Climate Change and its Effects on the Agriculture and water resources

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Received date: 03/05/2021; **Revised date:** 25/ 05 /2021 ; **Publication date:** 30/06/2021

Summary: The impact of climate change on agriculture is growing in all regions of the world. The main aim of this paper is provides an overview of the effects of climate change on agriculture, which drawn from a review of recent scientific literature on climate change, with considers expected effects on water resources and explores the challenges and opportunities for adaptation. The research results concludes that risk assessment is a key factor in reducing agriculture vulnerability to climate change. Successful adaptation depends primarily Climate risk management, understanding their impacts will allow the design and implementation of effective adaptation measures.

Keywords: water, Adaptation, agriculture, climate change, vulnerability.

Jel Classification Codes: Q54, Q19, L95.

I- Introduction :

Today, few scientists still have doubts about climate change. Most believe that the process of global warming is accelerating and that its consequences are worrying: ocean water is warming, glaciers are melting, sea levels are rising, and inhabited coastal areas could be inundated. Agricultural regions will move, climate fluctuations will increase, resulting in more violent storms (Epstein, 2000).

Like desertification, sustainable development, natural resources and biodiversity, climate change is one of the topics most discussed by the scientific community in natural science today. Pavé et al. (1998) rank climate change first among 11 priority problem groups with 11.5% of themes of concern to scientists.

Climate change is one of the biggest challenges to the world in present times. It is defined as significant changes in the average values of meteorological elements, such as precipitation and temperature, for which averages have been computed over a long period (WMO, 1992).

Climate change presents a novel challenge because of the sensitivity of agricultural system response to climatic variability and the complexity of interactions between agriculture and the global climate system. Interactions within the agricultural social- ecological system can result in synergistic effects that dampen or amplify the system response to climate change and complicate development of effective mitigation and adaptation options (Reidsma et al., 2010; Smith and Olesen, 2010).

Food production has increased with demand, yet in an increasingly populated world, malnutrition and poverty remain. The population continues to grow and fears are created due to the potential imbalance between the number of human beings and food needs. Some research (OECD, 2009; FAO, 2006; SIWI, 2004) estimates that world food production will have to increase by 70% by 2050 and that water requirements would double current needs by 2025. Agricultural productivity, in turn, it must improve, while land and water resources become less abundant, and the effects of climate change introduce great uncertainty (Huan et al.2011).

The increase in the average temperature of the air and the ocean, the melting of snow from the glaciers and the poles, and the rise in sea level are some of the effects of climate change (IPCC, 2007). As a consequence, a series of impacts could be experienced, on a global scale, including: changes in ecosystems, in water availability, in crop productivity and in the distribution of vectors and diseases; in addition to the possible increase in extreme meteorological events1 such as storms, droughts and floods (IPCC, 2007; Stern, 2006).

These effects make climate change threaten the basic elements for life such as access to water, food production, health, land use and ecosystems (Stern, 2006); that, in addition, significant restrictions are generated in various economic activities such as: agriculture, fishing, health, forestry, transport, tourism, energy and water systems (IPCC, 2007; Seo, 2011).

Possible impacts estimated by the Intergovernmental Panel on Climate Change (IPCC, 2007; Adger,2007).for agriculture include increased yields in colder environments and decreased production in warmer environments, damage to crops, increased pests, increased danger of forest fires and soil erosion. While water pollution, increased demand and decreased availability of fresh water are some of the possible effects on water resources.

Algeria, although it only contributes less than 0.5% of global GHG emissions, is vulnerable to climate change. In the agricultural context, the Algerian territory has a great capacity to supply the national market and has reached a recognized position in export products; however, the sector not only has to face the challenge posed by low productivity, one of the most lagging behind in the economy, but also needs to implement effective adaptation measures. Adaptation is the degree to which it is possible to make adjustments in the practices, processes and structures of the systems, depending on the provided or actual changes in the climate (IPCC, 2007; Adger, 2007).

The Mediterranean region is quite vulnerable to climate change since it lies in a transition zone between the arid climate of North Africa and the temperate and rainy climate of central Europe and it is affected by interactions between mid-latitude and tropical processes. Algeria, which is part of Mediterranean hot spot, is very vulnerable to climate change. Experts predict at the medium term an increase in temperature of 2 °C, a decrease in rainfall of 10 to 15% and more frequent droughts and more intensive.

Algeria, which is a country subject to a difficult climate (mainly arid and semi-arid), is strongly feeling the effects of climate change. In addition to the high warming of over 1.5 ° C (Chabane, 2012), causing prolonged droughts, the country experiences recurrent pockets of drought, late and irregular rains and devastating floods in recent years.

Climate change is a reality (IPCC, 2007; Stern, 2006) and agriculture faces the challenge not only of defining adaptation strategies, but also of implementing them and monitoring their results. Therefore, it is necessary to analyse not only the consequences of climate change, but also the causes of vulnerability and make the decision to act on them. Risk analysis makes it possible to assess the probability of future losses, analysing future scenarios.

This article aims to present a literatures review on the matter of Climate Change and its Impact on the Agriculture— initially summarizes the effects of climate change on the water cycle and on water resources; then describe the potential impacts on agriculture; finally, it raises some adaptation measures. It also aims to provide more information on a complex issue, which requires timely action in order to reduce the vulnerability of the sector.

II– Effects of Climate Change on the Water Cycle:

Water is a precious commodity whose preservation becomes an absolute priority and the management of water resources faces a major challenge: the ability to adapt to both excess and scarcity. Evaluating the impacts of climate change on the water cycle, at global, national and local scales, is therefore essential and involves continuing the efforts developed to set up forecasting systems as well as effective methods of monitoring, management and adaptation.

Climate change is one of the greatest pressures on the hydrological cycle along with population growth, pollution, land use changes and other factors (Aerts and Droogers, 2004). Agriculture of any kind is strongly influenced by the availability of water. Climate change will modify rainfall, evaporation, runoff, and soil moisture storage.

The relation between climate change and hydrological cycle was deeply discussed by Trenberth (2011); in his review, Trenberth elucidate the role of water in the climate system and climate change. Kusangaya et al. (2014) were analyzed the effect of greenhouse gases and were stated that the “increase of greenhouse gases will result in climate change which will increased frequency of extreme climatic events including intense storms, heavy rainfall events and droughts”. Kundzewics (2008) was confirmed that “every change in the climate system induces a change in the water system”. Arnell et al. (2013) studied the impacts of climate change on river flow regimes at the global scale. Regarding the groundwater impacts, Moseki (2017) presented a pure review article on climatic change impacts on groundwater; the aims are to collate and depict work done in this field as well as to serve as prelude to a research study in what and how appropriate response measure should be taken.

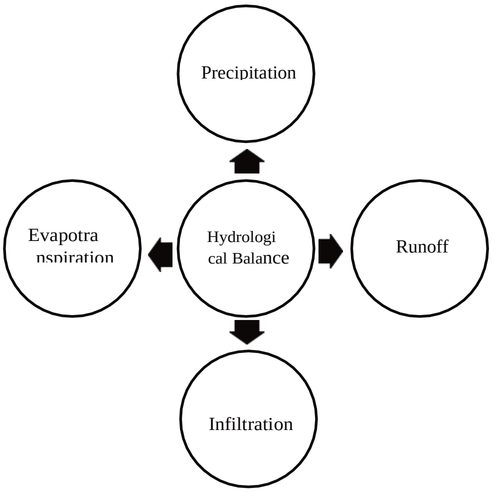
The hydrological cycle is closely linked to the radiation balance; In response to this balance, the climate system maintains the balance between incoming and outgoing energy, by adjusting its processes: precipitation, temperature, evaporation, etc. Due to the warming effect, the radiative forcing of the climate is positive and has been estimated at 1.6 W / m2 (IPCC, 2007).

Recent research (IPCC, 2008) shows correlations between temperature and precipitation, which show that the processes that control the hydrological cycle and temperature are coupled. With respect to temperature, the linear trend of increase, on a global scale, is 0.74 ° C (period between 1906 - 2005) (IPCC, 2007).

Some variations in the water cycle, on a global scale, have been related to climate change (IPCC, 2007; 2008); however, the components of the cycle are subject to natural variability, on interannual to ten-year time scales. On the other hand, human activities, —especially changes in land use, constructions, among others— can influence the processes. Therefore, there is uncertainty (IPCC,2008) regarding the trend of the hydrological cycle variables, due to the great geographic differences, the limitations of the monitoring networks, and the non-climate factors that may be locally important.

Despite the uncertainties, the IPCC (IPCC,2008) attributes some variations in the hydrological cycle (Figure 1), evaluated from long-term trends, to climate change, such as: increased water vapour content in the atmosphere, variation in precipitation patterns; decreased ice and snow cover, changes in soil moisture and runoff.

Figure 1. Hydrological balance processes susceptible to climate change



Source: Adapted from IPCC. (2007).

Increases in potential evaporation are estimated because a warmer atmosphere can contain more moisture and higher temperatures increase the rate of evaporation (IPCC, 2007). Precipitation and radiative forcing control changes in terrestrial evapotranspiration, and these, in turn, would affect runoff, soil moisture, therefore, infiltration, aquifer recharge and salinization (IPCC, 2007, 2008). Evapotranspiration could change due to the effect of increased atmospheric CO2 on plant physiology (IPCC, 2008).

With respect to precipitation, the changes are not linear over time and show significant decennial variability (IPCC, 2008). Modelling using hypothetical scenarios shows complex patterns of change with some regions receiving less and others more precipitation than current (IPCC, 2007). On the other hand, an increase in episodes of heavy rain (above the 95th percentile) has been observed; the modelling results lead to the same conclusions (IPCC, 2008). Consequently, the IPCC (IPCC, 2007, 2008) concludes that the frequency of episodes of intense precipitation is likely to have increased.

Variations in precipitation and temperature induce changes in runoff and in the availability of water resources (IPCC, 2007). On a global scale, there is evidence of variation in annual runoff. However, in many parts of the world climatic variability and non-climatic effects influence it.

In the Maghreb, water resources are vulnerable to variations in the climate. Water and its management are already present problems conditioning the future of this region, regardless of any climate change. The high sensitivity of hydrological basins to small variations in climatic variables implies that the volume of water that can be mobilized will be strongly affected by the decrease in runoff (Agoumi et al, 1999; UNDP-FEM, 1998). With regard to the estimates of sectoral needs, climate change could thus place these countries in uncomfortable situations since the maximum volume that can be mobilized would be at the limit of needs, or even in deficit in Algeria by 2022.

According to Chabane (2012), an increase in temperatures of 0.5 to 1 ° C will induce a decrease in precipitation, which will in turn induce a surface water deficit of around 10 to 30%. This water scarcity will probably combine with an increasingly strong growth in needs. The agricultural sector will be the most affected since large shares of water resources are devoted to it. In 2000, the water resources withdrawn were estimated at 6.074 km^3, including 3.938 km^3 for irrigation (65%), 1.335 km^3 for domestic use (22%) and 0.801 km^3 for industry (13%)

Algeria has been subjected to a persistent drought over the last several decades, although the intensity of this drought changes from one region to the next (Taibi et al. 2015). A growing number of studies have attempted to characterize this drought and determine its possible climate causes (e.g. Medjerab & Henia 2005; Meddi & Meddi 2007; Meddi & Talia 2008; Meddi et al. 2010). Some of these studies have shown that breaks in mean values of rainfall time series occurred during the 1970s (e.g. Meddi et al. 2010) and that these breaks are part of a regional trend observed throughout the Mediterranean basin (e.g. Xoplaki et al. 2000; Brunetti et al. 2001; Knippertz et al. 2003; Rodrigo & Trigo 2007).

The alteration of the hydrological cycle due to climate change has impacts on both the availability and the quality of water resources (IPCC, 2007, 2008). From the point of view of water quality, an additional stress could be induced (IPCC, 2007): with a higher temperature, the amount of dissolved oxygen is reduced, thus affecting the concentration of nutrients and pollutants, in a less water flow (IPCC, 2008). On the other hand, heavy rainfall and floods increase the risk of contamination of water sources, due to surface runoff from excess accumulated residual water, coming from agricultural and urban lands (IPCC, 2008; FAO).

There is evidence that water resources are vulnerable to climate change and that the consequences on society and ecosystems depend on adaptation measures (Adger, 2007). In conclusion, water stress, water quality problems and a higher demand for irrigation water are the most likely impacts on a global scale (IPCC, 2007). However, there are non-climatic factors that affect both the quantity and the quality of aquatic systems, such as changes in land use, reservoirs, watersheds, among others; thus, their vulnerability also depends on the integral management of the resource (IPCC,2008).

Algeria is highly vulnerable to water scarcity and water quality. Most of the water resources have medium to poor quality, and the salinity is often high. Water deficits and droughts are ongoing risks for the agricultural sector.

III- Impacts of Climate Change on Agriculture :

Agriculture is one of the most vulnerable sector to climate change, owing to its huge size and sensitivity to weather parameters, thereby causing huge economic impacts (Mendelsohn, 2009).

This is also the most important sector as it is directly related to poverty reduction, food security, and economic development. Agriculture accounts for approximately 33% of annual GHGs emissions worldwide (Matthews et al., 2000).

There is scientific evidence (IPCC, 2007) on the impact of climate change on agriculture due to the effect on the relevant related variables: temperature, precipitation, carbon dioxide concentration and soil moisture. However, management practices, technological changes, market dynamics and public policies affect the sector and create uncertainties, due to the difficulty of evaluating the influence of climate in isolation, with respect to other factors (Seo, 2011). For this reason, the IPCC (IPCC, 2007) recognizes the need to deepen studies to demonstrate cause-effect relationships.

Despite the uncertainties, the IPCC (IPCC, 2007) raises potential impacts of climate change on agriculture, without considering adaptation measures. Some research like Adger (2007) warns that climate change could have a direct impact on crop productivity and soil fertility; there is the probability of variations in soil degradation rates, increases in salinization, increase in irrigated areas, greater losses due to accidents, reductions in pollinating species and important modifications in the distribution and dynamics of pests and diseases.

An outstanding aspect in the studies (Parry et.al, 2004) is the effect of fertilization due to the high concentrations of CO_2 in the atmosphere, which could mitigate the negative repercussions of climate change on crop productivity. However, there is still uncertainty about the potential benefits, because there are many interactions and stressors that cannot be incorporated into current models (IPCC, 2007).

In the Maghreb countries (Algeria, Morocco, Tunisia, Libya and Mauritania), agriculture plays an important economic and social role and has been identified as the most vulnerable sector to the climatic changes (Abou Hadid, 2006). Particularly in Algeria, agriculture is mainly extensive in spite of efforts undertaken for its intensification, since such efforts have been limited by climatic conditions and lack of water resources.

In Algeria, agriculture sector contributes to about 10% of gross domestic product and employs 14% of the workforce. However, it fails to meet the food needs of the country's population since domestic production covers only 15% of the needs (Benbekhti 2008). Indeed, the Algerian agricultural sector is vulnerable to both natural climate variability and climate change.

IPCC (2007, 2008) Research's, estimate increases in the yield of some crops such as soybeans and sugar cane, and reductions in rice, barley and grapes; while for wheat and corn, the answer is erratic and depends on the type of model. It is important to note that small-scale agriculture is especially vulnerable and that socio-economic stressors often aggravate these conditions (IPCC, 2007).

Studies (Chabane, 2012) claim that increasing temperatures and their variability imply a lag and reduction in growth periods, as well as an acceleration of soil degradation and loss of productive land. As a result, agricultural production will show average reductions in cereal yields from 5.7% to almost 14%. Climate change will also induce yield reductions in vegetable production of 10 to 30% by 2030.

Studies concerning the coastline and agriculture of Maghreb countries (Agoumi, 2003) have highlighted the following risks:

- Alteration of coastal dynamics with effects on water recharge;

- Erosion of certain coastal fringes leading to great soil degradation;

- Loss of land for the benefit of marine waters, in particular certain islands and marshes;

- Intrusion of marine waters into land and salification of coastal waters;

- Changes in agricultural and aquatic productions along the coast;

- Socio-economic weakening of coastal areas linked to the high frequency of flooding and land erosion.

- Rainfed crop yield deficits that can reach 50% during 2000-2020;

- Risk of non-dormancy of certain arboreal species;

- Agricultural activities in coastal areas reduced in relation to the salification of water tables.

IV- Vulnerability and Adaptation:

It must be borne in mind that not every physical phenomenon generates a crisis that is classified as a disaster, it depends on vulnerability, that is, the degree of susceptibility or the inability to face adverse effects; Vulnerability, in turn, is a function of the sensitivity of the system (level of reaction to a change in climatic conditions) and of the capacity for adaptation, understood as the capacity to adjust to climate change, to regulate potential damage, seize opportunities or face consequences (IPCC, 2007; Adger, 2007). The methodology for estimating vulnerability is expressed in equations 1 and 2:

$$Risk = [Threat \times probability\ of\ occurrence] \times [vulnerability] \qquad (1)$$

$$Vulnerability = [Negative\ impacts] - [(Negative\ impacts \times capacity\ for\ adaptation] \quad (2)$$

To respond to climate change, a risk management process is required that involves a set of actions that make it possible to identify and assess risks, in order to effectively undertake the necessary measures to respond to them. Likewise, it covers the identification, qualification and evaluation of risks, the design and implementation of measures for adaptation, monitoring and evaluation.

For climate risk management, technological tools have been used (Balaghia et.al, 2010) that allow evaluation, monitoring and evaluation: development of vulnerability indicators, establishment of early warning systems, satellite information, simulation models of crops, systems of geographic information (GIS), geostatistical methods, collection and automatic transmission of data.

The adaptive process involves adjustments to reduce vulnerability and strengthen resilience after observed and expected changes in climate (Adger, 2007). Adaptation can be anticipated (before impact), autonomous (spontaneous), or planned (the result of a deliberate political decision) (Adger, 2007).

Some planned adaptation options for the agricultural sector include (IPCC, 2007) : modification of planting dates, choice of varieties, relocation of plantations, improvement of land management, support of diversity conservation systems agricultural biology, design of programs to consolidate new agricultural calendars by regions, technification of crops, genotypes adapted to stress conditions, development of sustainable production systems, optimal management of water resources (efficient irrigation systems, water recycling, saving water, etc.).

In Algeria, adaptation strategies, by general strategic line, include:

• Strengthen the management of research and knowledge transfer: Analysis of risk levels, assessments of the vulnerability of water resources at regional and local scale and determination of the economic impact of adaptation to climate change.

• Strengthen risk management: Research applied in the medium and long term in comprehensive risk management and strengthening of risk transfer mechanisms.

• Improve the use of the territory as a strategy to reduce vulnerability: Inclusion of risk and climate change management in the instruments of territorial planning and deepening of the instruments of land use planning such as the River Basin Management and Management Plans. - Hydrographic case

• Reduce environmental, economic and social impacts: Improve the resilience of productive systems, better use of land according to the production system and its particular water and temperature requirements, agricultural insurance and apply project adaptation measures. pilot with positive results.

• Improve the adaptive capacity of the most vulnerable communities: Strengthening of the social organization.

• Value and protect the productive base based on the goods and services of biodiversity: Strengthen initiatives for sustainable water management, establish diverse agricultural systems and incorporate ancestral knowledge of specific crops as well as varieties of species to maintain genetic diversity.

• Strengthen cooperation and resource management for adaptation.

There is growing evidence that adaptation measures can play an important role in response to the impacts of climate change on agriculture (IPCC, 2007; Adger, 2007). Adaptation is a challenge for the sector. Climate risk management, understanding the impacts and their vulnerability will allow the design and implementation of effective adaptation measures.

V- Constraints related to adaptation:

Many constraints limit the implementation of adaptation-related activities in Algeria. Despite the efforts made and the strategies adopted, the World Risk Report 2014, published by the United Nations University (UNU-EHS., 2014) ranks Algeria 60th among countries with strong risks in particular of climate change with an overall index of 7.63%, exposure to risks of 15.82%, vulnerability of 48.24% and above all, a lack of adaptation capacities of 73.76%.

The Sahara and Sahel Observatory (SSO, 2007) identifies the following constraints in North Africa:

- *Lack of data (76.67%)*: in most cases, data is collected strictly within the framework of specific projects, which poses the problem of the sustainability of the data collection process. Again, the national observation and collection networks cover a limited part of the national territory. Existing data is not very reliable, sufficient and precise to qualify climate change and identify alert thresholds. As for scientific references, the fact that they exist mainly in English poses a problem for the Maghreb countries which have French and Arabic as working languages.

- *Insufficient of the expertise (76%)*: this insufficiency results in poor training of agents who, in general, have a classic training profile (agronomy, hydrology, sociology, economics, etc.), but also in a lack of qualified resources.

- *Weak financial resources (76%)*: almost all of the institutions consulted, except NGOs, rely on state subsidies to carry out their activities. In general, state subsidies are very limited; recourse to external resources mobilized within the framework of projects is an option considered.

- *Low awareness of political decision-makers (56.67%)*: despite the frequent alerts launched at the international level, political decision-makers in Africa in general, and those in North Africa in particular, are not yet fully aware of the need to adapt properly to the negative impacts of climate change.

- *Low valuation of research work (56%)*: there is little research work on adaptation to climate change in North Africa, due in particular to the novelty of the topic but also to the fact that research does not constitute still a priority.

- *Lack of research resources (46.67%)*: research institutes and centres deplore the weakness of research resources (field equipment, laboratory materials, measurement and observation tools, etc.). There is also a disconnect in the region between universities, researchers and the development world.

- *Institutional weaknesses (43.33%)*: there are no institutions in North Africa specializing in climate change and adaptation. As for the existing institutions, they cooperate little with each other.

- *Lack of legislative and / or regulatory framework (40%)*: in each of the countries in the region, legislation relating to environmental issues exists. However, as everywhere in Africa, there is a real problem of implementation. Indeed, when the legislative framework exists, its application is lacking because it is insufficiently accompanied by means of implementation and control.

There is also a weak involvement of NGOs in the region, although they are making remarkable efforts with local communities. Likewise, the private sector is almost absent in the field of adaptation, as in that of the environment, areas which do not a priori have major economic and financial interests.

VI- Conclusion:

Agriculture is especially vulnerable to climate change; the proliferation of pests and diseases and water stress are aggravating factors. It is possible that moderate increases in temperature and CO2 fertilization have positive effects on production. However, if the increase in temperature exceeds the climatic safety standard, yields could decline across the board. The modelling cannot take into account all the adaptation possibilities nor all the non-climatic factors that stimulate change; therefore, they should be taken as indicators of the need to deepen the investigation and knowledge of the potential impacts.

Adaptation strategies must be defined through a risk management process that involves impacts, risk attitudes, and adaptation capacity. The use of this Comprehensive Management methodology in the agricultural sector will make it possible to systematically identify, qualify and evaluate potential risks, design and implement adaptation measures, and monitor and evaluate the results.

Scientific and technological innovations will be decisive in the definition of strategies aimed at counteracting the effects of climate change. Effective cooperation between researchers in engineering, meteorology, agriculture, forestry, among other areas, is crucial to provide farmers with useful and timely information, to face short and medium term agroclimatic risks, in all phases of cultivation.

Responses to climate change are a challenge for engineering; the impacts on the agricultural sector pose a series of challenges related to productivity, due to the need for increases to guarantee food security; with technological innovation, given the need for new technologies that allow better adaptation; with sustainability, to reduce the carbon footprint, improve the natural resource management and protecting biodiversity; with research, that they lead to a greater understanding of cause-effect relationships and the development of resilient varieties; and with knowledge management, because both scientific and technological knowledge, as well as traditional and ancestral knowledge, are key to face the potential impacts that climate change entails.

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How to cite this article by the APA method:

TOUITOU Mohammed (2021), **Climate Change and its Effects on the Agriculture and water resources** Review, Volume 06 (Number 01 Duplicate), Algeria: University of Eloued, pp. 176-187

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