has involved quite a few problems. The quality, transportation (geographical availability), application precision, and quality control were weak points in the use of this voluminous costly material as envelope for subsurface drainage pipes. (Nasralla et al., 2009) reviewed the constraints and problems of PVC pipes during transportation. The pipe coils are tightly strapped with ropes on the trucks or trailers with the results that many of the coils have one or more dents or cuts. Damaged pipe sections shown in Figure (4) have to be cut-out during installation and the pipe has to be reconnected with a coupler. This procedure takes time, the machine has to stop, and wastes pipe material and couplers.

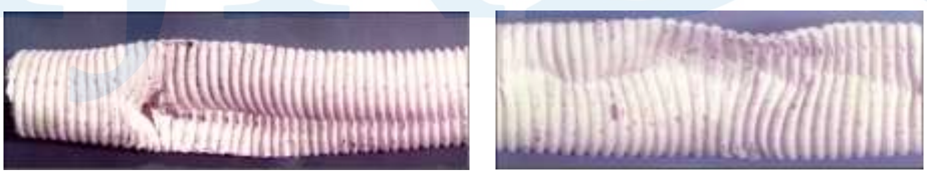

Figure 4. Damaged pipe sections (dents or cuts) during transportation

11) DRAINAGE MAINTENANCE AND PERFORMANCE

(Ritzema, 2009) reported that sustainable drainage systems must be maintained to ensure its effectiveness. The performance of the system has to be checked just after construction completion and before handing over the drainage system to the beneficiaries or organization that will take over the responsibility. Sophisticated checking equipment (Rodding technique and video camera inspection technique) with specialized personnel are required as shown in Figure (5). Maintenance of subsurface drainage systems consists mainly of removing sediment from the pipes and manholes, repairing and – if necessary - replacing these pipes, manholes and outlets. Maintenance of the open (main) drains is removing sediment and weeds. Improper maintenance of the downstream open drainage system will influence the functioning and maintenance of the subsurface drainage systems.

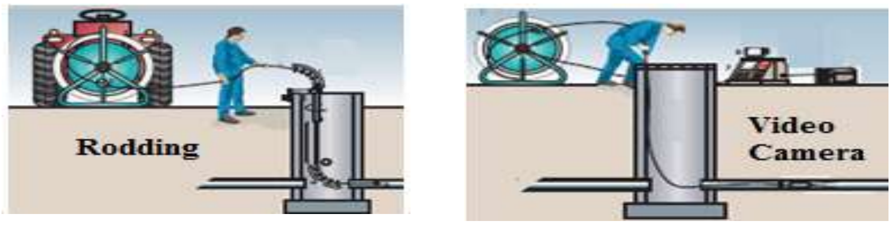

Figure 5. Rodding and video camera inspection techniques

The maintenance frequency is once every 3, 4 or 5 years will depend on the site-specific conditions and installation conditions. (Nijland et al, 2005) proposed measuring performance indicators such as crop yield, water ponding in the fields after irrigation, depth of the groundwater midway between the drains, discharge at the outlet, discharges in some selected manholes, water levels in manholes and sedimentation in manholes. Improved flushing equipment and methods to remove sediment from the drainage systems are proposed. (Nasralla et al., 2009) concluded that the quality indicator remains critical issue for implementing cost effective and efficient systems. Several steps are required to prevent misalignment and blockage of lateral drains such as good training of machine operators and field supervisors on the setting and use of laser equipment and regular calibration of laser control equipment. (DFRA, 2014) recommended to identify who will be responsible for maintenance and its funding either the farmers or the government. (Ritzema, 2009) mentioned that the introduction of the modified drainage system in Egypt in rice areas not only reduced operational costs, but also reduced maintenance needs as farmers no longer illegally blocked drains to reduce irrigation water losses. Increased farmer's participation led to more ownership and less misuse or illegal drain blocking.

12) PLANNING AND MANAGEMENT OF DRAINAGE SYSTEMS

Drainage planning of heavy clay soils has to be treated as an integrated part of water management. Using an integrated approach in land drainage plays an essential role in improving irrigation and drainage practices in these areas. (Nijland et al., 2005) recommended that administrative preparation process (drainage planning authority) should include specifications of drainage criteria, boundaries of the areas to be drained, type of system to be installed, outlet and pumping requirements, layout of the system, drainage materials to be used, installation equipment, implementation mode and budget. (Gehan, 2007) used a user-friendly knowledge based expert system computer program for Heavy Clay Management Expert System (HCMEXS) as an artificial intelligence management to help users to make appropriate decisions for improving heavy clay management. She utilized HCMEXS in an experimental field of 60 feddans area with saline sodic heavy clay soils in Tina Plain area of North Sinai northern Egypt. The recommended strategy of the expert system succeeded to decrease the soil salinity to about 50% within 6 months of leaching.

13) FUTURE PERSPICTIVES AND CHALLENGES

(De Wrachien, 2003) proposed a new planning principle, design criteria, operating rules, contingency plans and evaluation procedures to respond with climate change. (Bradley et al., 2005) reported that the effect of global climate change on functioning soil can be given by increasing summer temperature, increasing winter temperature, higher rainfall and sea level rise and increased coastal flood risk. (DEFRA, 2014) mentioned that warmer soil temperatures everywhere will accelerate soil processes, leading to more rapid decomposition of organic matter, increased microbiological activity, quicker release of nutrients, increased rates of nitrification and generally increased chemical weathering of minerals. However, soil temperatures will also be affected by the type of vegetation occurring at its surface, which may change itself because of climate change, or adaptation management. Increasing of drying soil will lead to increasing the difficulties of its management. The higher the seasonal fluctuations in soil moisture, the higher the risk of drastic changes to soil chemistry occurring, e.g. higher leaching of nutrients/pollutants, soil acidification, gradually lower soil cation exchange capacity and thus lower soil buffering capacity. Flooding and sea level rise are likely to lead to a loss of arable land in the coastal areas of Nile Delta. Drainage systems must be re-designed for more frequent extreme events where these are predicted to occur. Inattention could lead to greater frequency of washout events with consequent increase in sediment movement to surface drains. (Qadir et al., 2015) believes that the time has come to harness the potential of saline water and salt-affected land resources as potential business opportunities while adding value to the business dimension through resilience against climate change. (Prasad et al., 2017) stated that Sustainable growth of agriculture totally depends on the new and innovative techniques like nanotechnology. (Patra et al., 2016) mentioned that nanotechnology as an emerging science may play a greater role for managing these salt-affected marginal lands. Though nanotechnology, in respect of both research and development, is yet at a nascent stage, it can be effectively directed toward understanding and creating improved materials, devices, and systems and in exploiting the nano-properties for managing these lands. (Liu and Lal, 2012) proposed a practical strategy that applying nanotechnology in agricultural sector to increase the agricultural production, solve environmental problems. The specific nanotechnology to make a feasible use in soil reclamation and increase soil pH and fertility, improve soil physical structures, reduce mobility, availability, and toxicity of heavy metals and other environmental contaminants and those able to stabilize the soil components and abate soil erosion.

14) CONCLUSION

This paper gives an overview of the history, the present state and the outlook for the future of agricultural drainage practice and management of heavy clay soil in Egypt. The recent shift towards integrated water resources management in such soils has to consider planning, designing and implementing materials and installing technology for the new drainage projects in these soils. It is important to consider the impacts of climatic changes and new technologies on drainage water quantity and quality.

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