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Stressful Environments and Sustainable Soil Management: A Case Study of Kafr El-Sheikh, Egypt

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STRESSED environments have long been a question of great interest in a wide range of fields. So, many considerable literatures have grown up around this theme. In Egypt, there are several common problems related to the stressed environments. These stresses include decline of soil fertility, soil salinity and alkalinity, soil water logging, salt-affected soils, soil pollution, climate change, over-population growth, urban sprawl, land degradation, deterioration of natural resources, etc. More generally, national income will decline and will in turn result in the spread of social and political problems. Kafr El-Sheikh governorate can be considered one of the most important areas in Egypt, which calls "the governorate of the hope and the future" due to its location and wealths. Whereas, this governorate suffers from the most common stresses in Egypt including pollution, salinity, alkalinity and waterlogging. Great problems have been recorded in Kafr El-Sheikh related to stressed environments and suggested solutions also have been addressed. Therefore, a sustainable management should be adapted for overcoming these stressed environments in Kafr El-Sheikh.

Keywords: Plant nutrition, Soil management, Nutrients, Climate change, Egypt, Kafr El-Sheikh.

Introduction

Kafr El-Sheikh Governorate is a distinguished district located at the North of Nile Delta of Egypt. It has total area 3,437 km^2 and the total population in January 2019 was 3,488,138 inhabitants (CAPMAS 2019). Kafr El-Sheikh also suffers from many environmental problems, which include abiotic stresses such as pollution, soil salinity and alkalinity, waterlogging, drought and land degradation as well as sea water rise. These previous stresses are the common stresses in Kafr El-Sheikh, which cause a serious loss in the productivity of cultivated crops. Therefore, several studies have been published recently about Kafr

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El-Sheikh and their common problems specially using GIS and remote sensing (e.g., Elbasiouny et al. 2017b; AbdelRahman et al. 2018; Bakr and Afifi 2019). It is reported that, the growth and yield of staple food crops globally may decrease up to 70% due to the abiotic stressors including soil salinity (excess soluble salts), drought (water deficit), waterlogging (excessive soil moisture in rhizosphere) and extreme heat (Haddad et al. 2017; Sharma et al. 2017).

The issue of stress has received considerable critical attention several years ago. This stress can play an important role in addressing the issue of the agricultural production. Recently, there has been renewed interest in stress and several researchers have published different books on this topic (e.g., Vats 2018; Zargar and Zargar 2018; Wani 2018; Hasanuzzaman et al. 2019). Several plant stresses have been identified including abiotic (e.g., drought, salinity, flooding and others) and biotic (i.e., damage from living organisms including pathogens and parasites) stresses. Abiotic stresses are one of the most widely used groups of stress and have been extensively used for handling the effects of stress on agriculture. These stresses have been emerged as major challenges for the production of livestock, fisheries, crops and other commodities; linking to soil (edaphic) and causing chemical, physical and biological stresses (Minhas et al. 2017). Abiotic stresses cause several damages in growth and metabolism of plants as well as serious morphological, physiological, biochemical, and molecular changes. Plants have the ability to tolerate these stresses using different defense mechanisms such as enzymatic and non-enzymatic antioxidants, up-regulation of osmolytes, and osmo-protectants (Bhagat et al. 2014). Several investigations have been published regarding the abiotic stress on plants including drought (e.g., Hasanuzzaman et al. 2018; Wakelin et al. 2018), salinity (e.g., Mishra et al. 2018; Duhan et al. 2018), flooding (e.g., Wang et al. 2017; Wang and Komatsu 2018) and others (e.g., Srinivasarao et al. 2017; Kumar and Verma 2018). On the other hand, the modern agriculture faces great challenges including combined abiotic stresses (e.g., fluctuation in temperature, water scarcity, chemical toxicity and oxidative stress), global climate change and the security of environment (Eekhout and de Vente 2019).

Thus, there is an urgent need to address the agricultural sustainability problems caused by the stress. It is well documented that, the main aim of sustainable agriculture represents in creating a balance among the environmental, economic and social aspects of agriculture promoting a resilient farming system for the long-term (Rose et al. 2019). Therefore, there is an increasing concern towards the stress management and environmental sustainability should be followed due to its several advantages (Kumar et al. 2016). The crop production mainly depends on different agro-climatic variables and soil type, as well as more attention should be paid to the plausible shifts in the soil–climate combinations when planning the adaptation of the projected climate changes (Mäkinen et al. 2017). Furthermore, awareness for the farming communities is needed to prompt sustainable agriculture through creating a balance between the environmental and social outcomes and the agricultural productivity (Eekhout and de Vente 2019). As well, the sustainable management program should include the soil ecosystem services (Pereira et al. 2018).

Therefore, the aim of this review is to update the available information concerning sustainable management of stressed environments under Kafr El-Sheikh, North Nile Delta conditions. The common stressed environments in Kafr El-Sheikh (i.e., soil fertility problems, stress from soil salinity, alkalinity, water logging, pollution and climate change) and the best management practices for this sustainable management will be also highlighted.

Kafr El-Sheikh: a distinguished area

The location of Kafr El-sheikh governorate is a distinguished position due to its location typically northern part of the Delta in Egypt. It is the end of this Delta on the Mediterranean Sea with a coastline about 100 km extending from 31° 00′ to 31° 36′ Latitude, and from 30° 22′ to 31° 19′ Longitude. The borders of this governorate represent in the Mediterranean Sea in the north, Rosetta Nile Branch and Beheira governorate in the west, Dakahlia governorate in the east, and Gharbia governorate in the south. The governorate is divided administratively into 10 districts, which are further subdivided into 212 Localities (Fig. 1). The governorate is the lowest area located in the northern the Nile Delta, where the elevation values range between 5.5 and -0.4 m (below the sea level) based on digital elevation model (DEM) (Fig. 2). It could be noticed that, the elevation increases southward, whereas the lower elevation can be observed mostly in the northern part. Concerning the slope of the governorate, it is around 1-5% ranging from very gently to gently sloping. Kafr El-Sheikh is one of the main governorates in production of rice and fish production (Bakr and Afifi 2019).

Soils of Kafr El-Sheikh have a distinguished characterization and hence a special case of soil fertility. The classification, characterization and management of some agricultural soils in Kafr El-Sheikh have been investigated in detail by Shaheen et al. (2013). They confirmed that these soils have been developed from different sources and types of materials including lacustrine, fluvial, marine, sandy and fluvio-sandy and calcareous deposits. Furthermore, these soils belong to orders Entisols and Aridisols. These soils also can be classified according their different materials to (1) fluvial (Vertic Torrifluvents, Typic Torri fluvents, Typic Fluvaquents, and Typic Usti fluvents), (2) lacustrine (Typic Xerofluvents and Typic Fluvaquents), (3) marine (Typic Xeropsamments and Typic Psammiaquents), (4) sandy (Typic Quartzipsamments and Typic Torripsamments), and (5) calcareous (Typic Haplocalcids).

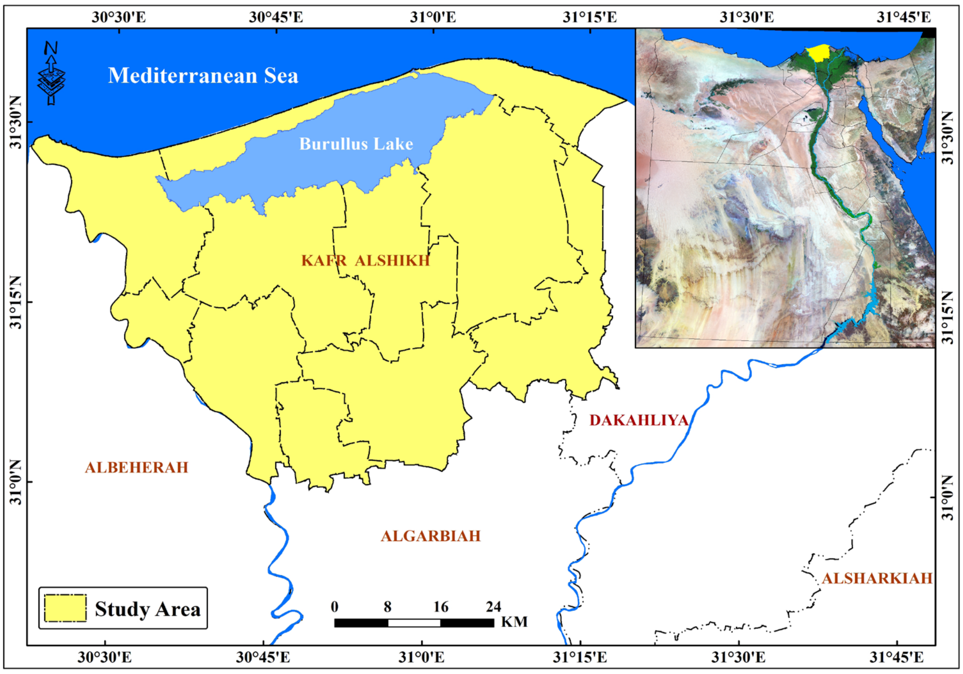

Fig. 1. Kafr El-Sheikh governorate on Egypt map with its administrative districts.

Source: Abo-El-Magd (2016), with kind permission

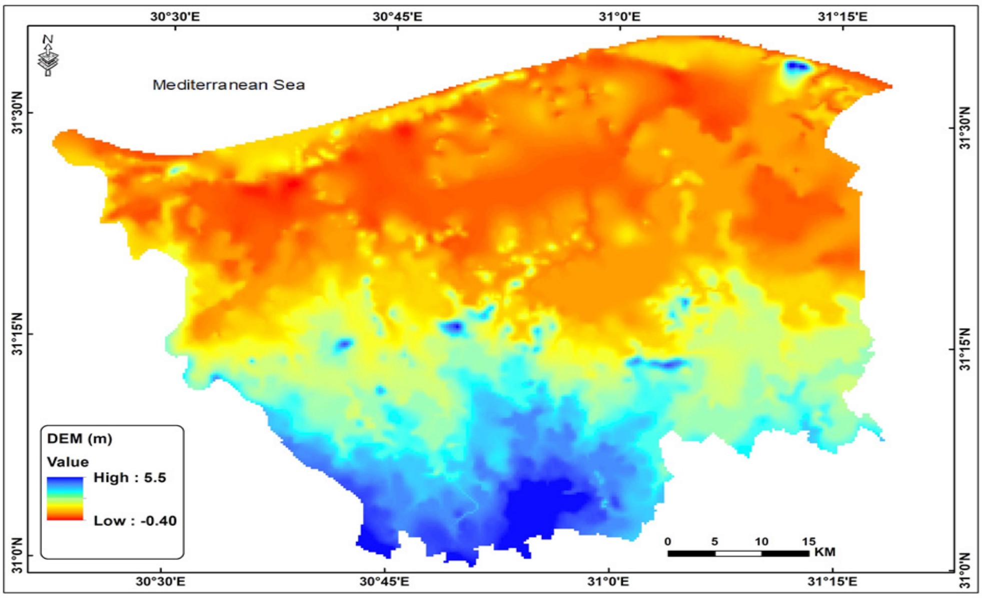

Fig. 2. Digital Elevation Model (DEM) or the elevation points for Kafr El-Sheikh governorate with high values range between 5.5 and -0.4 m (from Abo-El-Magd 2016, with kind permission).

Burullus Lake is a UNESCO protected area and a one of the most important geographical features in Kafr El-Sheikh, which is located at the coastal area of the governorate. A huge amount of water of the agricultural drainage from the surrounding rural areas is received by the lake. This lake is considered a low shallow depth (less than 1.5 m) and its area about 453 km² with brackish water as well as designated as world heritage site in 1988 (Elbehiry et al., 2018; Bakr and Afifi 2019).

The main cultivated crops include rice, sugar beet, clover, maize and the agricultural production suffers from water crisis (i.e. limited water resources because of, Egypt has fixed water share of Nile River and the recent development plans of Nile water-based in Ethiopia and Sudan, in addition to increased decline of water quality) as well as the high pollution rate. The threat from sea level rise is of real and serious problem facing the coastal areas with highvulnerable to erosion, flooding and damage of many urban centers and their infrastructure (Hassaan 2013; Fleifle and Allam, 2017; Negm et al., 2017).

Common stressed environments in Kafr El-Sheikh

Soil fertility and land degradation problems related to it

It is well documented that, the world population is expanding. Due to the limitation of global resources (arable lands, energy and water) and declination of global crop production, food security has been become a major challenge in the century. Thus, there is a need for 70% more food by 2050. In developing countries, the availability of land per person is expected to halve by 2050 due to high population growth. Therefore, the world is facing serious environmental problems including climate changes, energy and materials, air pollution, food and water security and biodiversity. Thus, the very difficult equation will be remained regarding the global facilities or resources and the global needs (food, energy and water demands). Furthermore, many global missions are required to achieve the global food security including (1) improving the application of fertilizers, (2) sustaining the nutrient management, (3) improving of soil fertility and (4) increasing food production (Six 2011).

Recently, researchers have shown an increased interest in handling the problems of soil fertility all over the world (e.g., Kome et al. 2018; Jin et al. 2019). In Egypt, several problems also have been recorded regarding the problem of soil fertility including (1) low levels of available micronutrients in Egyptian soils (e.g., coastal sandy, alkaline and sodic soils), (2) poor soil fertility (e.g., soils of deserts and coastal sandy lands), (3) improper nutrient management (in several areas), (4) low soil organic matter, (5) stress conditions (e.g., salinity, drought, waterlogging, pollution, etc.), (6) the lack of plant genotypes having high tolerance to environmental stresses, and (7) climate changes (El-Ramady et al. 2019). Moreover, researches of plant nutrition can provide us with invaluable information to overcome previous problems and then could sustain food security and well-being of humans without harming the environment. Therefore, there are many challenges face Egypt especially under climate changes including increase the stress on currently stressed resources. Therefore, a certain strategy should be adapted for each kind of stresses soils. The common problem concerning the Egyptian soil fertility represents in decline the soil fertility after building the High Dam and decrease of potassium content in the Egyptian soils (Khalifa and Moussa 2017).

Concerning some distinguished figures of this area, nearly all soils are alkaline in reaction (more than 8), the salinity may be more than 16 dS m^{-1} near to Burullus lake, high clay content around 55 % close to Kafr El-Sheikh city and high sand content close to the coastal soils, cation-exchange capacity (3.0–79.1 $cmol_c$ kg^{-1}) and soil organic matter content (2.9–26.8 g kg^{-1}; Fig. 3).

It is reported that, excessive soil salts (soil salinity) and moisture in rhizosphere (waterlogging) together may damage the production of crops on at least one-fourth of the irrigated land worldwide causing losses in crop yield ranging from 15 to 80% (Sharma et al. 2017). Under saline and submergence conditions, certain plant species could be found in such these stressed and complex environments. Therefore, further investigations are needed in order to understand abiotic stresses and the intrinsic relationship between soil, plant and water as well as the distribution and translocation of nutrients in the soil/plant system (Ferronato et al. 2018) as the case of such problems in Kafr El-Sheikh for soil fertility such as salt-affected soils, waterlogged, coastal sandy, alkaline and recently contaminated soils.

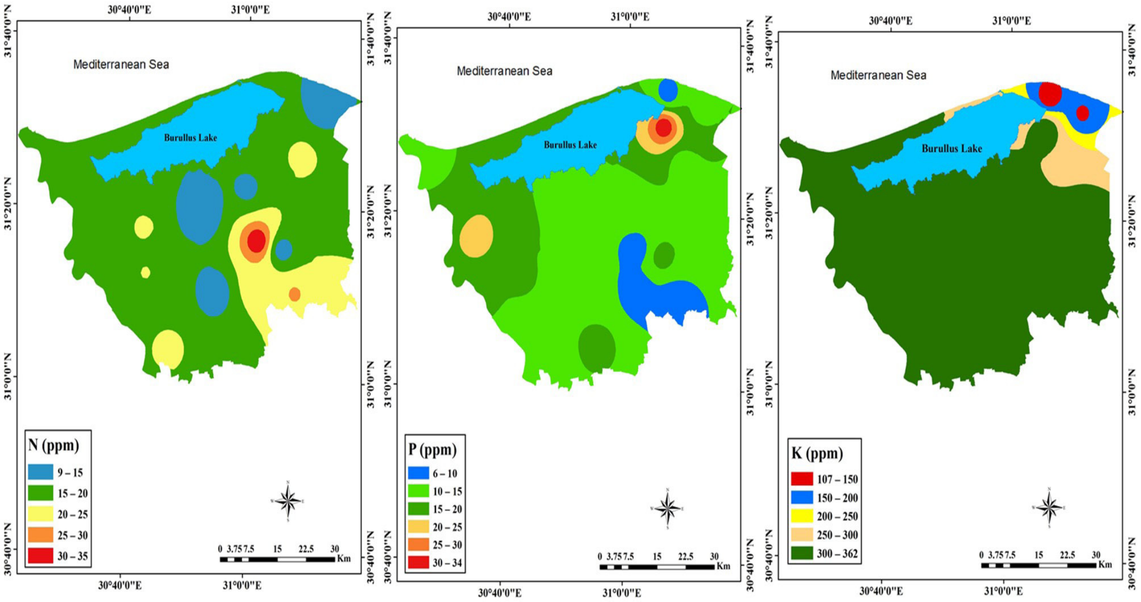

Fig. 3. Distribution of the available content of nitrogen (N), phosphorus (P), and potassium (K) (mg kg^{-1}) in soils of Kafr El-Sheikh from Abo-El-Magd (2016), with kind permission.

Coastal sandy soils

As mentioned-above, there is very long coastal line along of Mediterranean Sea extending more than 1000 km from Rafah to the south of Sallum. Kafr El-Sheikh is bounded from the north by Mediterranean Sea coast that located between the two branches of the Nile River; Damietta and Rosetta. This coastal shore in Kafr El-Sheikh is characterized by very low soil fertility, shallow water-table, saline and waterlogged soils making agricultural production problematic. Generally, coastal lands are salt-affected soils due to particular geographical and hydrologic conditions. Indeed, the salinity of these coastal areas represents the main factor for decline crop yields. As well, the northern coastal zone of Kafr El-Sheikh is generally low land and is consequently vulnerable to direct and indirect impacts of sea level rise or inundation due to projected climate changes (Elbasiouny et al. 2017a). So, the coastal lands in Kafr El-Sheikh are expected to suffer from extreme soil salinization and waterlogging as well as seawater intrusion. Due to limited soil and water resources, coastal lands should conserve and manage them into agricultural uses. Therefore, the conversion of these coastal lands adjacent to Nile Delta into agricultural uses is an important issue due to limited resources of soil and water (Elbasiouny et al. 2017b). Some coastal lands already cultivated several years ago by vegetables (e.g., tomatoes, watermelon, etc.) and fruits (e.g., guava, grapes, date palm, etc.) in Baltim city as well as by fisheries. Due to the potential of coastal sandy soils, many studies have been published focusing on problems and challenges like the vulnerability of these coastal areas to inundation (e.g., Elbasiouny et al. 2017a; Koraim and Negm 2017; Sharaky et al. 2017).

Salt-affected soils

Under arid and semiarid conditions, salinity stress is considered the most important environmental stress, which causes limitation for the growth of plants and crop production in many parts of the world. The salinization process and its effects could be observed in numerous vital soil functions (i.e., ecological and non-ecological ones). It is reported that, about more than 6 % of the worlds lands are salt-affected soils (approximately one billion hectare of 13.2 billion hectare). These soils globally have resulted from either human-induced causes or natural causes representing 20 % (45 million ha) of irrigated lands and 2 % (32 million ha) of dryland farmed areas. Due to the submergence of soils and seawater intrusion as well as the long-term accumulation of salts in the soil profile, natural soil salinization could be also happened (Arora et al. 2017, Zheng et al. 2018). It is reported that, the stress of salinity represents the main constraint for crop productivity at least one-fifth of the global irrigated lands due excess sodium on the soil exchange complex and/or presence of soluble salts in these soils This constraint includes alteration of many physiological and biochemical processes in plants and thereby causes a metabolic imbalance in plants (e.g., changes in protein hydration). The negative effect of salt stress also includes excess ions such as Na^+ and/or Cl^- in case of saline soils, whereas Na_2CO_3 is the common compound in sodic soils. Problems in soil physical conditions in particular soil structure, the availability of water and nutrient and deficiency of micronutrients these soils are also among several constraints have been recorded for salt-affected soils. Thus, the salinization of soils also causes serious disruption in the natural biochemical, biological, erosional and hydrological Earth cycles as well as human health and sociocultural issues (Arora 2017; Sharma et al. 2017; Zheng et al. 2018). Therefore, the main tolerant crops to salinity, which could be cultivated in Kafr El-Sheikh includes rice, sugar beet, date palm, etc.. Due to the high loss rate of lands and their productivity in dry lands, salt-affected soils are the most common and serious environmental hazard problems (Arnous and Green 2015). Soil salinity distribution in Kafr-Elsheikh is presented in Fig. (4).

These salt-affected soils include three categories saline, saline-sodic and sodic soils and represent about 37% of the total cultivated soils in the Nile Delta lands. The south lands in the Nile Delta are threatened by sodicity according to the low-salinity soils and highly carbonated irrigation water, while the north delta (Kafr El-Sheikh area) contains the highest area of saline and saline-sodic soils reaching 46% (Mohamed 2017). Salt-affected soils are characterized as the soils which have soil salinity (expressed by (electrical conductivity (EC), exchangeable sodium percent (ESP), and adsorption sodium ratio (SAR) with threshold values of 4 dS m^{-1}, 15% and 13 respectively as in (Table 1). It is stated also that these soils have adversely effects on the growth of most crop plants due to their low content of carbon and nitrogen comparing with non-saline soils as well as the decline in net primary production and vegetation biomass, which leads to an increase of CO_2 emission into the atmosphere (Elbasiouny et al. 2014, 2017b) Furthermore, in salt-affected soil, crop yields are decreased through toxic effects of specific salts and high osmotic pressure due to reducing water availability, disturbed metabolism, especially of N, due to the high ion concentrations of certain minerals, and some indirect effect of some of the ions, especially Na. on soil structure, as well due to high salt contents in the soil solution (Day and Ludeke, 1993; Elbasiouny, 2017a). In recent years, there has been an increasing interest in salt-affected soils in Kafr El-Sheikh such as (e.g., Amer 2016; Shalaby et al. 2017) and other (e.g., Elbasiouny et al. 2017a; Khalifa and Moussa 2017; Mohamed 2017; Abdel-Fattah 2019).

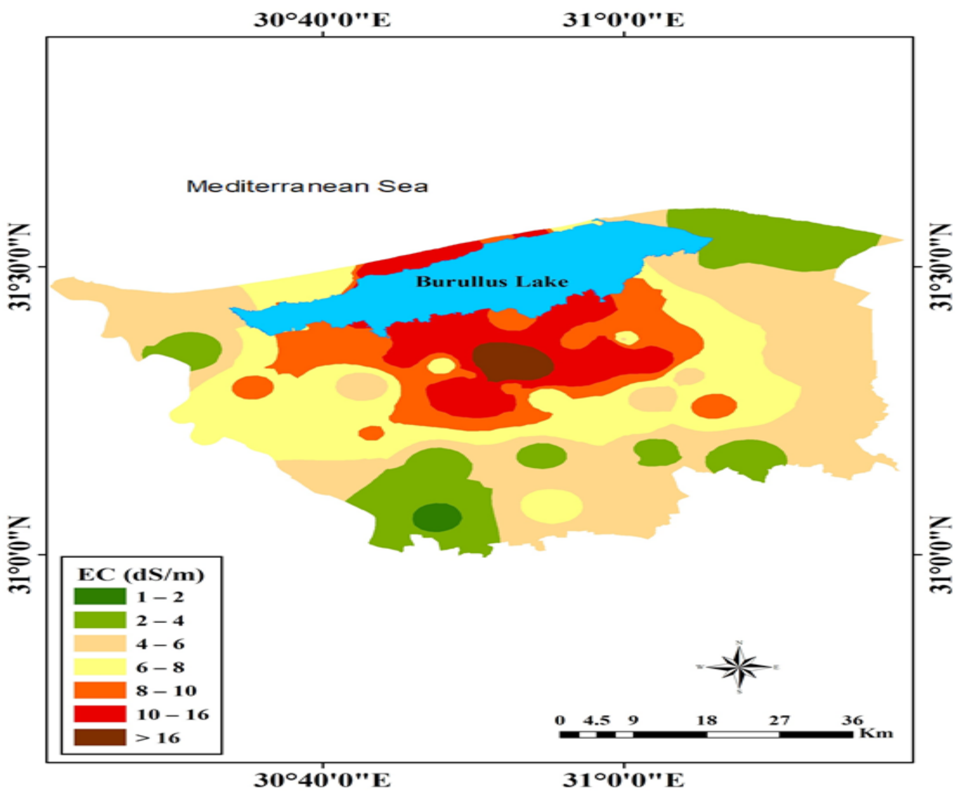

Fig. 4. Distribution of soil salinity (EC; dS m⁻¹) and soil reaction (pH) within the area of Kafr El-Sheikh (from Abo-El-Magd (2016), with kind permission).

TABLE 1. Characterization of salt-affected soils and their categories as well as effects on soil structure (adapted from Elbasiouny et al. 2017a; Arora et al. 2017).

Category	Soil EC (dS m^{-1})	Soil pH	Soil ESP (%)	Soil SAR (%)	Structure
None saline – none sodic	< 4	< 8.5	< 15	< 13	Good
Saline	> 4	< 8.5	< 15	< 13	Good
Sodic	< 4	> 8.5	> 15	> 13	Poor
Saline-sodic	> 4	> 8.5	> 15	> 13	Fair to good

EC: soil salinity; ESP: exchangeable sodium percent; SAR: adsorption sodium ratio.

Therefore, salt-affected soils should handle using some management strategies such as (1) leaching (to remove excess salts, prevent detrimental salt accumulation in the soil profile and maintain a favorable salt balance by supplying enough water), (2) the proper drainage to reclaim a saline, sodic or saline-sodic soil, (3) suitable irrigation method and enough applied water, (4) fertilizer management considering the nutrient source (i.e., mineral, organic, biological and nano-fertilizers), rate, timing and placement, and (5) application of soil amendments or acidifying amendments like gypsum ($CaSO_4$, $2H_2O$) or sulfuric acid, elemental sulfur (Mohamed 2017) or nanomaterials (El-Ramady et al. 2017a, b).

Soil Alkalinity Stress

In light of recent events in abiotic stress, it is becoming extremely difficult to ignore the existence of soil alkalinity stress (Liu et al., 2018). Soil alkalinity is also a condition that caused by the accumulation of soil soluble salts. The soil alkalinity degree is expressed by pH values, where its scale is divided into 14 pH units. Soil with a pH of 7 is neutral, soil below 7 is acid and soil above 7 is alkaline. In most soils, the pH value falls between 4 to 8. Slightly and neutral soils are suitable for most crop plants to grow and produce best. Alkali conditions are mostly caused by a high concentration of sodium carbonate. The alkaline conditions caused more spectacular injuries than those caused by salinity such as: the extreme effect of Na ion in destroying soil structure, toxicity of the CO_3^{-2} ion, reduced Ca uptake, and the mordant effect of high alkalinity. Plants tolerance to pH is varying. For example, sweet clover (*Melito us officinalis Lam*.) is stated to be relatively high tolerant to pH values, whereas tobacco (*Nicotiana tobacum L*.) is not tolerant. To reclaim alkali soils, adding soil amendments, such as gypsum for increasing the solubility of Ca and leaching of the Na ions from the soil, is recommended (Day and Ludeke, 1993).

The alkaline soils are often high in boron (B) (Day and Ludeke, 1993). Soil pH effects negatively on B availability. The B toxicity is a significant disorder, particularly on the soils of arid and semi-arid environments (Elbehiry et al., 2017). The Sugar beets (Beta vulgaris L.) are amongst the most crops tolerant to B, while field beans (Phaseolus vulgaris L.) are easily poisoned by B (Day and Ludeke, 1993).

Therefore, generally the alkalinity and salinity of soil represents in three parameters including soil salinity (EC) and acidity (pH), exchangeable sodium percent (ESP) adsorption sodium ratio (SAR) and structure (Table 1; Fig. 5). It is reported that, the stressed environments (e.g., extreme temperatures, drought, salinity and alkalinity) are predicted to increase due to the changing climate and intensive land-use change (Liu et al. 2018). According to previous parameters, salt-affected soils could be classified into following categories: none-saline-none-sodic, saline, sodic or alkaline and saline-sodic (Elbasiouny et al. 2017a; Arora et al. 2017). Due to the arid and semi-arid conditions in Egypt, soil saline and alkaline stresses and drought have been become the main environmental threat affecting their structure and function. Therefore, special strategy should be performed in dealing with the soil alkalinity problem. This strategy includes the removing of soluble ion of sodium (Na^+) from the colloid's surface of clays in these sodic-saline soils via reclamation process (Shi et al. 2019). Different soil amendments could be used in this reclamation process such as gypsum, phosphogypsum (Xue et al. 2019), and using genetic plant tolerance to soil salinity and alkalinity (Huang 2018).

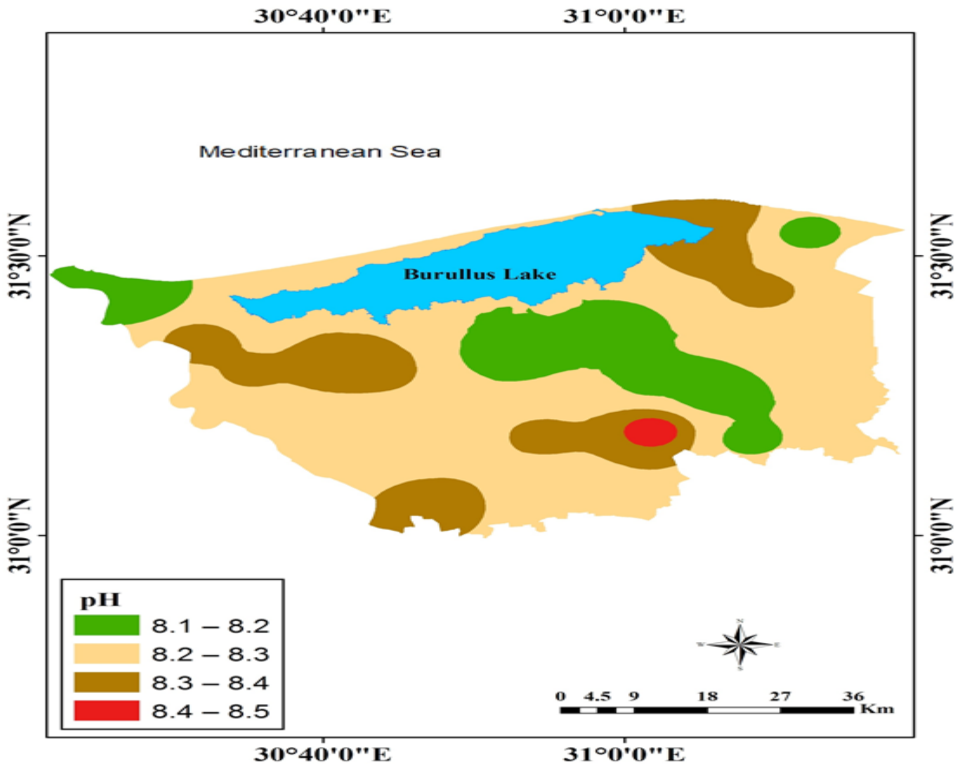

Fig. 5. Distribution of soil reaction (pH) within the area of Kafr El-Sheikh (from Abo-El-Magd (2016), with kind permission).

Water logging Stress

The water1ogging term could be defined as the excess water in soil that inhibits gas exchange between roots and the atmosphere. The waterlogging can be differentiated from flooding that is the complete or partial submergence of plant shoots. Under waterlogging conditions, there are direct blocking of the gases exchange between the atmosphere and the entire plant body resulting in decreased O_2 and CO_2 levels. Furthermore, the photosynthetic rate usually reduces over and above complete submergence due to limited light access underwater and low concentrations of CO_2 (Sharma et al. 2017).

Waterlogged soils are soils characterized with (1) high water-table (i.e., soil saturated pores in the root zone), (2) restriction of the normal circulation of the air, (3) decline in the level of oxygen and (4) increase in the level of carbon dioxide. The main problem for high water-table is the salinization of soil profile, which causes serious problems for plant nutrition. Soils could be classified according the depth of water-table into following categories: < 2 m, 2-3 m and > 3 m waterlogged, potentially waterlogged and safe soils (Arora 2017). In Egypt's Nile Delta, the water table has been rising much closer to the surface in many places in particular near to the Mediterranean coastal lands after building High Dam. Inefficient and/or absence drainage systems has been contributed to the development of salinity and waterlogged soils, which reduced land productivity by 15–30% (Khalifa and Moussa 2017).

In arid and semi-arid regions, the development of soil waterlogging and its salinization under irrigated farming conditions is a global phenomenon. In various countries, it is estimated that about 10-33 % of irrigated lands have adversely been affected due to soil waterlogging and salinization. It is found also that, there is an increasing in the rate soil waterlogging and salinization by 3000-4000 ha per annum since 1979-1980 (Arora 2017). Cultivated plants in waterlogged and saline soil conditions should be characterized with certain properties, which control the nutrition of these plants. These plants should be tolerant to salinization and waterlogging conditions. The common and suitable crop can grow in Kafr El-Sheikh is mainly rice and sugar beet. These previous crops have the ability to grow under saline and waterlogged conditions as well as high pH and exchangeable sodium of sodic soils. Therefore, continuous cultivation of rice crop in Kafr El-Sheikh has many benefits including (1) reduce the soil salinity due to flooding condition, (2) help in reclamation of saline-sodic soils, (3) improve the groundwater-table quality and (4) stop the intrusion of seawater during the rice growing season (Mohamed 2017).

Furthermore, studies over the past two decades have provided important information on soil waterlogging, which may happen under waterlogging for a few days or weeks (e.g., Wu et al. 2018; Ferronato et al. 2019). Exposure to soil waterlogging conditions has been shown to be related to adverse effects in the chemical and biochemical soil properties. These parameters include redox potential, pH, the chemistry of C, N, P and S; state of heavy metals, soil enzyme activities, the transport, mobilization and volatilization of C, N, and S gases (Haddad et al. 2017). Recently, it was revealed that anaerobic soil conditions will cause reduced nutrients availability to plants. In particular, the N availability might reduce as a result of the increase in denitrification and nitrate reduction or because of the decrease in the effective N concentration due to altered residues decomposition. Fully aerobic conditions cause the accumulation of NO3, while complete anaerobic conditions caused accumulation of NH4 (Matin and Jalali, 2017).

The waterlogging in low-lying areas close to the coastal zone has already existed in Kafr El-Sheikh governorate (Fig. 6). This is because Kafr El-Sheikh is located in the north of Egypt and is vulnerable to an expected rise in the sea level. A rise in global average sea levels is projected between 7 and 36 cm by the 2050s, by between 9 and 69 cm by the 2080s and by 30–80 cm by the year 2100 due to global warming (Koraim and Negm 2017).

In addition, a movement of sand dunes in the coastal zone is expected to be more severe in the future. Therefore, a decline in the soil productivity in Kafr El-Sheikh area is also expected due to the intrusion of saltwater. Without serious solution for this problem, physical, social and economic sectors will be affected representing in the deterioration of land productivity, food security, job opportunities and the movement of population (Koraim and Negm 2017).

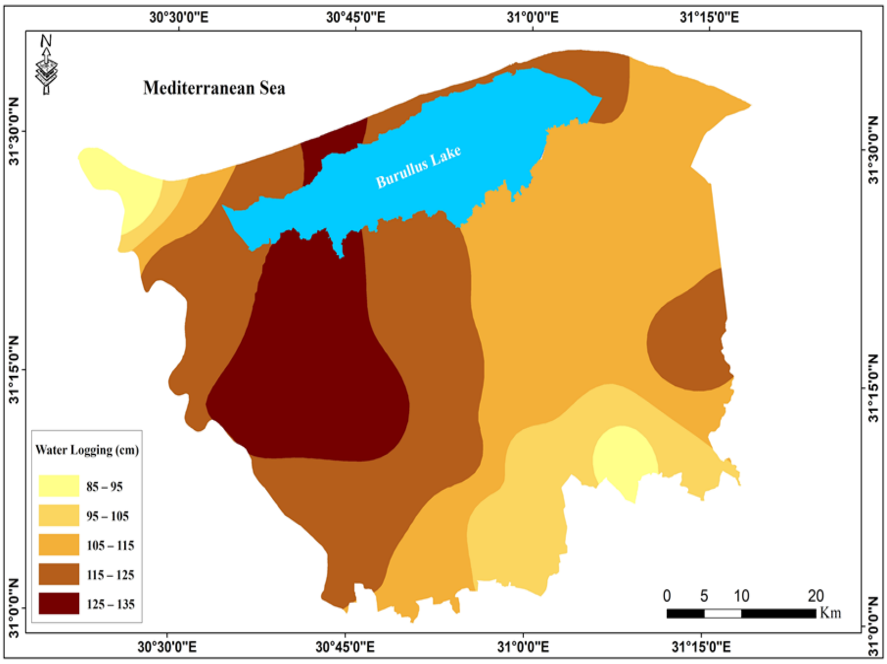

Fig. 6. Kafr El-Sheikh suffers from waterlogging, where the water table can be found near the soil surface to less than one meter (85 cm) causing a serious problem in this area and its cultivation (from Abo-El-Magd 2016, with kind permission)

Recently, a considerable literature has grown up around the theme of waterlogged soils in Egypt (including Kafr El-Sheikh) using new techniques like GIS and remote sensing (e.g., Omran 2017; Mohamed 2017; AbdelRahman et al. 2019). Therefore, it is shown that soil fertility of Kafr El-Sheikh suffers from several problems such as (a) low quality of irrigation water, (b) reuse of industrial wastage, sewage wastewater and saline drainage water, (c) waterlogging and shallow water table, (d) seawater intrusion and (e) overuse of chemical fertilizers and pesticides (Mohamed 2017). Under waterlogging conditions, the yield production of most crops (except paddy rice) is expected to reduce to about 27 % in case of wheat comparing with drained soil conditions. It is reported that, waterlogging condition has been increased the nutrient content (Fe, Al, Na and Na/K ratio) in wheat leaves comparing with drained conditions, whereas the content of K, P and S nutrients decreased in leaf (Singh and Sette 2017).

Therefore, waterlogging conditions may cause severe loss in yield of some cultivated crops except paddy rice even under short term flooding (i.e., for 2–6 days) in sodic soils due to critical toxicity or deficiency of nutrients in soils. Furthermore, the environment of waterlogging is very complex and diverse, and these waterlogging conditions may induce changes in element contents under salt-affected soils like Kafr El-Sheikh areas. Thus, further investigations are needed for more focus on the effects of waterlogging conditions on the productivity of different cultivated crops in particular under salt-affected soils in Kafr El-Sheikh.

Soil Pollution Stress

Generally, there are many global environmental problems including global warming, pollution, acid rain, ozone depletion, over-population, depletion of natural resources, salinization, waste disposal, deforestation and loss of global biodiversity (Singh and Singh 2017; Singh 2018, 2019). Over the last 50 years, environmental pollution has received large attention (Elbehiry et al., 2019). Soil pollution is a growing public health concern worldwide. This pollution is mainly associated with many anthropogenic activities (e.g., urbanization, development in agriculture and industry). Therefore, there is an urgent need to address the safety problems caused by this pollution (Elbana et al. 2019). Furthermore, soil pollution is considered a one of the most significant current discussions in legal and moral philosophy. It is considered also as a one of dangerous global problems. Several hazards could be listed resulting from soil pollution including (1) loss or decline in soil productivity, (2) reduce in soil biodiversity, (3) killing some plants, fishes and other aquatic organisms in rivers and lakes, (4) loss in crop diversity and (5) damaging soil stability that will be harmful for human health. It is estimated that, pollution of water and soil could reduce the yield of crops by about 15–25% over total cropped area and the years (Saha et al. 2017; Singh and Singh 2017). A considerable amount of literature has been published on the soil pollution as a serious problem around the world (e.g., He et al. 2019; Huang et al. 2019). This pollution has penetrated several sides of the human life including the domestic, industrialized and mining regions. The agricultural soils were and still one of the most important environmental issues, which has been studied by many researchers (e.g., Shi et al. 2018; Yang et al. 2018; Cai et al. 2019). It could be noticed that soil pollution is a major public health problem causing a stress on the surrounding environments for plants and humans (Šiukšta et al. 2019).

Based on its location, Kafr El-Sheikh receives several pollutants from different sources such as the wastes of different factories, overuse of pesticides and fertilizers. As well as the anthropogenic activities affected on soils, the Nile and its irrigation canals and drains in Kafr El-Sheikh (Omran and Negm 2019). Several problems regarding human health have been recorded in these areas particularly the diseases of liver and kidney. Therefore, several studies have been recently published regarding the pollution of the Nile River through many themes including the assessment of pollution (e.g., Elhadd and Al-Zyoud 2017; Sharaky et al. 2017, Elbehiry et al., 2019), monitoring of different pollutants (e.g., Dahshan et al. 2016; Redwan and Elhaddad 2016), effects of Nile water pollution on crop production in Egypt (e.g., Abou-Ali and El-Ayouti 2014), impact of water quality on ecosystems of the Nile River (e.g., El-Sheekh 2017) and other. It is found that, the River Nile water contains various pesticides including organo-chlorine pesticides (e.g., endrin, dieldrin, etc.) and organo-phosphorus pesticides (e.g., triazophos, quinalphos, fenitrothion, etc.) posing a hazardous risk to both environmental compartments and humans (Dahshan et al. 2016).

Climate Change and Stress

The atmospheric CO_2 concentration has been raised due to the continuous burning of fossil fuels and deforestation from 280 to 407 µmol CO_2 mol^{-1} air (ppm by volume) during the mid-18th century to mid-2017, respectively. This concentration of CO_2 is projected to reach 800 ppmV before the end of this century (Solomon et al. 2007; Karl et al. 2009). The atmospheric CO_2, as a greenhouse gas, is largely responsible for warmer temperatures and more severe precipitation events. Elevated CO_2 for C4 plants may increase the growth due to the indirect promoting the water-use efficiency through reduced stomatal conductance and transpiration rather than a direct increase in photosynthesis process (Allen et al. 2011; Prior et al. 2011). Therefore, the relationship between plant abiotic stress and climate changes (i.e., extreme weather events) and its effect on crop yields is a complex due to the increasing in frequency and intensity (Hatfield et al. 2011; Vaughan et al. 2018). Furthermore, warmer temperatures combined with drought or extreme precipitation is also projected to increase incidence of fungal infection further reducing yield quantity and quality (Sharma 2014). Consequently, future production of crops will be challenged by intensified abiotic stresses as well as biotic stresses (Jangra et al. 2017; Vaughan et al. 2018; Laloum et al. 2018).

Many reasons have been contributed to change in climate from the past century including the deforestation, the burning of fossil fuels, different industrial practices and agriculture (Ng et al. 2016). Globally, it is reported that, there is a significant increase in atmospheric surface temperature and CO_2 in air due to the changing in climate. These changes have been already caused considerable changes in geographical intensity and amount of precipitation as well as strong alterations in seasonal patterns may be expected in the future (IPCC 2013; Simon et al. 2017). For example, it is expected a decrease of summer precipitation from 9 to 41% until 2070 in Central Europe (Frei 2004), as well as an increase in intensity and frequency of extreme events like flooding and local heavy rain or exceptionally hot and dry summers (Wagner et al. 2013; Simon et al. 2017). It is found that, an increase by 0.8 °C (with approximately 70 % of this increase since 1980) in average temperature of the Earth and is expected to increase another 1.1–6.4 °C over the coming century, depending on the model used (Ng et al. 2016). The global atmospheric CO_2 content has been increased from 380, 401.85, 404.48, 406.07, 407.69 and 409.23 ppm in 2005, 2014, 2015, 2016, 2017 and 2018, respectively, as reported by the web site of https://www.co2.earth/annual-co2 in December 2018.

Because of a huge variation between different plants and even between different plant species or individuals, plant nutrition is a difficult issue to understand completely. The nutrition of plants is totally controlled by environmental and climatic conditions including temperature, humidity, precipitation, CO_2 in air and soil, etc. Furthermore, plant nutrition is the backbone of the agricultural production. This means that there is no agricultural production without proper and enough nutrition of cultivated plants or crops (e.g., El-Ramady et al. 2014a, b; El-Ramady et al. 2015; Reddy 2015). Recently, many investigations handled the effects of changing in climate on plant nutrition (e.g., Asad 2017; Ali et al. 2017; Aslam et al. 2017; Simon et al. 2017).

In Egypt, climate changes may be represented in many features such as the increase of mean air temperature, changing in patterns of rains, increasing the variability of both temperature and precipitation patterns, changing in the availability of water, the frequency and intensity of extreme events, sea-level rise (as expected in Kafr El-Sheikh) and salinization and perturbations in agroecosystems. Such climate extremes already occurred several years ago and might provide a hint at the future situation. All previous changing in climate may have profound impacts on agriculture and thus the nutrition of plants. Plant nutrition or crop production has direct and indirect relationships related to local extreme events, the outbreaks of sudden pest and diseases. These relationships lead to a great unpredictability in production from year to year and season to season and require rapid and adaptable management responses (Reddy 2015). Table (2) presented the significant impacts of climate change on crop production (i.e. plant nutrition). Furthermore, the extent of these impacts will depend not only on the timing or periodicity and intensity of the changes but also on their combination, which are more uncertain and on local conditions. It is reported that, climate change is expected to cause substantial crop reductions in Egypt up to more than 20, 30 and 50 % for wheat and maize, sunflower and tomatoes, respectively (El-Ramady et al. 20017a).

TABLE 2. Some examples of projected climate change impacts on plant nutrition or crop production (adapted from Reddy 2015).

Climatic event	Potential impact
A certain change in temperature of air or warming is projected	Decreased yields under Egyptian environments is expected, increased outbreaks of new insect pests and pathogens and decreased crop production
Expected heavy precipitation with high frequencies	Damage to cultivated crops; soil erosion; inability to cultivate land owing to water logging of soils
Likely increasing in drought-affected areas	Land degradation and soil erosion; lower yields from crop damage and failure; loss of arable land
Likely increasing in extreme high sea levels	Salinization of irrigation water and freshwater systems; loss of arable land

Agricultural activities are totally sensitive to the change in climatic conditions. Hence, any agricultural decisions should depend on knowing the elements of climate change. Furthermore, the assessment of possible impact of climate changes on crop production and its risks is urgent to help decision-makers and stakeholders to identify and implement suitable measures of adaptation (El Afandi 2015). Subsequently, climate changes have become one of the most heavily investigated issues in science in the last few years. On the other hand, there are many challenges face Egypt nowadays including population growth, climate changes, economic development, pollution and limited water resources. Therefore, negative impacts on Egypt are expected under changing climate such as (1) increased temperatures, (2) decreased precipitation levels, (3) the risk of inundation of Nile Delta risk, (4) water scarcity, (5) insufficiency of agriculture and food, (6) pressures on human health and (7) the national economy (Khedr 2017).

There is no doubt that, the changing in climate is one of the most important environmental problems facing the universe. Like sea level rise, abiotic stress is an associated problem to climate changes. This problem has serious effects on several sectors including agriculture, water resources, human health, coastal zones, human settlements, energy and biodiversity. It is expected that the global mean surface temperature may increase by the year 2100 about 1–3.5 ºC causing a raise in sea level by about 15–95 cm (Koraim and Negm 2017). Based on collected meteorological data (1983-2016) from Kafr El-Sheikh station, it is reported that air temperature varied between 12.16 and 18.5 °C with average mean temperature of 14.9 °C during January. The respective minimum and maximum temperatures for August are 24.2 and 32.2 °C with average mean temperature of 27.7 °C (Table 4; El-Marsafawy et al. 2019). It is reported also that, changing climate has impacts on soil salinization inducing (i) sea level rise, (ii) temperature increase and (iii) irrigation water shortage. It could be noticed that, distinguished variations in the hydrological cycle will be happened due to the future warmer climate as well as the rising in sea levels and the increase in soil salinity. It is worth to mention that, the combination between sea level rise and the overexploitation of groundwater is expected to intensify the saltwater intrusion in coastal lands (Daliakopoulos et al. 2016). It could be concluded the projected impacts of climate change in Kafr El-Sheikh as listed in Table (5).

There is a shortage in the studies concerning the role of soil carbon and nitrogen pools on climate change in Egypt although its importance. Several soils of Kafr El-Sheikh are characterized as salt-affected soils with low content or deficient in carbon and nitrogen. This low content in N and C in salt-affected soils has been resulted from several adverse edaphic factors, which decline plant productivity including high concentration of Na^{+}, Mg^{+2}, Cl^{-}, and SO_4^{-2} ions. Beside these excessive salts, toxicity and elemental imbalance could be happened causing adverse soil physical conditions in the rhizosphere as well as waterlogging also could inhibit plant growth under Kafr El-Sheikh conditions. Furthermore, the major way to loss nitrogen in salt-affected soils is back to high soil pH value in NH_3 volatilization in these soils (Elbasiouny et al. 2014).

TABLE 4. Averages of thirty-four years (1983 – 2016) temperature (°C), relative humidity (%), and wind speed (m/s) during January and August in Kafr El-Sheikh Governorate (adapted from El-Marsafawy et al. 2019).

Meteorological Station	January					August				
	Temperature (°C)			Relative humidity (%)	Wind Speed (m/s)	Temperature (°C)			Relative humidity (%)	Wind Speed (m/s)
	Mean	Min.	Max.			Mean	Min.	Max.		
Baltim	14.8	11.7	18.7	65	4.6	28.1	24.1	33.1	60	4.2
Kafr El-Sheikh	14.9	12.1	18.5	66	4.8	27.7	24.2	32.2	63	4.4

Source: Data collected and analyzed from the following web site: http://power.larc.nasa.gov

TABLE 5. The projected impacts of climate changes: implications and threats.

Projected driving change	Resulting threat
Groundwater recharge may be reduced	Increase soil salinization in marginal areas
In coastal areas, heavy precipitation risk or flooding or flash flood hazards	Waterlogging risk will threaten cultivated crops
Increased atmospheric temperature and evapotranspiration in combination with reduced groundwater recharge	Intensification of soil salinization due to increased evapotranspiration under brackish water irrigation
Sea level rise, land subsidence and changes in water recharge	Intensify the salinization of shallow soils, groundwater and surface waters
Reduction in precipitation and river flow	Soil salinization due to sea water intrusion
Shifting in water the availability in soils as a result of change in precipitation and evapotranspiration	Change in the seasonal pattern of rainfall-induced leaching of the accumulated salt in soils due to irrigation the cultivated crops
Increase in evapotranspiration – and the frequency of extreme high rainfall events - the frequency of extreme drought conditions	Due to the upward movement of hyper-saline groundwater

Source: adapted from (Daliakopoulos et al. 2016).

Sustainable Management of Stressed Environments in Kafr El-Sheikh

In the following sub-sections, sustainable management of stressed environments will be highlighted including the sustainable management of soil fertility, and pollution as well as the mitigation of climate change.

Sustainable Management of Soil Fertility

There is a growing body of literature that recognizes the importance of soil fertility. The sustainable management can play an important role in addressing the issue of soil fertility. In recent years, there has been an increasing interest in the challenge's problems of soil fertility all over the world (e.g., El-Naggar et al. 2019; Hozzein et al. 2019). These problems may impact on the crop production in the coastal sandy soils in Egypt including waterlogged soils, polluted soils, salt-affected soils, and alkaline soils (pH more than 8, then several micronutrients will be not available). Therefore, a certain strategy should be adapted for each kind of these soils. Therefore, there is a crucial need for more understanding of the fundamental principles of soil fertility and plant nutrition, which can help us to develop and extend optimized field practices and to improve public policies to ensure sustainable food production (Doltra et al. 2019; Sánchez-Navarro et al. 2019). Concerning the sustainable management of salt-affected soils in Kafr El-Sheikh, some strategies may be used including the managing of the leaching of excess soluble salts and prevent the accumulation of these salts in soil profile, removal of soluble salts through the improved drainage, using the proper irrigation and fertilization methods (Mohamed 2017).

Regarding, the sustainable management of coastal sandy soils, many problems had led to the declines in the fertility of the coastal sandy soils. These problems include wind erosion, low soil fertility due to low soil organic matter, high soil salinity, high salinity of ground water, pollution etc. The sustainable management of these soils should depend on the anthropogenic practices or solutions. Recently many investigators have examined the effects of sustainable management on coastal sandy soils all over the world (e.g., Ali et al. 2018; Fuentes et al. 2018; Williams et al. 2018; Ramkumar et al. 2019) and Egypt (e.g., Elbasiouny et al. 2017b; Shaheen et al. 2019).

Sustainable Management of Stressed Areas for Pollution control

Management and remediation measurements of contaminated locations depend on the contamination level and its distribution. The existence of significant soil pollution due to anthropogenic activities has been stated in many studies. The remediation of contaminated sites has been promoted by government organizations, environmentalists, landowners and policy makers to restore the functions of natural ecosystem, to prevent these to contaminate other environment components, and to increase the life quality of human and animals dependent on the polluted area. Soil remediation is defined as a set of processes and techniques that reduce the mobile and subsequently, bioavailable fractions of contaminant in soils (Saha et al. 2017; Ashraf et al. 2019).

Conventional techniques for managing and remediation contaminated soils are cost and environmental non-friendly. However, remediation techniques of contaminates affected soils that performed by plants is cost-effective and environment friendly and depends on the bioavailability of contaminates. Biological remediation approaches of contaminated sites are environmentally sustainable ways to achieve this purpose. These approaches include bioremediation, phytoremediation and integration between them. Bioremediation depends always on converting contaminates to other forms microbially, while phytoremediation is an emerging depends on implementing green plants for cleaning up the contaminants from the environment (Ashraf et al. 2019). In this context, Misra and Misra (2019) reported that phytoremediation in the pressing circumstances, is a clean and green emerging alternative and promising technology that can support safe and sustainable ecosystems life.

Sustainable Management of Stressed Areas for Climate Change Mitigation

Sustainable development of agricultural systems is confronted by some environmental issues and challenges (such as the mentioned above issues)that have in mutual specific characteristics such as universal occurrence, complex and interrelated nature, and great difficulty to resolve. Rising pressure from environmental problems including climate change may claim greening of agricultural management practices, or climate smart agriculture (CSA). The CSA agriculture practices include integrated crop managements and farming systems, conservation agriculture, management of agricultural residues, agronomic adaptation, agro-forestry processes, water conservation and irrigation management. These agriculture approaches sustainably support adaptation and mitigation processes representing in increasing productivity, resilience, reduces greenhouse gases. This warrants a paradigm shifting not only in agricultural planning, but also in research and development, biotic and abiotic risk reduction, food systems innovations, hazard and climate management. (Venkatramanan and Shah 2019). Sharma et al. (2019) confirmed also that climate resilient management practices are so much essential for sustainable agricultural production especially at the weather uncertainty in some region (such as our study area). Elbasiouny and Elbehiry (2019) also, in the context of mitigating climate change in addition to improving soil quality and fertility, emphasized on adopting sustainable management practices that increase soil C and N sequestration are recommended. Among these practices, conservation tillage, reduced tillage, residues retention, in addition to utilizing animal or green manure.

Conclusion

Kafr El-Sheikh is a promising governorate located in the north of Egypt. This distinguished area has a lot of wealths and at the same time a lot of constraints. These problems include a harsher environment, which may suffer from a lot of stresses. These stresses include the soil fertility problems (in particular in the coastal sandy soils and the salt-affected lands), problems of soil salinization due to high water table or waterlogging, as well as the problems of pollution and risks of climate changes. Therefore, these stressful environments need much more efforts for the sustainable management using traditional and modern approaches. These approaches should be achieved at the local and national level and with real collaboration with all partners including stockholders, farmers, and governmental sides. Hence, there is an urgent need to sustain the agricultural production including vegetative and animal production. The environment pollution also is increasingly recognized as a serious, worldwide public health concern. It could remediate this pollution in soils and waters using the sustainable phytoremediation through the non-food crops, which have the ability to overcome this pollution and at the same time producing the bioenergy.

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