# Rice Production in Egypt: The Challenges of Climate Change and Water Deficiency

Heba Elbasiouny and Fathy Elbehiry

**Abstract** Climate change has become one of the major global environmental problems of the 21st century. Rice is the main cereal crop for over 50% of the world's population. Rice cultivation is known as an important emitter of greenhouse gases emission especially methane due to rice management practices and burning of rice straw after harvesting. However, many studies confirmed that rice soils accumulate carbon higher than other crops such as wheat and corn. The cultivated area of rice in Egypt is approximately 650,000 ha from the whole cultivated area in Egypt; approximately 3.3 million ha; i.e. around 20% of the cultivated area in Egypt. Egypt relies on the Nile for 97% of its water requirements. The expected scenario of water deficiency in Nasser lake due to the Grand Ethiopian Renaissance Dam construction, with pulling of deficiency from Dam Lake; is emphasizing on wasting approximately 1.7 million ha of Egypt's cultivated area. As well, the expected high scenario of a relative sea level rise in Egypt; especially Nile Delta increases the amount of land that lying under risk from inundation in the north Nile Delta by 300 km$^2$, which estimated by one-fifth of the total agricultural land in the northeast Nile Delta only. Also, all crops are projected to have a decrease in yields and an increase in irrigation needs. Thus; all these challenges will increase the stresses on rice production and decrease soil C storage in Egypt as a result of climate change and water shortage due to establishing GERD. Therefore, the changing in rice management practice; such as decreasing ploughing, creating another alternative to rice straw burning and balanced fertilizer application; will lead to mitigating of greenhouse gases emission from rice cultivation and improving soil organic matter (SOM) stocks, subsequently soil quality and productivity.

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## 1 Introduction

Rice (*Oryza sativa*) is one of the main field crops and a major staple food in most parts of the world. More than 160 million ha of arable land dedicated to its production, and more than 730 million tons produced in 2012. The top producers in the world are China, India, and Indonesia [1]. Flooding/Basin irrigation is the most common pattern for irrigating rice; it is always called paddies or paddy basins. Basin irrigation is useful if leaching is required to remove salts from the soil [2]. Rice crop is stunningly diverse and unique because of its ability to grow in wet ecosystems, while other crops cannot survive. Rice paddies are estimated by a large portion of the wetland ecosystem; mainly in Asian countries [3]. It is the most broadly grown under irrigation [2]. Paddy soils are featured by high organic material inputs with rather a low decomposition rate under anaerobic conditions, which favors organic matter accumulation [4]. Also, paddy rice is best grown on clayey soils which are almost impermeable to decline losses by percolation. Rice could also be cultivated on sandy soils, but losses by percolation are high without maintaining a shallow water table. Such conditions sometimes take place in valley bottoms. Loamy soils are preferred with basin irrigation to avoid waterlogging (permanent saturation of the soil) [2].

Climate change has been one of the main topics in environmental policy. It is highlighted as a major security issue. Climate change impacts include increased frequency of flash flood events, droughts, or periods of water deficiencies and rising temperatures. As well, sea level rise is also an important issue. Future observed trends and projections indicate a strong susceptibility to changes in hydrological regimes, a rising general deficiency of water resources and thus threats to water availability and management. The volume of water consumed in Egypt is about 68 $km^3$ of which 86% is dedicated to agriculture. Ninety-five percent of the water consumed in Egypt derives from the Nile River. In the context of the construction of the Grand Ethiopian Renaissance Dam under establishment on the upper Nile, geopolitical stability requires better knowledge of water threats over the region [5].

Mitigation atmospheric GHGs ($CO_2$, $CH_4$ and $N_2O$) which contributes considerably to global warming is generating a major challenge in recent day agriculture. Soil organic carbon (SOC) content is one of the most important indicators of soil fertility or quality. Soil carbon, as included globally in an important biogeochemical C cycle, is of great significance to climate change. Therefore, enhanced agricultural management practices have been studied to reduce the loss of SOC and crop residues, sequestering SOC, reducing atmospheric GHGs, especially there is need to reduce GHG emissions from agriculture and rice production while increasing or maintaining rice production levels which consider a major challenge [6, 7].

## 2 Rice Production in the World

Rice is one of the fundamental agricultural commodities and food sources, feeding approximately 50% of the world's population (more than 3.5 billion people) as a staple food, which directly nourishes people more than any other crop. It is covering about 160 Mha of the world's land surface [1–4, 7–11]. Moreover, rice is a key source of employment and income for the rural people most of whom live in developing countries. The crop occupies one-third of the world's total area cultivated by cereals [2]. Approximately 75% rice is produced worldwide in irrigated lowlands [10]. Staple foods are well known as reasonable, regularly available, energy-rich and essential for daily life. Mainly staple foods are resulted from cereals, such as rice, maize, wheat, and barley. Rice and maize either single and double-crop rice, spring, and summer maize) are the most staple food crops [4]. Rice is a healthy, nutritious, and versatile food. Its content of complicated carbohydrates is transformed to glycogen by digestive processes in the human body. Glycogen is stored in muscle tissues and released as a required energy for the activities. As the rice being the staple food of most Egyptians, its local consumption rate is 35–40 kg/capita/annum [12].

Over 90% of rice is produced and consumed in Asian, and the African countries, where mostly all rice is produced by smallholders on farms ranges from 0.5 to 3 ha. In many Asian counties, rice yield/ha has doubled up through 20 years of the Green Revolution. There are many reasons contributing in this yield such as the adoption of high yielding rice varieties and increasing the cropping intensity and farm inputs. Therefore, during the 1970s and 1980s, global rice production increased at a rate of 2.3–2.5% per year. Consequently, however, the growth rate declined to 1.5% during 1990s as well during the first decade of 21st century, primarily due to land degradation problems. The population in major rice consuming countries are increased at an annual rate of 1.5%, and thus, the present growth rate of rice production is not enough to feed them; therefore, a gradual annual increase of about two million tons in production is required to fulfill the rising demand [13]. Rice is cultivated in 16 countries in the Near East region; Afghanistan, Algeria, Azerbaijan, Egypt, Iran, Iraq, Kazakhstan, Kyrgyzstan, Mauritania, Morocco, Pakistan, Somalia, Sudan, Tajikistan, Turkey, and Turkmenistan. Approximately, 92% of this region rice yield is produced mainly in Pakistan, Egypt, and Iran [2].

It is stated that to cope with the world's rising rice consumption level, the world's rice production also expanded. Rice production has increased greatly since the 1960s. During the last decades of 20th century, rice has seen steady increases in demand. Its growing importance is evident in the strategic food security planning policies. This is applied in many countries, except in few countries in the Near East Region that have accomplished self-sufficiency in rice production and imported the large quantities of rice that overtake the demand to meet demand at a huge charge in hard currency [2]. It is reported that it is estimated that a 40% increase in rice production is needed to meet the surging demand from the hastily increasing population by the end of 2030. Numerous strategies of agricultural management are now being developed for improving rice productivity as well as soil C sequestration, such as water and fertilization management, cultivation methods, developing new rice cultivars, and utilizing of interesting materials such as biochar and rice straw [14].

## 3 Rice Production in Egypt

Only about 4% of Egypt's total area is agricultural land. This area includes one of the heaviest population densities worldwide. The remaining 96% of Egypt's land area is arid desert [15]. Egypt is the largest producer of rice in the Near East region, as well it has the most productive rice farms worldwide with an average yield of $9 \times 5$ ton $ha^{-1}$ based on 2012 data. As well, with a whole production of about 6 million-ton $year^{-1}$, Egypt is the highest rice producer in Africa [1]. Therefore, rice is one of the major field crops in Egypt. It engages about 0.65 million ha with about 6 million metric tons yearly of rough rice contributing about 20% to the per capita cereal consumption. Rice, in Egypt, is one of the potential export crops that can supply foreign exchange to the country. Moreover, it has an important socio-economic influence since many of the labor force is employed in the rice production sector. The inability to accomplish self-sufficiency in rice production in some countries is resulting from several major limitations; mainly water scarcity [2].

Rice is mainly grown in the Nile Delta [1, 12]. However, the country has several production zones and grades as one of the highest producers per area unit in the world [2]. Rice cultivation is intensified in the Delta mainly because of its soils that consisted of a thick clay layer. The formation of this layer was associated with the deposition of sediments that were carried along the Nile river path by historic floods. Sediment depositions in the northern part of the Delta (coastal area) led to forming a compact muddy clay layer that is almost impermeable. Thus, soil drainage is hindered by heavy clays that extended over large areas of this region, endangering the cultivation of non-flooded crops. It worthy noticed that the northern strip of the Delta is also distinguished by highly saline groundwater because of subsurface intrusion of seawater and/or marine entrance which attributed to continuous submergence of this Delta part underneath sea water in historical periods. Intensive irrigation of the low-permeable soils in the northern Delta would result in long flooding period, thus creating an appropriate environment for high water-consuming plants, such as rice and berseem [12]. It is stated that in Egypt and most other developing countries that produce rice, it is commonly cultivated under continuous flooding with about 5 cm depth of standing water during the growing season [1]. Rice cultivation in such method would also lead to leaching salts and/or pushing away salty groundwater from the root zone. Subsequently, poorly drained parts of the northern Delta may be considered as areas for rice and berseem cultivation only, being inappropriate for rotation alternatives. The other area of the Delta (the southern part) varies in its suitability for crop rotations. Therefore, cultivated rice in the southern part of the Delta may be considered as useful for a cash crop as well as for its role in leaching salts and/or improving soil conditions [12]. A comparison of the net profits among crops shows that cultivating rice has higher benefit to farmers; subsequently, many farmers in the Nile Delta have converted to intensive paddy rice despite the implications of some of commonly used practices on soil quality, environment and natural resources which have been mostly ignored in most of the developing countries [1].

According to the Egyptian agriculture calendar, rice is a summer crop. Rice areas in Egypt have steadily increased after the construction of the nationwide irrigation network in the 19th century. Rice cultivations is usually rotated with cotton and maize cultivation in the two types of crop rotation commonly carried out in the Nile Delta (i.e. two-year and three-year rotation systems) [12]. Those rotation systems present two patterns of crop rotation in Egypt, one of them include rice with the rotation (i.e. berseem, wheat, rice, cotton, maize, and beans) and other without rice (i.e. berseem, cotton, wheat, maize, beans, and vegetables) [1]. There is limited potential for an additional increase of the rice area in Egypt because of rice is high water consumption crop thus all area has to be irrigated therefore the supply of irrigation water is the most important limiting factor. Moreover, many other factors, including soil type, climate, also controlling the choice of suitable areas for rice cultivation. On the other hand, there are many economic factors should be considered by the farmers like yield, cost, farm-gate price, and net return to take a decision regarding cultivate or not cultivate rice [2].

## 4 The Potential of Paddy Soils for Carbon Sequestration

The soil is an important part of the global carbon (C) cycle and has the double potential to store C than the atmosphere. The SOC plays a vital role in enhancing soil fertility as well as sustaining soil productivity because of its influences on soil physical, chemical, and biological properties. Furthermore, climate change feedback and crop productivity in agricultural soils essentially depend on SOC dynamics and C storage [16–19]. The SOC sequestration in cropland could reduce agricultural GHGs by approximately 90% by improved management practices, such as minimum or no tillage, fertilization, perennial or extended cropping systems, manure application, crop residue recycling, and irrigation practices … etc. [20, 21]. As well, changes in SOC are affected by many management practices, such as fertilizer application, straw return, and tillage. However, SOC is always not sensitive to short-term changes in agricultural management practices because of large background levels of SOC [21].

The concentration of atmospheric $CO_2$ in has increased from 280 $\mu$mol mol$^{-1}$ before the industrial revolution to 391 $\mu$mol mol$^{-1}$ in 2011. Much attention has been paid to carbon (C) sequestration for reducing the $CO_2$ concentration to mitigate global climate change [14, 22, 20, 23]. Soil acts both as source for greenhouse gases (GHGs) (by releasing $CO_2$ and $CH_4$ to the atmosphere through soil respiration and anaerobic decomposition) and sink of GHGs by sequestering SOC [18, 23] depending on soil use and management [22]. Concerns regarding rising atmospheric $CO_2$ levels have driven considerable interest recently concerning the potential of SOC as a sink for atmospheric $CO_2$. Because of the important role of SOC in terrestrial ecosystems and its large stock, minor changes in SOC due to disturbances, such as changes in land use or climate, may influence not only long-term ecosystem functions but also the global atmospheric carbon budget and. Cropland soils contain slightly more than 10% (about 170 Pg C) of the total SOC pool. Therefore, a great attention is paid to carbon sequestration in agricultural soils [24] because of its potential impact on global climate change [22]. Subsequently, boosting C sequestration and minimizing GHG emissions has become one of the essential tasks worldwide to the effective combat of upcoming climate change. In considering the magnitude of soil C stock, even small changes in this reservoir can exert a substantial influence on gaseous C emissions and concentrations of atmospheric $CH_4$ and $CO_2$, thus affecting global climate change. Under active human interference and cultivation, the soils in paddy fields usually have a larger potentiality of C sequestration than natural wetland soils [14].

Respecting soil C stocks, submerged rice ecology has also emerged as a potential C sink. Very few studies have demonstrated the unique soil C chemistry in rice soils. Slow decomposition of organic substances is common in rice soils under extended waterlogging, anaerobic conditions due to depletion of $O_2$ levels and the absence of iron oxides and hydroxides as electron acceptors. This leads to higher accumulation of stable fractions of C or in the other meaning, SOC sequestration in rice systems [18]. However, under such conditions of submergence and increasing the quantity of SOM, the degradation of soil quality because of the breakdown of stable aggregates and deterioration of soil organic matter occurs. Crop rotations are known to favor the enforcement of SOC and improving soil nutrients comparing to monocultures. Continuous monoculture will not be active in sequestering C [25]. It is stated that in the past decades, the SOC declined in high-yielding cropping systems, especially in rice production systems, due to using chemical fertilizers and pesticides instead cover crops and organic mature to retain crop growth and to increase grain yields [17]. However, SOC accumulation was attributed to the increased application of chemical fertilizers that stimulate greater rice yields, higher biomass production, and higher returning of crop residues to the soil, over the last several decades [23].

Owing to its high accumulation rate of SOC, rice cultivation may play a substantial role in mitigation $CO_2$ in the atmosphere [23]. The dynamics of soil carbon (C) and nitrogen (N) in submerged rice soils are different from those of aerobic, because of maintaining submerged rice soils at lower redox potentials. Recently, stagnation or decline in yields has been observed worldwide under the intensive rice-based cultivation systems; this is attributed to the loss of quality and quantity of SOC which influenced nutrient supply, specifically N [3]. It is reported that SOC in the surface layer (0–20 cm) of paddy field is higher than its corresponding in the upland croplands. They explained that the strong aggregate stability of paddy soil boosts the SOC conservation and the enrichment of SOC in macro-aggregates, resulting in a greater carbon sequestration potential in this soil. They also reported a declining tendency of SOC after paddy conversion into the vegetable field [26].

On the other hand, rice agriculture contributes meaningfully to global straw production. These agricultural residues are spread in the field, removed from the field, burned in situ, piled, incorporated to the soil, or mulched on the next crop. In the past, straw was regularly removed from the field and used as fuels or construction materials in many countries. Agricultural lands worldwide suffer from the increment of pest attacks and hardening of soil agglomerates because of the excessive fertilizer application. This has led to enlarge the practice of applying straw return to the field after harvesting, which has led to improve soil fertility, upgrade soil physical and chemical properties, enhance crop yield, boost soil C sequestration, and mitigate GHG emissions [14]. However, the farmers, to save time and labor, were used to directly burn straw in fields, causing serious atmospheric problems [27]. It is stated that utilizing of plant residues as mulch, instead of burning, has valuable effects for refilling SOC, and returning to the soil of 1 Mg $ha^{-1}$ of rice, wheat, and maize straw each year, thus sequestering about 130 kg C $ha^{-1}$ $year^{-1}$ [24]. It is reported that the rates of rice residue inputs in rice production systems managed by farmers are variable, so the change of SOC in field experiments does not sufficiently represent the actuality of C sequestration in paddy ecosystems. Therefore, it is important to know more information about SOC responding to variation in C inputs due to changes in paddy rice production [23].

## 5 Rice Fields as a Source of Greenhouse Gas (GHG) Emissions

Climate change has been one of the main global environmental issues of the 21st century, with increasing anthropogenic GHG emissions being the principal reason. Nitrous oxide ($N_2O$) and methane ($CH_4$) are the two significant GHGs, due to their positive increases for radiative forcing and the permanence in the atmosphere, responsible for global warming, which contribute to shape the overall earth's climate system [14, 27, 28]. It is mentioned that agriculture is responsible for about 13% of annual GHG emissions that are related to all human activities [29]. While, it is stated that agriculture only contributes to approximately 20% of the current atmospheric GHG concentrations, with methane ($CH_4$) and carbon dioxide ($CO_2$) as the two most effective carbon-containing GHGs released from agricultural activities [14]. However, it is reported that approximately 50.1 Gt$CO_2$e GHG emissions were released from anthropogenic sources in 2010 worldwide. Agriculture only accounts for approximately 5.0–5.8 Gt$CO_2$e (i.e. 10–12%) of these emissions. They also pointed to these percentages only are the direct sources. If indirect sources are also taken into consideration, agriculture probably accounts for an additional 3–6% of the global emissions. Modern intensive farming, which heavily depends on irrigation and chemical fertilizer application, is the largest source of $CH_4$ and nitrous oxide ($N_2O$) emissions [13, 30]. It is counted approximately 50% or more than 50% of the global anthropogenic emissions of $N_2O$ and $CH_4$ released from agricultural soils [27, 29]. While it is reported that flooded-rice ecosystems accounted for approximately for 20% of the total global $CH_4$ budget [31]. It is considered that edaphic condition and meteorological factor, in addition to agricultural management such as tillage, irrigation, fertilization, and organic amendment application could significantly affect $N_2O$ and $CH_4$ flux [27].

Rice paddy fields play an important role in the global budget of GHGs, such as $CO_2$ and $CH_4$ [10]. Rice farming systems tend to consume higher energy and have a higher carbon footprint than many further comparable cropping systems. As well, production, packaging, transportation, and the utilizing of extra farm inputs need more energy. Subsequently it is likely to emit more GHGs. For example, since 1990–2005, the global agriculture emissions increased by approximately 14%, an average rate of 49 $MtCO_2e$ $year^{-1}$ [13]. Rice is an important emitter of $CH_4$ which contribute to the warming as 19–25 times higher than that of $CO_2$ per unit of weight based on 100-year global warming potentials [32]. Rice production does not only play a major role in sustaining global food security, creates wealth and jobs in the cultivating areas, but also results in significant environmental impacts such as atmospheric GHG emissions [7, 31]. It is mentioned that $CH_4$ is produced by methanogens in flooded soil and released to the atmosphere through the rice growing season. $N_2O$ is produced by nitrification and denitrification processes primarily from agricultural soil management activities, such as OM application, fertilization, and irrigation. They added that the global paddy rice cultivation in 2000–2010 emitted 22–25 Mt $CH_4$ $year^{-1}$ (i.e. 472–518 Mt $CO_2eq$ $year^{-1}$). The annual total non-$CO_2$ GHG emissions from agriculture in 2000–2010 was reported to range from 4.6 to 5.1 Gt $CO_2eq$ $year^{-1}$, representing 57% from $N_2O$ emission and 43% from $CH_4$ emission. Approximately, 75% of worldwide rice production is performed in continuously flooded paddies. Farmers believe that this practice has many advantages such as retaining soil moisture and temperature, increasing soil C, and suppressing the soil-borne disease and weeds. However, flooding causes anaerobic conditions and therefore promotes methanogenesis and methane emissions [8, 10, 13]. It is also emphasized on paddy rise and pond aquaculture as major sources of atmospheric $CH_4$ and $N_2O$, mainly due to the periodic dry/wet alteration episodes and intensive inputs of organic material and nitrogen fertilizers [28]. Methane emissions from flooded-rice cultivation have been revealed to be affected by various soil and plant properties, especially soil texture, soil management practices, former crop, and selected cultivars. They also mentioned that up to 90% of the produced $CH_4$ in flooded-rice cultivation is emitted into the atmosphere. The remaining 10% of $CH_4$ in the soil is often re-oxidized into $CO_2$ and released into the atmosphere. Methane emissions are differentially regulated by rice growth stage and vary extensively among rice cultivars such as hybrids, inbred lines, and conventional ones. This variation is a result of physiological differences among cultivars in the production of $CH_4$ and methanotrophic activity in the rhizosphere [31].

Furthermore, rice stubble is left on the ground to decay or burnt to ashes, which is likely to produce both $CH_4$ and $N_2O$ emissions [13]. The Intergovernmental Panel on Climate Change [7, 32, 33] estimated the annual global emission rate from paddy fields averages 60 Tg $year^{-1}$, with a range of 20–100 Tg $year^{-1}$ which counted about 5–20% of the total $CH_4$ emissions from anthropogenic sources. This figure is primarily based on field measurements from different paddy fields in different countries such as the United States, Spain, Italy, China, India, Australia, Japan, and

Thailand. It is referred to that observed seasonal rice $CH_4$ emissions worldwide demonstrate large ranges, which reflects the effects of local and regional variations in agricultural, biological, and climatic factors [29]. It is also reported that although the rice production, among the crops, is being the world's second most produced staple crop, it is one of the largest anthropogenic sources of $CH_4$ emission. Rice cover 11% of the global arable land area and it is responsible for 10.1% of total agricultural GHG emissions and about 1.3–1.8% of the global human-source GHG emissions [13].

In Egypt, rice is important in Egyptian agriculture sector, as Egypt is the largest rice producer in the Near East region. The total area used for rice cultivation in Egypt is about 600 thousand ha or approximately 22% of all cultivated area in Egypt during the summer. The mean yield is 8.2 tons $ha^{-1}$ with an estimated straw production of approximately 5–7 tons $ha^{-1}$ [29]. The carbon footprint of crop production depends on various factors, such as soil types, crop types, cultivation practices, management factors, types and amounts of farm inputs, irrigation conditions, etc. For a specific crop type, these factors also differ among different countries and even within a country, for example in Australia, irrigate barley, chickpea, wheat, and rice cropping produce about 2.5 $tCO_2e$ $ha^{-1}$, 2.6 $tCO_2e$ $ha^{-1}$, 2.8 $tCO_2e$ $ha^{-1}$ and 1.7 $tCO_2e$ $ha^{-1}$of GHGs, respectively. The sources of $CO_2$ simply represented in: on-farm fuel and electricity consumption; production, packaging, storage, and transportation of agrochemicals (fertilizers, herbicides, insecticides, fungicides, plant regulators etc.); $N_2O$ emissions resulted from soils associated with application of synthetic nitrogen fertilizers; and farm machinery usage [13].

Therefore, a concern of GHGs-C emission and anxiety about global warming has resulted in grown attention on soil C storage, which is a function of climate, soil type, cropping systems, management practices such as tillage and fertilizers application. Particularly, the net C emissions from the paddy soil (i.e. $CO_2$ or $CH_4$) are governed by several factors including soil types, crop biomass, growing condition, type of cultivars, fertilizer practices, amendments use, water management, air transport mechanisms, and cultural practices [16]. Recently, more studies are greatly required to focus also on GHG emissions from aquaculture wetlands, mainly because of intensive input of organic feeding materials and frequent loading of chemical nutrients. The available budgets of global $CH_4$ and $N_2O$ emissions from aquaculture were obtained from modeling approaches data based on surface water dissolved $CH_4$ and $N_2O$ concentrations. However, there is still a lack of direct field estimations of $CH_4$ and $N_2O$ fluxes to get a perception of regional or global estimations of $CH_4$ and $N_2O$ source strengths from aquaculture wetlands. Particularly, it is not well known if the current shift in agricultural land use from rice paddies to inland aquaculture would point to what extent of shape the direction and rate of $CH_4$ and $N_2O$ fluxes [28]. Therefore, with the accumulating evidence on climate change, there has been concerning about investigating the GHGs contribution of production practices and products to identify intensive emitting options that could be the target of GHG mitigation actions [29]. Since the global warming potential of $CH_4$ and $N_2O$ is 25 and 298 times higher than $CO_2$ respectively, it is well realized that attention on reducing $CH_4$ or $N_2O$ emissions may be an effective climate change mitigation strategy [30].

In many places, rice straw is not commercially valuable and is disposed of in different ways [9]. It is burned in fields which makes rice residue as another emission source yielding $CO_2$, $CH_4$, and $N_2O$, in addition to, pollutants such as carbon monoxide (CO), particulate matter (PM), and toxic polycyclic aromatic hydrocarbons (PAHs). Thus, the burning of these residues causes many problems such as air pollution, damaging to human health, and loss of soil C and nutrients [7, 29]. Rice straw residue also is left in the situ or removed from the fields for animal feed. Therefore, the incorporation of rice straw residues into the fields has been widely encouraged to preserve SOM and nutrients in the soil. Nonetheless, the incorporation of crop residues into paddy rice fields significantly increases $CH_4$ emissions because $CH_4$ production in flooded fields mainly relies on the availability of readily decomposable OM [7]. In 2008, about 620 million tons of rice straw was produced in Asia alone, with increasing quantity every year. Rice straw consists of about 0.6% (w) N, 0.1% P, 1.5% K, 5% Si, 0.1% S and 40% C, being a convenient source of plant nutrients because of its on-the-spot availability in amounts varying from 2 to 10 t $ha^{-1}$. Although residue retention is crucial for the sustainable soil management of mixed and non-rice cropping, incorporation of rice straw directly into soil commonly causes $CH_4$ emissions due to its anaerobic breakdown. Therefore, the promoting a proper rice straw treatment method before its incorporation into the soil is urgently needed [9]. As well, with a target to reduce GHG emissions from agriculture and rural development sectors, there is a critical requiring to mitigate rice $CH_4$ emissions while increasing or maintaining rice production levels which presents a major scientific and societal challenge [7].

## 6 The Impact of Climate Change and Sea Level Rice on Land Loss and Rice Production in Egypt

Climate change characterized by global warming has already had noticeable impacts on the ecological systems and human societies. The historical records indicate increasing the global mean surface temperature by 0.89 °C from 1901 to 2012. This warming trend expected to continue in the upcoming decades and would lead to more significant impacts on ecosystems and human societies. The main reason for current global warming is the human-induced GHG emissions [30]. The energy sector emissions are generated from fuel combustion in the different sectors such as industry, transportation, electricity generation, agriculture, residential and commercial, petroleum production and industries. Industrial emissions are related to heavy industries such as cement, iron, and steel production. Agricultural emissions are mainly released from rice cultivation, enteric fermentation of livestock, manure management, agricultural soils and field burning of agricultural residues [34].

Crop cultivation has moved northward since the 1940s. Rapid urbanization, policy changes in agriculture and land use, mechanization, and changes in farm management have driven this movement. As well, climate change has also played an important part

[4]. Climatic factors are key factors that are controlling crop production processes. Solar radiation, rainfall and temperature fluctuations lead to water deficit, changing in soil moisture content, flood, pest, and diseases outbreak that limit crop growth and can account for 15–80% of the variation of inter-annual yield resources [35]. It has already been a global consent that climate factors and their changes play an important role in agriculture, particularly in grain production which is the main essential sector for feeding a population over the world. Therefore, agricultural production is sensitive to climate change, not only due to the direct impacts of changes in temperature and precipitation but also due to changes in hydrological processes such as availability of water resources and the demand for irrigation water. Agricultural irrigation has an important role in the utilization of water resources as well as the distribution of farmland [4]. Meanwhile, extreme climate events such as drought, flooding, or drought immediately followed by flooding in recent years have led to severe negative impacts on crop production [23].

It is well known from the rich literature of climate change and its impacts on grain production, that there is growing evidence of crop yield response to current global warming. Various approaches were used in such studies as using crop model to calculate the contribution of weather to grain yield, simulation, and empirical statistical approach such as linear regression analysis that has been mostly used for calculating the impact of climate factors on grain yield. It was reported that had the increased temperature by 1–2 °C during the paddy earring stage, could have decreased the paddy rice production by 10–20% [36]. It is reported that climate change implies further pressure on the world's food supply system. It affects food production directly through changes in agro-ecological conditions which affects the overall food supply. Extensive research shows that high temperatures, variable rainfall, floods, droughts, and cyclones may cause a large decrease in global food production, especially in developing countries. For example, the increase in temperature reduces the phenological phases of crops (i.e. planting, flowering, and harvesting) and affects plant growth and development [37].

Several researchers have studied the probable impact of climate change on rice production and conducted that it is pivotal to determine how climate change affects rice production and water use efficiency to prepare plans and policies for adapting the agricultural system versus the changing climate [37]. Chen et al. [23] indicated a decreased rice yields associated with global warming in Philippines. They also referred that in other Asian countries, long-term field experiments have also conducted declining or stagnating yields in rice-based cropping systems. However, the impacts of climate change on the future rice production is still under debate in the three highest producing countries; China, India, and Indonesia. This is attributed to the counterbalance between the beneficial effects of increasing atmospheric $CO_2$ concentration and the exacerbation of abiotic stresses on crop growth, such as heat, drought, and salinity. The available estimations are discordant and vary between an increase of 10–15% in 2020 to 7–10% yield losses per every 1 °C increase in air temperature. With the prominent role of rice as a staple food for humans and the necessity of doubling crop production by 2050 to meet the proposed demand of the global population, the efforts are still required to better understand the current knowledge. Currently, rice cultivators and stakeholders of the rice sector are already applying adaptation strategies, varying from individual autonomous local reactions to planned policy interventions, to mitigate the negative impacts of climate change in the main producing environments. Nevertheless, less research has been dedicated to analyzing the impacts of climate change on rice production in Europe, where rice is the 6th most produced cereal. Even though not being a staple food crop in Europe, rice plays a focal sociocultural and ecological role in many Mediterranean countries, where the human consumption is steadily increasing. With elevated temperatures because of climate change, heat stress could be more common on temperate rice crop. Recent findings on rice physiology reveal that heat stress causing sterility in the exerted part of the panicle may occur even in Mediterranean countries, especially in warm and humid years [4].

Egypt is one of the countries assuming to face damaging impacts of climate change [34, 38], although its contribution to the global greenhouse gas (GHG) emissions is 0.57% and despite the fact of not considering it in a non-annexe I country not requiring any certain emission reduction targets under the Kyoto protocol. However, Egypt has included in its National plans mitigation actions to reduce greenhouse gas emissions from its main sectors contributing to climate change; energy, industry, agriculture, and waste [34]. Agriculture in Egypt is one of the significant sectors that is expected to be affected by climate change. Rice in Egypt is a strategic crop, and it occupies the second class of the cultivated crops in Egypt [39]. He employed the CERES-RICE model (a mechanistic, process-oriented model from grain cereals that includes crop development) to understand physiological processes and yield of rice production. He used actual measurements for rice production characteristics in the comparison between present and future. He extracted meteorological data representing in temperature, solar radiation, and precipitation for the years 1998 and 1999 from outputs of RegcM3. The climate data is used from HADCM3 for SRES—A2 Scenario for 2040 and switched in RegcM3. The results of his work indicate changes in flowering dates, physiological maturity, and production. He expected over the country with the studied climate change scenario, the rice maturity period is projected to diminish by 20% and yield to decrease by 25.8% on average. As well, it is conducted that rice production in Egypt will be declined under expected climate change. Subsequently, a gap between rice production and consumption will be created. Furthermore, when the increased population is considered, this gap will widen. Therefore, in the face of climate change, better understanding of climatic impacts on rice production is vital to identifying solutions that will enhance current food production and increase the adaptability of these systems in the future [35, 40].

The acceleration in global Sea Level Rise since the last decades of the 20th century is one of the most evident consequences of the higher temperature as the main impact of climate change. This phenomenon has been considered in all the Assessment Reports published by the Intergovernmental Panel on Climate Change (IPCC). IPCC provided different scenarios of the sea level rice in 2065 and 2100, with the worst one estimated as 0.98 m in 2100 [41]. Sea level rise as a result of both natural and human-induced climate change, it is one of the main reasons of salinity intrusion into soil and groundwater. Considering other forms of lands, deltas are easily vulnerable to sea level rise. For instance, several studies found that Nile Delta and some other deltas are facing constant inundation and saline intrusion because of exposure to the sea [42]. He added that the predicted sea level rise due to climate change would submerge a lot of low-lying lands worldwide by 2050, and salinity intrusion will be more severe. It is also emphasized on that the worldwide low-lying areas; the main alluvial coastal plain; is accounted as one of the most vulnerable areas by sea level rise. They highlighted the Nile Delta, Egypt, in the Mediterranean area and mentioned that currently, about 10% of the global population already live in low-lying coastal regions, between 0 and 10 m above sea level. They also reported that the sea level rise associated with global warming is also intensified by local factors, such as the subsidence, due to both natural and anthropogenic causes [41]. It is found in the study of [43] on the impact of sea level rice on Nile Delta, Egypt that that mean sea level is projected (based on IPCC scenarios which generate by MAGICC/SCENGEN program) to rise by 14.0 to 18.9 cm between 1990 and 2100, for the full range of all scenarios. The range between the best case A1 (low) and the worst case B1(low) is 4.8 cm. This will affect the developmental activities in these areas due to heavy population and high productivity of the best fertile areas in Egypt. The results of all scenarios show that A1+ land subsidence was the highest case, ranged between (48.2 and 48.9 cm), while B1+ land subsidence was the lowest case (44.0–44.1 cm) till the year 2100. Therefore, in this context, the impact of climate change on agriculture productivity, water shortage and shifting growing seasons can't be neglected in the Nile Delta. This is because the area is vulnerable to negative impacts of climate change such as loosing, salinization of considerable areas of cultivated lands (because of rising sea level) and rapid decomposition of OM as result of increasing temperature. It is expected also in the study of [44] that relative sea level rise in the high scenario increases the amount of land risk from inundation in the northern Nile Delta by 300 km$^2$, or more than one-fifth of the total agricultural land in the northeast Nile Delta only. As well they added; all crops are projected to have a decrease in yields and an increase in irrigation needs. All these will lead to a decline in C and N in agricultural soil. Thus; under such previous stresses on C and N in North Nile Delta Egypt as a result of climate change and water shortage due to establishing GERD, the actions should be taking towards either mitigation or adaptation of this stresses.

## 7 The Impact of Water Deficiency on Rice Production in Egypt

Egypt covers an area of about 1.0 million km$^2$ [45]. The Nile valley plus Delta region cover about 4% of this area [46]. Agriculture is practiced over an area of approximately 3.5 million ha, involving recently reclaimed lands. As a highly populated country with a population of approximately up to 90 million, Egypt is an agriculturally based country. Agriculture remains a major sector and a very lifelike component of the economy. Even though its performance stayed relatively modest in the last few years, it has successfully attracted considerable investments. Agriculture employs about 31% of the labor force, and about 14% of the GDP is produced by agricultural production. Because of the favorable agro-climatic, perennial water supplies and rich fertile soils, Egypt produces a diversity of crops, vegetables, and fruits for feeding its population and earning foreign exchange through exports. The country's main crops include cotton, rice, wheat, sugarcane, beet, clover, fodders, vegetables, sesame, peanut, sunflower, beans, lentils, and onion, in addition to fruits such as citrus and dates [45].

Water resources in Egypt are limited to the Nile River, rainfall, and deep groundwater [47]. The water of the Nile River has a great value for Egypt as it provides approximately 95% of its water needs. Egypt's portion of the water of the Nile River is almost 55.5 billion m$^3$. Agriculture uses most of it; about 85.6% of the used water. This verifies the saying "Egypt is the Nile's Gift" as Egypt does not have a large portion of the rain, so we find that life in Egypt is concentrated on the sides of the Nile and any shortage in the of supplied water in the river inevitably causes a disaster. The Nile River stems from two springs in the upper lands in Ethiopia and the lakes that cover parts of Uganda, Kenya, Tanzania, and Congo. Then the Nile flows till North Cairo and reaches to its two main branches, Damietta, and Rashid (about 6680 km from its springs till the Mediterranean Sea) that end in the Mediterranean Sea [48, 49]. The river revenue is featured by two main periods, flood period during August, September, and October in which the river increases, and Althariq period in the other months of the year in which the river revenue is declining a lot. The annual revenue of the three major tributaries of the Nile is around 84 billion m$^3$, where approximately 48.7 billion m$^3$ form the Blue Nile, 24.4 billion m$^3$ of form the White Nile and 10.9 billion m$^3$ for the branch of Atbara [49]. With the fast growth in the population and increasing water consumption in different fields, such as agriculture, industry, domestic use etc., it is supposed that Egypt will relay somewhat on the groundwater to develop some new projects such as East Eweinat. There are two main ways that can reduce concise demand with supply by reducing demand or by increasing supply. Despite the increasing shortage of water, there are almost no indications of efforts to reduce water demand in the three-main water-consuming sectors [48].

In Egypt, water planning established in 1933 for using extra storage capacity that was available after the second elevating of both dams of old Aswan and the Gabal El-Awlia in Sudan. This plan generated programs for many purposes such as land reclamation, conversion of some basin irrigation to perennial irrigation, and increases the rice cultivation area. This strategy was first revised in 1974 and again in 1975 when a new plan was prepared to hold the further volumes of water resulting from the construction of the Aswan High Dam. The multi-year regulatory storage capacity posed by the Aswan High Dam was a reason for stability to Egypt water resources by delivering a reserve storage capacity during years more than the requirements and providing additional resources during loan year. Currently, adopting more efforts are running for water management and application of different available water resources [48]. Although there are several uses for water in Egypt, agriculture engages about

85.6% of the used water; estimated by about 69.30 billion $m^3$. A large portion of this water is groundwater used directly, or after mixing with Nile fresh water, and treating to be appropriate for using [49]. Rains are not sufficient and effective enough to depend upon for production. Rain-fed agriculture is practiced in only 2% of the total area. The per capita rate of Nile water is nearly 850 $m^3$ $year^{-1}$—under the water scarcity—whereas the minimum per capita needs should be up to one thousand $m^3$ $year^{-1}$. Egypt is among 35 water deficit countries in the world. In Egypt, 87.7% of the total water is being consumed by agriculture, 5.4% by industry while the total human consumption touches the figure of 6.8% of the total water. For the irrigation of the new land, each drop of water has become the focus of the government in Egypt. Efforts are being increased to focus in the future on the enhancement of the irrigation systems, the introduction of real irrigation technologies that could be effectively utilized to irrigate the newly reclaimed agricultural areas. Modern irrigation methods such as drip irrigation and sprinkler need to be used for overcoming the water shortage and scarcity [45].

Rice is the second major staple crop and is considered the most profitable export crop of the summer season. Egypt reported a 2.3% growth in production to a total of 6.9 million tons in 2008 due to a 5.6% extension in productive land. The increased rice cultivation that has been resulted in a hike on international markets has added pressure on water resources since rice cultivation is outstandingly water intensive. Farmers practice fish-farming in rice fields to enhance a rice farmer's income. In 2008, because of water management policy, the restrictions were imposed on the area that will be brought under rice cultivation, but policy proved ineffectual. Therefore, the government placed an export forbid in for reducing the domestic price of rice. The raising of the ban has allowed exports to increase again, and to benefit from the high international prices of the commodity. Rice Cultivation also helped farmers to realize higher profits as compared to other traditional summer crops [45].

Rice is easy cultivation crop with assured results. Local rice productivity is estimated at around 3.5 tons/acre. The present practice of rice cultivation is requiring fewer farming efforts, can satisfy farmers' daily nutritional requirements as well as can wash salty lands. A tendency to grow large patterns of rice throughout the Delta is also created among farmers due to the free delivery of irrigation water, according to which rice becomes of better profitability compared to other crops. The deformation in making cropping decisions promotes the extension of rice areas even with deficiencies concerning water requirements for the country reclamation strategy [12]. Rice water consumption is approximately 2–3 times higher than is required for producing other cereals, such as maize or wheat [10, 37]. In addition to the land and energy issues, with most of the rice being grown under irrigated conditions, water is another scarce resource that is crucial for rice production. Producing one kg of rice requires around 2672 L of water-about 2.5 times the amount of water needed to grow a kg of wheat or maize [13]. Despite the importance of rice production, it also adversely affects the environment. For instance, besides the highwater extraction required for rice production, heavy pesticide usage is another burning concern. Also, when rice is flooded, it undergoes anaerobic processes, resulting in the formation and release of large amounts of methane into the atmosphere [37].

In Egypt, the Per capita fresh water availability was dropped from 1893 cubic meters in 1959 to 900–950 $m^3$ in 2000, to about 670 $m^3$ in the year 2017 and the author expected to decline further to 536 by 2025. The main reason behind this rapid fall is the mixed water resources and the rising pressure from population growth. Water resources in Egypt are becoming rare. Surface water resources originating from the Nile are currently fully exploited, while groundwater sources are being brought into full production. Egypt is facing growing water needs, demanded by rapidly increasing population, increased urbanization, higher standards of living and by an agricultural policy which emphasizes intensifying production to feed the growing population. The population is presently increasing by more than one million persons a year. With a population of Egypt is expected to increase to about 100 million by 2025. The most critical limitation facing Egypt is the growing deficiency of water resources associated with degradation of water Quality [47]. As previously shown, rice is usually grown in the Delta under continuous flooding. During most of the growing season, expanding from May to October, rice fields are flooded understanding water layers of variable depths. The outlined irrigation process reflects the intense need for rice for water diversions. Exposed to temperatures ranging from 30 to 40 °C, rice fields are subject to excessive evaporation in addition to percolation, causing significant rates of water loss. Almost 50% of water amount diverted to rice fields is consumed by evapotranspiration, and the rest is lost via percolation [12]. Despite all the prior efforts for planning water resources management in Egypt, we still have to make more attempts to achieve the required balance between the available water resources and the high growth population and water needs subsequently [48].

The economic evaluation of crop production requires realizing the value of water used in irrigation. Rural water pricing is not applied in Egypt based on a rule implying free delivery of irrigation water to farmers. Nevertheless, assumed the underlying natural resource limitations facing the country, it is necessary to guarantee efficient use of water across introducing a value that reflects the vital concern for water as a most important restrictive factor of Egypt's agricultural production [12]. Upcoming stresses on the Nile's water promotes Egyptian demand to Egypt's "historic rights" of the Nile. Egypt relies on the Nile for 97% of its water needs. In line with current aspects of water misusing, population growth and the possible redistribution of the Nile's resources to other riparian countries, Egypt confronts the challenge of coping with severe future water scarcity. Water deficiency and limited arable land mean that Egypt already depends heavily on food imports to satisfy its population demands for food (Egypt imports 60% of its total food needs). Egypt's agricultural sector currently uses 80% of the country's water resources. As the population growths, water requirements will increase because of household and industrial use as well to ensure the country's food security by producing the food. Egypt's dependency on food imports makes it vulnerable to global food price rise and supply scarcities. To mitigate the security risk, Egypt has to continue in land reclamation plans in desert areas, which require huge water quantities and will place additional restricts on the portions of other agricultural, industrial, and municipal water consumers. As the population grows, the country will need more water than its current available share; however, shifting geostrategic alliances among upstream countries mean that its allocation is likely to decline. Unless it goes on a large-scale modification of its inefficient water networks, Egypt could go through upcoming major water crises that could cause conflicts with its neighbors [50].

Currently, major challenge confronting Egypt is the crucial need for better development and management of the available restricted resources of water, land, and energy to face the needs of population growth [48]. The decreasing availability and increasing costs of water menace the traditional way of cultivated rice under irrigated conditions. Hence, due to the increasing deficiency of water for agriculture and competition from non-agriculture sectors, there is an urgent calling for better understanding water use efficiency in irrigated agricultural ecosystems [10]. In addition to environmental and demand pressures and potential conflict, the Nile is threatened by many environmental stresses, such as climate change, pollution, and degradation. Climate change will put sever challenges for the Nile, including decreased river flow, land degradation, the increased droughts and floods probability, and rising rates of disease. Dam establishment on the Nile is responsible for watershed land degradation. Population growth models in Egypt and upstream Nile countries, such as Uganda and Ethiopia, will undoubtedly cause future environmental issues such as raising in municipal, industrial, and agricultural wastes. Egypt has depleted the Nile's water resources by overdrawing its share, through projects such as the desert reclamation in the Toshka Depression and the Sinai Desert by the Al-Salam Canal system [50].

## *7.1 Water Deficiency Due to Climate Change*

Agricultural sector is one of the main water consuming sectors. The water used for agriculture has reached about 59.30 BCM in 2009/2010. Under conditions of climate change, required water to irrigate various crops are expected to increase to about 61.8 BCM in 2024/2025 as a direct impact of high temperature. This will be associated with high efficiency of using water by some crops because of the increasing concentration of $CO_2$ [49]. Hence, the issue of water deficiency in Egypt, associated with its probable exacerbating factors such as economic, population and food demand growth, climate change and the current debate over the share of the Nile's water among its ten basin countries) is widely documented in the recent literature [51]. Climate change is impacting the Mediterranean region in myriad and distinct ways such as sea level rise, increased frequency of flash flood events, droughts, or periods of water shortage and rising temperatures. Observed trends and projections for the future indicate a strong vulnerability to changes in hydrological regimes, an increasing shortage of water resources and following threats to water availability and management [5].

Population growth and economic development are motivating significant raise in agricultural and industrial water demand. Water use in agriculture accounts for more than two-thirds globally, including as much as 90% in developing countries. Much of the demand is resulting from expected increases in the world population from 6.6 billion to about 8 billion by 2030 and more than 9 billion by 2050. Climate change will likely increase water demand for agriculture, mainly for irrigation, due to long dry periods and severe drought, especially it is estimated at over 40% increase in irrigated land by 2080. As well, it will likely increase water demand for billions of farm animals due to higher atmospheric temperatures thus hydration needs. Also climate change will likely increase water quantities that needed for industrial cooling because of increased atmospheric and water temperature [52].

In the future, water may become more expensive, less available and allocations will be less secure, especially for water-intensive activities such as rice. Rice industry stake-holders and growers have already adopted a risk-averse approach. At some place in the world such as California and Papua New Guinea, there is a flexible and effective global supply network for warranting and processing to ensure continuous supply through critical periods. At the farm level, during years of low water availability, rice growers trade water as a tactical response and move to low water-intensive or dryland farming. This, however, has caused highly variable rice supplies and has filled some production gaps [53]. It is added that water has many competing usages, but in the currently, climate change is further aggravating the water scarcity issues by decreasing its availability for irrigation purposes. Approximately 15–20 million ha of irrigated rice may suffer from water scarcity by the year 2025. Furthermore, the upcoming increased concentration of atmospheric $CO_2$ may increase the GHG intensity of rice production. Therefore, improving rice varieties and better management practices that need less water, land, and energy, and those that improve the rice productivity is urgent in the 21st century. Also, a farmer seeking to cultivate a given crop under increasingly the stress of water resources will utilize in the available adaptation options to improve the efficiency of water usage and will amplify the adaptive effort because access to water resources becomes more restricted. At some point, adaptation efforts under the existing regime will become inconsistent to the benefits and a new adaptation action such as a novel irrigation system or altering a crop will be needed to retain a farming livelihood [13, 54].

## *7.2 Water Deficiency Due to Grand Ethiopian Renaissance Dam Construction*

The Nile River is one of the most important rivers in the world. Eleven countries are depending on the Nile River water; Burundi, Eritrea, Tanzania, Uganda, Ethiopia, Rwanda, the Democratic Republic of Congo, Kenya, Sudan, and Egypt. Egypt share from the Nile River fresh water is limited by a covenant signed in 1959 between Sudan and Egypt where Egypt share is 55.5 Billion Cubic Meters (BCM) $\text{year}^{-1}$ and Sudan share is 18.5 BCM $\text{year}^{-1}$. Most of the Nile River water comes mainly from the Ethiopian plateau cross the Blue Nile and Atbara in the flood period of the flood that starting from August to December. Ethiopia's tributaries provide approximately 86% of the Nile River water. Ethiopia began constructing the GERD. In 2011, on Guba that located on the Blue Nile approximately 60 km from Sudan and 750 km northwest of Addis Ababa. The GERD reservoir will extend for an area of 1874 km$^2$ with a full supply of 640 m above mean sea level, with total and effective storage volumes of 74 BCM. The main concern about the construction of Grand Ethiopian Renaissance Dam (GERD) is the filling period of its reservoir which will decline Egypt's share from Nile River water and as a result affecting water security of Egypt [55]. Thinking about the construction of the dam for power generation on the Blue Nile started in the sixties in the 20th century. The U.S. Office of Land Reclamation in 1964, has studied the establishment of around 11 dams, most importantly the four large dams on the Blue Nile with a total capacity of 80 BCM and these dams have been involved in the Nile Basin Initiative. However, the establishment of the Renaissance Dam was announced with a total capacity of 74 BCM [i.e. five times the size and capacity of the total of the four old dams in the American Studies (14.5 BCM)] [49].

Construction of GERD will have some negative implication on many sectors in Egypt including agriculture and water deficiency. Lack of supplied water to Nasser Lake due to water storage in front of the Renaissance Dam (by approximately 25–33 BCM year$^{-1}$ unless there is pulling of shortage from Dam Lake) means wasting approximately 3–5 million feddan of Egypt's cultivated area. Each feddan requires about 5 thousand cubic meters (CM) of water according to the estimation of the Irrigation Ministry in Egypt. Therefore, the minimum of wasting cultivated lands will lead to a lack of cultivated area of approximately 46.9%, while the maximum wasting limit of cultivated land will be approximately 67.6% of cultivated lands. As well, deficiency of irrigation water will lead to increasing the use of agricultural drainage water for irrigation up to about 7 BCM year$^{-1}$, which duplicate the salinity 3 times following irrigation and thus reaching the water to the banks again with higher concentrations in each irrigation, which lead to increasing in water salinity of agricultural lands in the Delta. Additionally; lack of water flow means stopping all land reclamation projects, agricultural expansion, and ending of some great agriculture projects in Egypt such as Toshka project, Al-Salam Canal, and El Hamam Canal in the Northwestern coast of Egypt. Anyhow, there will be an urgent need for establishing many wastewater treatment plants, for treating contaminated water to become suitable for irrigation, and also treating industrial wastewater and sewage, which costs Egyptian country millions of dollars [49].

Based on the previous mention data, there will be a decline in rice cultivated area which store C and N more than other cultivated areas, especially in the surface layer. Already it is noticed obviously in Egypt this year that farmers are suffering from drought and inability to cultivate their preferred crop; rice; as a result of water shortage. Thus, loss of 50% of cultivated area in Egypt based on the previous scenario of [49] will lead to a loss of approximately 50% of cultivated rice area also, the loss of 50% of C and N storage in those soils (equal approximately third of C and N of Egypt's cultivated soils) because of converting rice to dry crops. Also; some soils in Egypt, especially in North Nile Delta (more 95% or rice cultivation in Egypt is concentrated in this area), is salt-affected soil; thus, rice cultivation is one of the most important practices that lead to salinity leaching. Saline soil requires a huge amount of water irrigation for salt leaching to be suitable for agricultural activities. In such case, rice cultivating could be the best solution, while, other areas with non-saline soil could be cultivated with other crop types [56]. Furthermore, the negative impacts on salinity on soil properties and productivity, salinity is one of the major sources of declining net primary production the OM, C, and N in soil [57, 58].

## 8 The Effect of Agriculture Management Practice on Enhanced Rice Production for Confronting the Challenges of Climate Change and Expected Water Deficiency

Enhancement agricultural productivity in the last five decades has mainly been related to energy-intensive systems for growing crops such as rice and wheat. A high input conventional tillage and intensive weed management systems consist of primary and secondary tillage implements. Furthermore, transplanted paddy cultivation demands a huge amount of energy regarding labor for land preparation, puddling and transplanting. Transplanted rice paddy requires 4000–5000 L $kg^{-1}$ of water for rice production. Moreover, a huge amount of energy is required for application of water, as well caused significant $CH_4$ emission. On the progress of second-generation farm apparatus and global concern about energy savings and GHGs emissions issues, zero tillage, residue retention, green manuring, using of small farm machinery, real-time N management through leaf color chart offer a platform to highlight these issues. Among these techniques, zero-till transplanting without puddling provides a new opportunity for energy and C saving [16]. As rice cultivation requires a great quantity of water, the cultivation of rice in rotation with other crops that need low water consumption in the dry season is an interesting option. Crop rotation in rice fields can enhance the utilization of agricultural land [8].

As previously reported, the OM plays a fundamental role in a various biological, chemical, and physical processes in the soil ecosystem; the SOC stock is one of the essential indicators of soil health and quality. The SOC represents a large C stock in the global C cycle, acting as a dynamic balance between C inputs (through photosynthesis and deposition) and losses (via respiration, erosion, and leaching). The SOC accumulation can convert atmospheric $CO_2$ into stable organic C stocks in the soil and sequester atmospheric $CO_2$, to mitigate climate change. Subsequently, increasing and sustaining the SOC stock is a critical issue for reaching desired soil functions and sequestering atmospheric $CO_2$. Therefore, in agroecosystems, the SOC balance is affected by management practices as OM additions, fertilization, tillage intensity, irrigation, and crop rotation. Thus, the utilization of organic amendments such as farmyard manure, green manure, and crop residues has been recognized as the most practical method for increasing the SOC stock [59]. The potential carbon sequestration by improving soil C stocks via sustainable land management has now been realized for world agriculture. Management practices such as crop rotations, soil tillage, fallow periods and water management could either reduce or increase soil C sequestration. Paddy fields are documented to have higher SOC storage, and sequestration compared to drier croplands. Organic C accumulation in paddy ecosystems was faster and more distinct than other arable ecosystems because OM decomposition is reduced in lowland rice fields apparently due to extremely reduced conditions. As well, the deficiency of oxygen for microbial activity under submerged conditions results in a decline in the decomposition rate. Incomplete decomposition of organic materials has been reported in addition to decreased humification of OM under submerged conditions, causing net accumulation of OM in paddy soils. In the long term, soil management governs the weathering and mineral formation as well as accumulation of organic nitrogen in paddy soils. The suggested mechanisms for the accumulation of SOM in paddy soils are known as an occlusion in aggregates, the formation of organo-mineral associations, the addition of pyrogenic OM [25].

Over recent years, the scarcity and competition for water have been growing globally, and opportunities for developing new water resources for irrigation became increasingly limited. Rice as a dominant irrigated crop, representing about 30% of the total irrigated area. More than 50% of the rice area in the world is irrigated. With water becoming scarcer, the future of rice production will, therefore, rely heavily on developing and adopting efficient water use strategies and practices in irrigation schemes. This situation applies in many parts of the world; however, it is particularly critical for the Near East region because water is among the most limiting factors for general development and particularly for agriculture [2].

Rice cultivation is known as an important emitter of greenhouse gases emission especially methane (as a result of rice management practices, rice straw burning after harvesting and machinery activities [29]. However, some studies such as [2, 29, 60] recommended that changing management practices (such as decreasing ploughin, converting to agriculture conservation, replace burning of rice straw to some other uses and balanced fertilizer application) will lead to mitigating of greenhouse gases emission from rice cultivation. As well, such management practices improve build-up of soil organic matter stocks and enhance the environmental impacts of current management practices.

## 9 Conclusions

Agricultural soils in North Nile Delta Egypt is vulnerable to water shortage and climate change. Rice system in this area has higher C and N pools. However the area of rice production is expected to decline because of many reasons such as Establishing GERD and climate change. Management practices should be taken into consideration to avoid such decline in those soils and consequently decline in SOC which considers one of the most important methods to mitigate climate change if sequestered in the soil. Sequestering SOC decline $CO_2$ in the atmosphere where $CO_2$ is one of the most important GHG that cause climate change. Therefore, the attention should be paid for soil C sequestration in the North Nile Delta Egypt for balancing the excepted decline in C and N, due to reducing rice cultivation area because of many challenges such as climate change, water deficiency and sea level rice, as well for climate change mitigation.

## 10 Recommendations

1. Enhancing soil C stock should be considered not only for climate change mitigation but also for improving soil quality and agricultural productivity.
2. Rice field is one of the most important fields maintaining soil organic matter and soil C, therefore the quality of these fields should be enhanced or conserved.
3. Under the expected deficiency in water, rice cultivation should be directed in saving water and maintaining soil C through finding new cultivars consume less water and new methods reduce irrigation water.

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