**Water Resources Productivity in Egyptian Soils Under Climate Changes – A review**

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**Abstract**

One of the biggest economic and social concerns of the century will be the issues of water resource in arid regions of the Mediterranean, where mismanagement of water resources is threat to sustainable development. Egypt is one of the nations that will face significant issues due to its steady portion of the Nile's water. Climate change influences the spatial and temporal distribution of water supplies and the amount of crop evapotranspiration. In addition, water use in agriculture is by far the highest and is frequently criticized as being the least efficient. So, gaining more output per unit of utilized water is the idea behind improving agricultural water productivity. Identifying water resources, improving water productivity techniques are an essential in making most effective use of the agriculture sector in the Mediterranean agriculture areas. Freshwater resources in Egypt include the flow of the Nile, precipitation, and groundwater. Egypt also uses a variety of low-quality water sources, including treated wastewater and agricultural drainage water and desalination is utilized to provide residential water for several regions along the Mediterranean and Red Sea coasts. The paper will cover the water resources in Egypt, irrigation systems, methods of water-saving and improving water productivity.

**Key words**: Water resources, Climate changes, Egypt.

**Introduction**

Egypt depends mostly on the Nile River for its water supply, is experiencing water stress as a result of scarce resources, increased population and water competition for countries in the upper Nile Basin. Also, climate change affects the flow of the Nile and presents another challenge for Egypt's water resources (Abd Ellah 2020). Egypt is known for having a dry climate, little rainfall, most of its area covered by desert, and unreliable water supplies (Allam and Allam 2007). The total land area of Egypt is about 1 million km2 (238 million feddans). About 8.6 million feddan of the total land area, is cultivated, the majority of which is made up of recently reclaimed ground. Between 80 and 85% of the yearly water supply is used by agriculture, which is reliant on the Nile's water (Cooper *et al.* 2007). The Nile Delta, which is situated between the Damietta east tributary and Rosetta tributary on the west, and the narrow strip along the river Nile, where the majority of Egypt's agricultural land is concentrated, together account for less than 4% of the country's total area. Freshwater scarcity and misuse are a severe and growing challenge to environmental conservation and sustainable development (Medany *et al.* 1997). Nearly 98% of Egypt's freshwater supplies come from sources outside of its borders. Nile River meets more than 95% of the nation's needs for various types of water (Abdin and Gaafar 2009). Recent challenges pose the greatest danger to Egypt's water security, with the Ethiopian Renaissance Dam standing out (Mulat and Moges 2014). Additionally, population growth must be taken into consideration because urbanization, economic expansion, and population growth have all reduced the amount of commercially viable water resources in the area (Hamdy 2007). Egypt seems to be especially sensitive to climate change, particularly given its issue with water scarcity. Climate change will have an impact on how water resources are distributed both spatially and temporally, as well as increase crop evapotranspiration (Khalil *et al.* 2016). Understanding climate variables help to make suitable management decisions such as crop choice, sowing date and fertilizer rate (Sadras and McDonald 2012). Globally, the problem of water scarcity is enduring and getting worse, particularly in areas where water resources are being exploited for irrigation. According to climate change estimates, there would be an increase in evapotranspiration rates, which will have an impact on withdrawals and water stress. According to the FAO, agricultural water requirements will grow by 17% by 2050 under "business as usual" circumstances and by nearly 30% when climate change is taken into consideration, including projected expansions in irrigated areas. Climate change could result in a doubling of withdrawals by 2050 if the current WUE (as a ratio of crop water consumption to water withdrawals) stays around 50% (FAO 2021).

According to IPCC (2007) forecasts, between 75 and 250 million people would experience significant water stress during the coming decades due to climate change. Also, developing nations, notably those in Africa, are most at danger of suffering severe climate change-related consequences. Climate variability is one of the constrains for achieving crop water productivity level particularly in water-scarce locations (Wallace 2000). However, a practical approach to Egypt's water crisis consists only of bettering management and distribution procedures as well as modernizing and upgrading water supply systems. Development and management of water resources must be in harmony with energy policies and strategies for efficient resource conservation (Abou-Hadid 2006). Enhancing water productivity in water-scarce regions requires a change in the way agriculture practices and irrigation techniques. On-farm water-productive methods as combined with better management will significantly increase water productivity (Waraich *et al.* 2011). Food production must be dependent on increasing irrigation and water use efficiency to support this expanding population. Research has demonstrated that significant and long-lasting increases in water production are possible by utilizing integrated approaches to managing natural resources (Oweis and Hachum 2006). As Egypt is facing many challenges, there is a pressing need to improve water efficiency and supplement the current water sources with more sustainable alternatives. So, this paper is overview on water resources and the methods of improving irrigation water productivity in soils of Egypt.

**Water Resources in Egypt**

The main difficulty is to address the issue of the fast-expanding hole among the scarce water supplies and the growing demand for freshwater since the Egyptian water resources system is complex and uncertain (Fig. 1). The traditional sources of water in Egypt are the inflow of the Nile River, groundwater, and rainfall. However, using wastewater and desalinating seawater are examples of unconventional water supplies (Djuma 2016). The yearly per capita use of renewed freshwater in 2015 was 650 m3, which is much less than the 1,000 m3/year water scarcity criterion. Nearly 98% of freshwater resources, like the Nile River and underground aquifers, are found outside of its borders. In fact, 93% of the country's water needs are met by the Nile River. An estimate of the overall volume of deep groundwater puts it at around 40,000 billion cubic meters (BCM). Rainfall in Egypt is primarily concentrated in the north, totaling about 1 BCM every year (MWRI 2014).

Fig. (1): Water resources in Egypt (billion m3) (Ministry of water resources and irrigation, MWRI) (Abd Ellah 2020)

**Nile water**

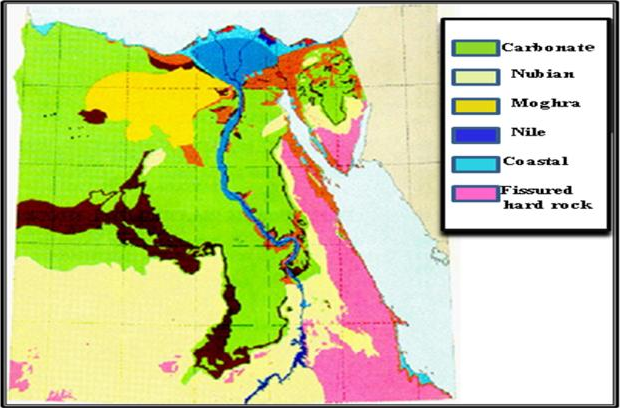
The river originates (Fig. 2) in the center of Africa and flows through the nations of “Tanzania, Burundi, Rwanda, Kenya, Congo, Uganda, Ethiopia, Eretria, South Sudan, Sudan and Egypt” (Muala *et al.* 2014). The Blue Nile (59%), Sobat (14%), and Atbara (13%), which contribute 86% of the Nile's flow, and the White Nile, which contributes 14%, both originate in the Ethiopian Plateau (Swain 2011). Since there is extremely little rainfall in Egypt, most Egyptians live close to the Nile River and depend on it for all their water needs (Ibrahim 2018). According to the 1959 Nile water deal Egypt has with Sudan, Egypt receives 55.5 billion cubic meters of Nile water annually. Since then, Egypt's population has been steadily growing, and in 2050, the country's share of renewable water resources per person is anticipated to reach 250 m3/person/year (Amer *et al.* 2017). Egypt dependent on the Nile River for 95% of its water resources, is experiencing water stress due to the limited water resources, expanding population, and greater competition for water from nations in the upper Nile basin. Climate change consequences on the Nile flow are adding to the pressure on Egypt's water management (Nour El-Din 2013).

Map

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**Fig. 2:** The countries of Nile River Basin (The World Bank)

**Ground water**

Egypt has a significant hydrogeologic potential due to its extensive groundwater aquifer network. One of Egypt's most significant water resources is groundwater. Water source and the type of the rocks that hold the water are the two key elements that affect the quality of groundwater (Elnashar 2014). Most aquifers in Egypt are typically made of unconsolidated or consolidated granular (sand and gravel) material or in fissured and karstified limestone. These aquifers are either unconfined or partially confined. In the Nile River region, there are various groundwater aquifers with varying levels of importance for extraction. They range from local shallow aquifers that are replenished by rainfall to deep aquifers that have non-renewable supplies that are heavily exploited (Abdel Moneim *et al.* 2014). Groundwater which can be found in various, and it is consider the second source of freshwater in Egypt which provides around 12% of the country's water and it is not an easily renewable resource (Soliman and Soliman 2017). They range from local shallow aquifers that are replenished by rainfall to deep aquifers. The Nile Valley and Delta system's groundwater is included in the first. The "Western Desert-Nubian Sandstone Aquifer" contains the nonrenewable type of aquifer, which is the second category. It is projected that non-renewable groundwater is used at a rate of 1.65 billion m3 per year (BCM/year) (Abdel-Shafy and Kamel 2016). On the other hand, as shown in Fig. 1 around 6.1 BCM/yr of groundwater is extracted in Delta, Sinai, and New Valley. The main underground reservoirs in Egypt (Fig. 3) are Nile aquifer, Nubian Sandstone aquifer, Moghra aquifer, Coastal aquifer, Fissured Carbonate aquifer, Pre-Cambrian Fissured and weathered hard rock aquifer, Groundwater in Sinai, Groundwater in the Western Nile Delta aquifers (Allam *et al.* 2003).

**Fig. 3:** Main groundwater aquifers in Egypt (MWRI 2005)

**Rainwater**

In Egypt, precipitation (mostly rain or rainfall) is primarily limited to the country's narrow north coast. The majority of Egypt's remaining land (more than 95%) is desert. Rainfall ranges from zero millimeters per year in the desert to over 200 millimeters per year at the northern coastal area (Abdel-Shafy *et al.* 2010). In several parts of Egypt, flash flooding and sporadic heavy rain are seen. Severe incidents with more than 200 mm of rain per day for the Mediterranean basin between 1973 and 2010 occurred in October (Mariani and Parisi 2014). While there have been exceptional rainfall events in Egypt, with Marsa Matruh (the northern coastal governorate) recording the highest total annual precipitation of 401 mm in 1994 (Gado 2017).

Map

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**Fig.4:** Allocation of mean annual precipitation in Egypt (Gado and El-Agha 2020).

A recent severe rainfall occurrence with powerful storms in October 2016 in Ras Gharib city on the Gulf of Suez resulted in a flash flood tragedy at the city's oil production sector (Elnazer *et al.* 2017). Most of Egypt is a hyper arid country with limited rainfall in winter season (Abdel-Maksoud 2018). Rainwater is mostly focused on a small area of land along Egypt's coast and gradually declines to the south (Abou Rayan 2004). Less precipitation and more evaporation result in less groundwater recharge. It is anticipated that these dry conditions and the decline in rainfall will increase the strain on the water supply. Additionally, rising sea levels and temperatures will also trigger seawater intrusion in coastal groundwater aquifers (Iglesias 2007). Total amount of rainwater is about 1.3 billion m3/year and should be used at different areas in Egypt as follows 0.38 billion m3/year as supplement to irrigation in the Nile Delta, 0.45 billion m3/year in Sinai, 0.20 billion m3/year in the Red Sea Coast and 0.27 billion m3/year in Alexandria and Marsa-Matrouh (Abdel-Shafy 2010). As shown in Fig. 4, a lot of rainwater can be harvested in Alexanderia, Baltim, Marsa Matrooh, and Dabaa. The rainfall resource comprises a minor part of water resources of Alexandria governorate while it has comparatively substantial percentages in both North Sinai and Marsa Matrouh Governorates. Rainwater harvest from Alexandria's urban areas has the potential to boost rainfall in the governorate's water resources by 50%. Also, water harvest from urban areas like Marsa Matrouh and Dabaa cities can substitute for some of the water needed for seawater desalination, reducing the associated overall expenses (Gabr *et al.* 2022)

**Drainage water**

Egypt's water demand is greater than its traditional supply, making the utilization of unconventional water resources essential. Since 1920, Egypt has been one of the first countries to reuse water (Abu-Zeid 2014). One of the newest applications for which Egypt has enough water is the treatment of drainage water (Abdin and Gaafar 2009). At several locations, drainage water is reinjected into the streams that supply the Nile Delta. This recycling greatly raises the Delta's overall water efficiency (Molle *et al.* 2016). According to Abd Ellah (2020) the reuse of agricultural drainage water in the Nile delta is 9.70 billion m3 per year (BCM) and domestic treated wastewater is 2.90 BCM.

**Desalination**

Water companies in Egypt produce daily about 25.1 million cubic meters serving about 98 million people. Most of the drinking water comes from surface water resources (approximately 85%), groundwater resources (about 10%), and desalination (about 5%) (HCWW 2020). Egypt's precarious water resource status compels the government to enhance its use of unconventional water sources (reuse of wastewater and desalination). These resources make up 22.2% of all the water that is readily available. According to estimates, desalination produces 0.5 BCM of water annually, and by 2030, that number will have increased to 1 BCM (Abdel Wahaab *et al.* 2021). Desalination has been taken into consideration in Egypt as a strategic water resource alternative for the development of rural areas, particularly in coastal areas. Also, it can be use agriculture drainage water after desalinized. Batisha (2007) showed that there are about 9 billion m3/year agricultural drainage water discharges to the Mediterranean due to its high salinity which prohibits its reuse. Desalination processes included three branches groundwater desalination, seawater desalination, and wastewater desalination. Egypt has extensive coastlines on both the Red Sea and the Mediterranean Sea (Fried and Serio 2012).

**Improving of irrigation water productivity**

The ratio of output to input is what is often meant by the phrase "efficiency" Efficiency is a word that is frequently used in irrigation system engineering design, evaluation, and management when referring to water. In irrigation, there are numerous names for efficiency; each one has a distinct definition and application (Keller and Bliesner 1990). The system is regarded to be more productive or efficient if the ratio is higher. Similar to this, irrigation efficiency describes the proportion of applied water to water used. The marketable crop generated per unit of water consumed in evapotranspiration is known as water use efficiency or productivity (Singh *et al.* 2014). Crop water productivity is controlled by plant specific factors, climate factors and management factors (Connor *et al.* 2011). To boost water use effectiveness and make the transition to a more sustainable use of water in agriculture, there must be an improvement in water use efficiency. There are a lot of methods for improving irrigation productivity: -

**Water Saving**

The improving of water use efficiency mainly depended on improving productivity or by saving water. Numerous variables, including meteorological conditions, edaphic factors, plant characteristics, and agronomic methods, have an impact on the efficiency of water consumption (Singh *et al.* 2014). To produce a high yield with the least amount of water input, must emphasize how to increase utilization rates and water usage efficiency. An agricultural system that saves water is one that uses integrated farming practices to better utilize irrigation systems and natural rainfall (Shan 2002). In other words, the aim is to maximize the economic benefit/biomass yield; water consumption/soil storage of water; transpiration/water consumption; soil-stored water content/ volume of precipitation (Deng *et al.* 2006). To meet crop water needs, irrigation scheduling techniques and proper irrigation system selection and use are critical components of water conservation and saving while conserving water use and simultaneously maximizing crop profit within the limitations of water shortage (Amer *et al.* 2017).

**Water harvesting**

In dry areas, precipitation is typically insufficient to meet crops' essential needs. It is negatively distributed throughout the growth season for crops and frequently manifests as a high intensity. The Mediterranean region frequently has dry spells throughout the growth season for crops because rain typically arrives in intermittent, unexpected storms and is largely lost to evaporation and runoff (Oweis *et al.* 1999). Water harvesting is a potential technique that has gained widespread acceptance around the globe and is used to address issues with water scarcity in agricultural production. In dry, semi-arid, and tropical regions, micro- and macro water gathering techniques are employed depending on the circumstance and the objective. Depending on the situation and the goal, micro- and macro water harvesting techniques are used in dry, semiarid, and tropical locations. By providing irrigation water at a crop's vital growing stage, the implementation of a water collecting system has been proved to have a favorable impact on agricultural productivity and increase yields (Komariah and Senge 2013). In arid and semiarid environments, rainwater harvesting is crucial for water conservation. It is imperative that these techniques be improved in order to lessen water stress caused by climate change and population increase (Mourad and Berndtsson 2011).

**Limited irrigation**

Agriculture is undoubtedly being forced to cede some of its share to higher priority users, particularly the home and industrial sectors, due to the fierce competition among water-using industries. Limited irrigation refers to the provision of supplemental irrigation during crucial growth stages while inducing a soil water deficit during noncritical periods of crop development. It is a technique for crop management in which irrigation systems that can only deliver a part of the water needed for crop growth are paired with dryland farming. (Shan *et al.* 2000). The most significant barrier to increasing agricultural production in locations with limited water resources is water. Deficit irrigation, which irrigates for less yield per unit land, can save a significant amount of water that can then be used to irrigate more land, increasing the amount of food that can be produced with the water that is available (Amer *et al.* 2017). Also, a great option for increasing crop yields in arid lands is supplemental irrigation, which combines dryland farming and minimal irrigation (Bai and Dong 2001). For effective irrigation planning, the timing and volume of water applied must correspond to the actual field conditions. In limited irrigation as opposed to full irrigation, more control over water application level and timing is required (Jabeen *et al.* 2022).

**Crop management**

Increasing crop yield per unit evapotranspiration is becoming a global obligation of every individual since water demand is increasingly higher than the supply. Additionally, this requires a mindset change away from maximizing yield per unit. The photosynthetic metabolic process differs between C3 and C4 plants. Because of this, there are differences between these two plant groups in the trade-off between photosynthetic leaf carbon uptake and water loss, which is often higher in C4 plants. For instance, sorghum and maize produce more grain per unit of seasonal transpiration than their C3 counterparts, wheat and barley (Sadras *et al.* 2011). By selecting crop varieties that are well suited to the environment, decreasing wasteful water use, and maintaining healthy, vigorously growing crops through improved water, fertilizer, and agronomic management, agricultural water productivity can be increased (Descheemaeker *et al.* 2013).Generally, adoption of various agronomic/management practices, such as growing hybrid/improved varieties rather than local varieties, timely crop sowing, crop sowing at optimal inter and intra row spacing, application of the optimum dose of fertilizers at the proper time, all these lead to improve water use efficiency.

**Soil management**

**Mulching**

To encourage plant growth and crop, Mulching is the process of applying an organic or synthetic mulch to the soil's surface around plants. It insulates soil to protect roots of plants and living organisms from a variety of weather conditions (Kader *et al.* 2019; Yu *et al.* 2018). In arid and semi-arid regions, mulching has emerged as a crucial water conservation technique in current agricultural production. The mulch material blocks sunlight from reaching the soil's surface, preventing evaporation by holding onto soil moisture, adjusting soil temperature and increase water use efficiently (Kader *et al.* 2019). Advantage of mulching primary is to preserve soil moisture by minimizing surface evaporation and erosion (Qin *et al.* 2016). Mulching is a practical technique that may help to retain moisture, reduce evaporation, change soil temperature, improve aeration, and release nutrients from the soil profile (Sharma *et al.* 2005; Ahmad *et al.* 2007). Mulching process increases lettuce yield and soil moisture retention. As a moisture-conservation strategy, grass mulch should be used because it will significantly boost lettuce output (Mkhabela *et al.* 2019). Mulching has been positively impacting crop development as well as the quantity and quality of the yields produced (Ramakrishna *et al.* 2005). Plastic mulches can be effectively used for sustaining plant growth and yield as well as controlling environmental pollution due to the use of plastics (Sharma and Bhardwaj 2017).

**Soil conditioners**

The behavior of soil-water-plant relationships and the availability of nutrients to plants are both impacted by soil management. In essence, proper soil moisture management and efficient water use are essential for realizing the arid and semi-arid considerable potential for further enhancing the efficiency of agricultural water utilization (Jabeen *et al.* 2022). Therefore, it is critical that soil be properly managed to improve crop water productivity (CWP). Water use efficiency and soil water content retention may be significantly impacted by soil amendments mixed with irrigation (Ali *et al.* 2018). Soil management practices that improve water retention, help roots draw more water from the soil, reduce leaching losses all have the potential to improve water use efficiency (WUE). The capacity of the soil to hold water would benefit from improved soil management practices that increase the quantity of organic matter in the soil (Hatfield *et al.* 2001). Certain organic compounds and soil conditioners improve the water retention capacity of sandy soils with low aggregate stability and water retaining capacity (Brady and Weil 2008).

**Nutritional management**

A significant way to increase production and water use efficiency is through proper plant nutrition. When there is a limited supply of water, plant nutrients are crucial for improving water usage efficiency (Waraich *et al.* 2011). In dry and semi-arid regions, the addition of organic fertilizer to N and P fertilizer improved soil water use efficiency (WUE) and crop yield (Liu *et al.* 2020). Also, the rational fertilization under water-limited conditions had a good effect to improve water use efficiency (Guo *et al.* 2019). Fertilization can improve a crop's capacity to utilize deep-layer soil water while decreasing the amount of water used in the soil (Ren *et al.* 2019). The addition that the use of organic and inorganic fertilizers enhanced WUE and had a direct impact on soil water storage (Zhang *et al.* 2019). There is some need to develop new technology for the efficient use of water and fertilizer for agriculture due to rising food demand and declining water resources. It must be taken the environmental sustainability and the preservation of soil and water resources. Therefore, using water and fertilizer efficiently and sparingly is crucial for protecting the environment (Hagin *et al.* 2003).

**Irrigation systems management**

**Conventional irrigation methods**

Poor irrigation technologies and management have been causing low crop water productivity (CWP) in water limited areas, especially in developing (Lacirignola *et al.* 2014). It is necessary to applied water accounting and change from traditional agricultural production methods that attempted to maximize yield per unit area of soil to more water-conscious techniques that strive to optimize crop output per unit water consumption, which is measured by evapotranspiration (Kilemo 2022). The flood irrigation system, which accounts for 60% of the country's irrigated land, is the most popular one in Egypt. Its effectiveness is between 40% and 50% (Karajeh *et al.* 2013). To accomplish the aims of the 2030 Sustainable Development Strategy, which sought to embrace the integrated water resources management method, it is crucial to increase the deployment of advanced irrigation technologies. This improves the efficiency of the irrigation system from 40% to 80% (Wahba *et al.* 2018).

**New irrigation systems**

Irrigation is essential for enhancing agricultural output in semiarid and arid climates. To boost productivity per unit area in the face of water scarcity, new technology must be used (Okasha *et al.* 2016). As is common knowledge, pressured irrigation systems like sprinkler and drip irrigation utilize substantially less water than traditional irrigation techniques (surface irrigation). Use of contemporary irrigation systems in newly reclaimed soil, conversion of surface irrigation to drip irrigation systems can achieve higher water use efficiency and higher advantages. Chemicals and fertilizers can also be used in the precise concentrations needed drip irrigation and fertigation have the capacity to greatly increase the availability and uptake of water and nutrients in soil, increasing crop yield (Çetin and Akalp 2019). The adoption of sophisticated irrigation systems has raised irrigation efficiency in some countries from 65% to 87% (Berbel *et al.* 2019). The use of new irrigation systems it’s very important to increase the yield per unit of water used and decreasing water loss. Also, the management and creative design of integrated water distribution and application schemes could lead to enhance gain yield. It is essential to preserve water and encourage the highest crop growth to maximize water use efficiency (WUE) through reduce weeds' transpiration, runoff, seepage, and evaporation and choose cultivars that are well suited to the local soil and climatic conditions can achieve the main goal (De Pascale *et al.* 2011). So, knowledge of the soil moisture levels at the time of irrigation is necessary. Additionally, adopting water-saving methods for water transportation and application is a requirement for irrigation that uses less water by converting to more effective irrigation system to improve WUE (Deng *et al.* 2006).

A smart irrigation system that can conserve water is necessary since irrigation uses a lot of water. By automatically watering plants and gardens according to their needs, it also aids in water conservation. Smart systems enable overall water savings of 67% when compared to conventional methods. So, in water-scarce places and for individuals living far from their farms, effective water uses and visit-free monitoring offer clever solutions (Nawandar and Satpute 2019). This technology ensures irrigation pumps last a long time, recycles used water to reduce water loss. In this way, it makes sure that different plants are watered according to the different amounts of water they require for efficient growth. It would be helpful in areas where the practice of irrigation is complicated by a lack of water (Ogidan *et al.* 2019).

**Climate change**

Climate change is a long-term, decades-long, or even longer-term change in climate variables or factors (Najjar *et al.* 2017). The studies forecast that the global food and water resource issue will get worse due to prolonged climate change (Pokhrel *et al.* 2021). One of the main concerns in agricultural systems is global climate change, which is characterized by the global warming brought on by an increase in atmospheric carbon dioxide concentration (IPCC *et al.* 2014). The increase in greenhouse gas emissions will result in a temperature rise of around 2.12 °C in 2050 and 3.96 °C in 2100 over the middle Egypt region. As a result, in 2050 and 2100, the irrigation water requirements for the wheat crop are anticipated to rise by 6.2 and 11.8%, respectively. The productivity of wheat will also decrease by 8.6 in 2050 and 11.1% in 2100 (Mostafa *et al.* 2021). Availability of water resources may be impacted by climate change. In many areas, agriculture depends on groundwater. Recharge of groundwater is a by-product of irrigation return flow. Aquifer storage may therefore be important as a result of climate change (Yu *et al.* 2010).

Egypt may have major negative economic effects from climate change. The Nile River's flow may drop, and this could have an impact on the nation. Egypt features a sizable area of low-lying coastal regions that are densely populated and have a robust agricultural sector. These regions are extremely susceptible by climate change. Given its reliance on Nile water and susceptibility to temperature increases, agriculture is extremely vulnerable (Smith *et al.* 2014). Also, many climatological studies predict that as temperatures rise, evapotranspiration will significantly increase on Egyptian soil, especially given the country's historically irrigated agriculture. Additionally, the anticipated high temperature would raise local water demands, particularly for the agriculture industry. The greatest obstacle to horizontal agricultural expansion in Egypt under the current and future climates is the country's limited water resources and water scarcity (Khalil *et al.* 2016). The total amount of water needed for agriculture in the Arabic countries will rise by a percentage ranging from 9% to 36% under a 2oC temperature increase (Ouda *et al.* 2011). Water requirements for wheat and maize will increase by 2 and 15%, respectively in 2040 at El-Behira governorate (North Egypt) (Ouda *et al.* 2015). Under future climate change, the pressure on agricultural water use will increased. Climate change circumstances are predicted to raise the evapotranspiration values for all of Egypt's governorates, which will have an impact on water requirements, especially at Upper Egypt and some sections of Lower Egypt (Khalil *et al.* 2016).

Projections of agricultural land use heavily rely on the relationship between soil and climate (Soleimani *et al.* 2017). Three major issues are the result of climate change in Egypt: (1) rising of sea level, which could endanger the coastal region and the Nile Delta; (2) the rising temperature, which would require Egypt to alter her agricultural policy; and (3) water shortage (Mahmoud 2017). As a result, Egypt may face a serious threat from climate change in the areas of agriculture, food safety, and water shortage. Egypt should therefore establish an urgent plan to prevent any problems that may arise as a result of these changes in the country's climate (Froehlich and Al-Saidi 2017). Due to its geographic location, Egypt experiences unusual weather, with Mediterranean-like conditions for its coastal parts in the winter and dry conditions in the summer, with temperatures occasionally topping 40 °C in the deserts. The principal cities of Egypt that are situated in the desert, such as Luxor, Aswan, Asyut, Siwa, or Sohag, have greater summertime temperatures than higher elevations, such as some of the mountains in Sinai like Saint Catherine. Egyptian geological zones, which include the Sinai Peninsula (6%), the Eastern desert (22%), the Western desert (68%), and the Nile River and delta (approximately 4% of the country's total size), could be utilized to describe Egypt climate (El-Marsafawy *et al.* 2018). The Mediterranean Sea has a considerable impact on climate of northern coastal areas. The climate in Egypt varies greatly, ranging from a temperate Mediterranean environment along the northern coast to a hot desert temperature in the Upper Egypt region. The winter months in Egypt are December through February, whereas the summer months are June through August. Crop production extremely susceptible to climatic variations. Thus, this will result in significant changes in crop distribution as a result of climate change. Additionally, it has been predicted that in the twenty-first century, climate changes cause crop damage or yield reductions in several parts of the world (Osman 2013). Monthly climatology of temperature and precipitation 1991-2020 of Egypt are shown in Fig. 5 and 6 respectively.

Fig. (5): Monthly climatology of Min-temperature, Mean- temperature and M-ax-temperature 1991-2020 of Egypt. (Data is presented at a 0.5º x 0.5º (50km x 50km) resolution by the Climatic Research Unit (CRU) of University of East Anglia. (Climate change knowledge portal). <https://climateknowledgeportal>. World bank. org/country/ Egypt/climate-data-historical).

Fig. (6): Monthly climatology of precipitation 1991-2020 of Egypt. (Data is presented at a 0.5º x 0.5º (50km x 50km) resolution by the Climatic Research Unit (CRU) of University of East Anglia. (Climate change knowledge portal). <https://climateknowledgeportal>. World bank. org/country/ Egypt/climate-data-historical).

**Conclusion**

All studies showed that improving water productivity in irrigated agriculture is unavoidable due to climatic change and limited water. To increase water use efficiency, further development measures necessitate a review of current water allocations. Additionally, to close the gap between water supply and demand, nonconventional water resource choices must be investigated. Effective moisture conservation and efficient use of the limited water resources are necessary to significantly improve agricultural water use efficiency. This calls for a change in crop production methods from traditional ones that sought to maximize crop yield per unit area of land to more water-conscious ones that try to optimize crop yield per unit of water consumption, which is determined by evapotranspiration. So, Egypt should be creating a quick plan to stop any issues that might occur from these climate changes and water shortage by using rainwater harvesting; Managing agricultural water resources to maximize crop productivity by using less water; enhancing the effectiveness of the water supply, identifying leaks, and improving irrigation distribution and conveyance efficiency; use modern irrigation systems and launching water-saving initiatives. Under virtual water trade agreements, it is advised that water-poor countries plant high-value crops and use the proceeds to acquire food from water-rich countries.

**Conflicts Interests**

The author has declared that no competing interest exists.

**References**

Abd Ellah R G (2020). Water resources in Egypt and their challenges, Lake Nasser case study- *Egypt. J Aquat Res* 46(1):1-12.‏

Abdel Moneim AA, Zaki S, Diab M (2014). Groundwater Conditions and the Geo environmental Impacts of the Recent Development in the Southeastern Part of the Western Desert of Egypt. *J Water Resource Prot* 6: 381-401.

Abdel Wahaab R, Elsayed M W H, Ibrahim M S, Hasballah A F (2021). Application of Water Safety Plans to Improve Desalination Water Supply at Matrouh Governorate, *Egypt. Egyptian J Chem* 64(11): 6749-6759.‏

[Abdel-Maksoud BM (2018). Estimation of air temperature and rainfall trends in](http://refhub.elsevier.com/S1687-4285(20)30020-0/h0030) [Egypt. *Asian J Adv Res Rep* 1 (4): 1–22](http://refhub.elsevier.com/S1687-4285(20)30020-0/h0030).

Abdel-Shafy HI, Kamel AH (2016). Groundwater in Egypt issue: resources, location, amount, contamination, protection, renewal, future overview. *Egypt J Chem* 59(3): 321-362.‏

Abdel-Shafy HI, El-Saharty A A, Regelsberger M, Platzer C (2010). Rainwater in Egypt: quantity, distribution and harvesting. *Mediterr Mar Sci* 11(2):245–257.

Abdin A E, Gaafar I R (2009). Rational water use in Egypt. In Moujabber M. (ed.), Mandi L. (ed.), Trisorio-Liuzza G. (ed.), Martin I. (ed.) Rabi A. (ed.) Rodriguez R. (ed.). Technological perspective for rational use of water resources in the Mediterranean region. Bari: CIHEAM, 2009. 17p

Abou Rayan M, Djebedijian B, Khaled I (2004). Evaluation of the effectiveness and performance of desalination equipment in Egypt. Eight Intern Water Techn Conf, IWTC8, Alexandria, Egypt, 653- 668.

Abou-Hadid AF (2006). Water use efficiency in Egypt. AARINENA Water Use Efficiency Network, 38.‏

AbuZeid K, Elrawady M (2014). 2030 strategic vision for treated wastewater reuse in Egypt”. *Water Resour Manage Prog*‏ 48p.

Ahmad MD, Turral H, Masih I, Giordano M, Masood Z (2007). Water saving technologies: myths and realities revealed in Pakistan’s rice–wheat system. In: International Water Management Institute (IWMI) research Paper 108, Colombo, Sri-Lanka, 44 pp.

Ali S, Jan A, Sohail A, Khan A, Khan M I, Zhang J, Daur I (2018). Soil amendments strategies to improve water-use efficiency and productivity of maize under different irrigation conditions. *Agric Water Manage* 210: 88-95.‏

Allam AR, Saaf E, Dawoud MA (2003). Desalination of brackish groundwater in Egypt. Desalination 152: 19-26.

[Allam MN, Allam GI (2007). Water resources in Egypt: Future challenges and](http://refhub.elsevier.com/S1687-4285(20)30020-0/h0060) [opportunities. *Water Inter* 32 (2): 205–218](http://refhub.elsevier.com/S1687-4285(20)30020-0/h0060)

Amer M H, Abd El Hafez S A, Abd El Ghany M B (2017). Water Saving in irrigated agriculture in Egypt. LAP LAMBERT Academic Publishing: Saarbrücken, Germany.‏

Bai QJ, Dong ST (2001). Agricultural high-efficient water usage and sustainable development of water saving agriculture. *J Shandong Agric Univ* 32: 331–335.

Batisha, A. (2007 March). Water desalination industry in Egypt. In Eleventh international water technology conference, IWTC11.‏

Berbe l J., Expósito A, Gutiérrez-Martín C, Mateos L (2019). Effects of the irrigation modernization in Spain 2002–2015. *Water Resour Manage* 33:1835–1849.

Brady N C, Weil R R (2008). The nature and properties of soils. 13: 662-710. Upper Saddle River, NJ: Prentice Hall.

Çetin O, Akalp E (2019). Efficient use of water and fertilizers in irrigated agriculture: drip irrigation and fertigation. *Acta Horticulturae et Regiotecturae* 22(2): 97-102.‏

Connor DJ, Loomis RS, Cassman KG (2011). Crop Ecology: Productivity the Management in Agricultural Systems. 2nd Edition, Cambridge University Press, Cambridge.

Cooper A F, Antkiewicz A, Shaw T M (2007). Lessons from BRICSAM about South-North Relations at the Start of the 21st Century: Economic Size Trumps All Else? Int Stud Rev 9 (4): 675-687.

De Pascale S, Dalla Costa L, Vallone S, Barbieri G, Maggio A (2011). Increasing water use efficiency in vegetable crop production: from plant to irrigation systems efficiency. *Hort Technology* 21(3): 301-308.‏

Deng X P, Shan L, Zhang H, Turner N C (2006). Improving agricultural water use efficiency in arid and semiarid areas of China. *Agri water manage* 80(1-3): 23-40

Descheemaeker K, Bunting SW, Bindraban P, Muthuri C, Molden D, Beveridge M, Van Brakel M, Herrero M, Clement F, Boelee E, Jarvis DI (2013). Increasing Water Productivity in Agriculture. In: Boelee, E., Ed., Managing Water the Agroecosystems for Food Security, CAB International, Wallingford, 104-123.

Djuma H, Bruggeman A, Eliades M, Lange MA (2016). Non-conventional water resources research in semi-arid countries of the Middle East. *Desalin Water Treat* 57 (5): 2290–2303.

El-Marsafawy S, Bakr N, Elbana T, El-Ramady H (2018). The Soils of Egypt, 69.‏

Elnazer,AA, Salman SA, Asmoay AS (2017). Flash flood hazard affected Ras Gharib city, Red Sea, Egypt: a proposed flash flood channel. Nat Hazards.

FAO (2021). The State of the World’s Land and Water Resources for Food and Agriculture: Systems at breaking point. Synthesis report.

[Fried A, Serio B (2012). Water industry segment report desalination. World Trade](http://refhub.elsevier.com/S1687-4285(20)30020-0/h0165) [Center, San Diago- Desalination Industry Report, p. 35](http://refhub.elsevier.com/S1687-4285(20)30020-0/h0165).

Froehlich P, Al-Saidi M (2017). Community-based adaptation to climate change in Egypt: status Quo and future policies. In: Leal Filho W (ed) Climate change research at universities. Springer International Publishing AG, pp 235–250.

Gabr M, El-Ghandour H, Elabd S (2022). Rainwater harvesting from urban coastal cities using recharging wells: a case study of Egypt. *Port-Said Engi Res J* 26(3): 17-36.‏

Gado T A, El-Agha D E (2020). Feasibility of rainwater harvesting for sustainable water management in urban areas of Egypt. *Environ Sci Pollut Rese* 27(26): 32304-32317.‏

Gado TA (2017). Statistical characteristics of extreme rainfall events in Egypt. In: Twentieth international water technology conference, IWTC20. Hurghada, Egypt

Guo Q, Cheng C, Jiang H, Liu B, Wang Y (2019). Comparative rates of wind and water erosion on typical farmland at the northern end of the Loess Plateau, China. – *Geoderma* 352: 104-15.

Hagin J, Sneh M, Lowengart-Aycicegi A (2003). Fertigation, Fertilization through Irrigation. International Potash Instituıte, IPI Research Topics, Basel, Switzerland, 2003, 23.

Hamdy A (2007). Water use efficiency in irrigated agriculture: an analytical review. Water use efficiency and water productivity: WASAMED project 9-19.‏

Hatfield J L, Sauer TJ, Prueger JH (2001). Managing soils to achieve greater water use efficiency: a review. *Agronomy J* 93(2): 271-280.‏

HCWW (2020). Internal report. Holding Company for Water and Wastewater, Cairo

Ibrahim M, Al-Zyoudand S, Elhaddad E (2018). Surface water quality monitoring for RiverNile, Egypt using GIS-techniques. *The Open Geology J* 8: 161– 173.

[Iglesias A, Garrote L, Flores F, Moneo M (2007). Challenges to manage the risk of](http://refhub.elsevier.com/S1687-4285(20)30020-0/h0205) [water scarcity and climate change in the Mediterranean. *Water Resources*](http://refhub.elsevier.com/S1687-4285(20)30020-0/h0205) [*Manage* 21: 775–788](http://refhub.elsevier.com/S1687-4285(20)30020-0/h0205).

IPCC (2007). Climate change 2007: the physical science basis, summary for policy makers. Contribution of working group 1 to the fourth assessment report of the intergovernmental panel on climate change, WMO. UNEP, 18 p.

IPCC (2014). Climate change 2014: Impacts, adaptation, and vulnerability. In: Field, C.B. Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., White, L.L. (Eds.), Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jabeen M, Ahmed S R, Ahmed M (2022). Enhancing water use efficiency and grain yield of wheat by optimizing irrigation supply in arid and semi-arid regions of Pakistan. *Saudi J Biolo Sci*29(2): 878-885.‏

Kader M A, Singha A, Begum M A, Jewel A, Khan F H, Khan N I (2019). Mulching as water-saving technique in dryland agriculture. *Bull Natl Res Cent* 43(1): 1-6.‏

Karajeh F, Oweis T, El-Gindy S A A, El-Quosy D, Khalifa H, El-Kholy M, Abd El-Hafez S (2013). Water and agriculture in Egypt. Working Papers 253822, International Center for Agricultural Research in the Dry Areas (ICARDA), Cairo, Egypt

Keller J, Bliesner RD (1990). Sprinkle and Trickle Irrigation. Van Nostrand Reinhold. Publish. New York. PP 652.

Khalil A A, Essa Y H, Hashem F A, Refaie K M (2016). Water consumption variability for major crops in Egypt under climate condition. Int J Adv Res Publ 4(9): 1157-1168.‏

Kilemo DB (2022). The Review of Water Use Efficiency and Water Productivity Metrics and Their Role in Sustainable Water Resources Management. *Open Access Libr J* 9: (1) 1-21.

Komariah and Senge M (2013). The Development of Water Harvesting Research for Agriculture. *Rev Agric Sci* 1: 31-42

Lacirignola C, Capone R, Debs P, El Bilali H, Bottalico F (2014). Natural Resources-Food Nexus: Food-Related Environmental Footprints in the Mediterranean Countries. *Front Nutr1*- 23.

Liu Q, Mu X M, Zhao G J, Gao P, Sun WY (2020). Effects of fertilization on soil water use efficiency and crop yield on the loess plateau, China. *Appl Ecol Environ Res* 18: 6555-6568.‏

Mahmoud MA (2017). Impact of climate change on the agricultural sector in Egypt. In: Negm AM (ed) Conventional water resources and agriculture in Egypt, Handbook Environment of Chemistry. Springer International Publishing AG.

Mariani L, Parisi SG (2014). Extreme rainfalls in the Mediterranean area. In Diodato N, Bellocchi G (eds) Storminess and environmental change, advances in natural and technological hazards research, Vol 39. Springer Science + Business Media Dordrecht, pp 17–37.

Medany M A, Wadid M M, Abou-Hadid A F (1997). New Extension System for Modern Irrigation Management in Egypt.

Mkhabela K T, Dlamini M V, Manyatsi AM (2019). The effect of mulching on soil moisture retention and yield of lettuce (Lactuca sativa L.). *Intl J Environ Ag Res* 5(9): 47-50.‏

Molle F, Gaafar I, El-Agha DE, Rap E (2016). Irrigation efficiency and the Nile Delta water balance. Egypt

Mostafa S M, Wahed O, El-Nashar W Y, El-Marsafawy S M, Abd-Elhamid H F (2021). Impact of climate change on water resources and crop yield in the Middle Egypt region. AQUA-Water Infrastructure. *Eco Soc* 70(7): 1066-1084.

Mourad K A, Berndtsson R (2011). Potential water saving from rainwater harvesting in Syria.‏

Muala E, Mohamed Y, Duan Z. van der Zaag P (2014). Estimation of reservoir discharges from Lake Nasser and Roseires reservoir in the Nile basin using satellite altimetry and imagery data. *Remote Sensing* 6: 7522–7545

Mulat AG, Moges SA (2014). Assessment of the impact of the Grand Ethiopian Renaissance Dam on the performance of the High Aswan Dam. *J Water Res Protec* 6: 583–598.

MWRI (2014). ‘Water Scarcity in Egypt.’ Available at [www.mfa.gov.eg/SiteCollectionDocuments/Egypt%20](http://www.mfa.gov.eg/SiteCollectionDocuments/Egypt%20) Water % 20 Resources % 20Paper\_2014.pdf, accessed [10-11-2018].

MWRI (2005) National Water Resources Plan for Egypt–2017, Ministry of Water Resources and Irrigation, Planning Sector, Arab Republic of Egypt

Najjar S, Bhatia U, Ganguly AR (2017). Climate adaptation: introduction. In: Shekhar S et al (eds) Encyclopedia of GIS. Springer International Publishing AG, pp 174–179.

Nawandar N K, Satpute V R (2019). IoT based low cost and intelligent module for smart irrigation system. *Comput Electron Agric* 162: 979-990.‏

Nour El-Din, M.M. (2013). Climate change risk management in Egypt and proposed climate change adaptation strategy for the ministry of water resources & irrigation in Egypt. UNESCO.

Ogidan, O.K., Onile, A.E. and Adegboro, O.G. (2019). Smart Irrigation System: A Water Management Procedure. *Agric Sci* 10: 25-31.

Okasha A M, EL Metwally WF, Attaffey TM (2016). Effect of different types of irrigation systems on soybean production under clayey soil conditions. *Misr J Ag Eng* 33 (1): 43 – 62.

Osman KT (2013). Climate change and soil. In: Osman KT (ed) Soils: principles, properties and management. Springer Science + Business Media Dordrecht, pp 253–261.

Pokhrel Y, Felfelani F, Satoh Y, Boulange J, Burek P, Gädeke A, Wada Y (2021). Global terrestrial water storage and drought severity under climate change. *Nat Clim Chang* 11(3): 226–233

Ouda S, Khalil F, El Afendi G, Abd El-Hafez S (2011). Prediction of total water requirements for agriculture in the Arab World under climate change.15th International Water Technology Conference. 11501163.

Ouda S, Noreldin T, Abd El-Latif K (2015). Water requirements for wheat (Triticum spp.) and maize (Zea mays) under climate change in north Nile Delta. *Span J Agric Res* 13(1):1-10.

Oweis T, Hachum A (2006). From water use efficiency to water productivity: issues of research and development. AARINENA water use efficiency network, 14.‏

Oweis T, Hachum A, Kijne J (1999). Water Harvesting and Supplemental Irrigation for Improved Water Use Efficiency in the Dry Areas. SWIM Paper 7. Colombo, Sri Lanks: International Water Management Institute

Qin S, Li S, Kang S, Du T, Tong L, Ding R (2016). Can the drip irrigation under film mulch reduce crop evapotranspiration and save water under the sufficient irrigation condition? *Agric Water Manage* 177:128–137.

Ramakrishna A, Tam H, Wani S, Long T (2005). Effect of mulch on soil temperature, moisture, weed infestation and yield of ground nut in northern Vietnam. *Field Crops Research* 95(2-3): 115-125.

Ren K, Zhang X, Li X, Yu X, Liu Z, Wang G, An G, Jiang B (2019). Effects of organic and chemical fertilizers on nutrient absorption and yield of potato. – Soil fertilizer 6: 1672-3635.

Sadras OV, McDonald G (2012). Water Use Efficiency of Grain Crops in Australia: Principles, Benchmarks the Management. Grains Research the Development Corporation, South Australian Research the Development Institute, the University of Adelaide, Adelaide.

Sadras VO, Grassin IP, Steduto P (2011). Status of Water Use Efficiency of Main Crops. SOLAW Background Thematic Report-TR07. Food and Agriculture Organization of the United Nations, Rome, 41 p.

Shan L (2002). Development of tendency on dry land farming technologies. *Agric Sci China* 1: 934–944.

Shan L, Huang Z.B, Zhang SQ (2000). Water-saving Agriculture. Tsinghua University Press, Beijing, Peoples Republic of China

Sharma AR, Singh R, Dhyani SK (2005). Conservation tillage and mulching for optimizing productivity in maize–wheat cropping system in the western Himalayan region. *Indian J Soil Conserv* 33: 35–53.

Sharma R, Bhardwaj S (2017) Effect of mulching on soil and water conservation-A review. *Agric Rev* 38(4): 311-315

Singh L, Mirza KAB, Akhter S, Qayoom S, Lone BA, Singh P, Singh P (2014). Efficient techniques to increase water use efficiency under rainfed eco-systems. *J Agri Search* 1(4): 193-200.

Smith J B, McCarl B, Kirshen P, Jones R, Deck L, Abdrabo M A, Hynninen R (2014). Egypt’s economic vulnerability to climate change. *Climate Res* 62(1): 59-70.‏

Soleimani A, Hosseini SM, Bavani ARM, Jafari M, Francaviglia R (2017). Simulating soil organic carbon stock as affected by land cover change and climate change, Hyrcanian forests (northern Iran). *Sci Total Environ* 599–600:1646–1657

Soliman A, Soliman M (2017). Groundwater potential in the new valley southwest of the Nile Delta in Egypt. In: Negm A. (eds) Groundwater in the Nile Delta. Handbook of Envir Chem73: 585- 621.

Swain A (2011). Challenges for water sharing in the Nile basin: Changing geopolitics and changing climate. *Hydrol Sci J* 56 (4): 687–702.

Wahba, S.M., Scott, K., Steinberger, J.K. (2018) Analyzing Egypt’s water footprint based on trade balance and expenditure inequality. *J Cleaner Prod* 198:1526–1535

Wallace JS (2000). Increasing Agricultural Water Use Efficiency to Meet Future Food Production. *Agric Eco Environ* 82, 105-119.

Waraich E A, Ahmad R, Ashraf M, Saifullah Y, Ahmad M (2011) Improving agricultural water use efficiency by nutrient management in crop plants.   
Acta Agric Scand - B *Soil Plant Sci* 61(4): 291-304.‏

Yu YY, Turner NC, Gong YH, Li FM, Fan C, Ge LJ, Ye JS (2018). Benefits and limitations to straw- and plastic-film mulch on maize yield and water use efficiency: a meta-analysis across hydrothermal gradients. *Eur J Agron* 99: 138–147

Yu Z, François Z, Yanxin W, Yilian L (2010). Impact of climate change on irrigation requirements in terms of grou,ndwater resources. *Hydrogeol J* 18 (7): 1571–1582.

Zhang Y, Wang R, Wang H, Wang S, Wang X, Li J (2019). Soil water use and crop yield increase under different long-term fertilization practices incorporated with two-year tillage rotations. *Agr Water Manage* 221: 362-370.