

Impact of climate change on agriculture and food security
in the Kingdom of Saudi Arabia

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INTRODUCTION

In recent decades, the world has witnessed large-scale climate changes whose effects have been reflected in various sectors, especially agriculture and food security. Statistics from the Food and Agriculture Organization of the United Nations (FAO) indicate that global demand for cereals will increase by 70% by 2050 compared to the current situation, with a doubling expected in many low-income countries, as a result of the continuous increase in population and high per capita food consumption in communities with growing incomes, especially in Asia (FAO, 2009; 2024a).

At the regional level, many Arab countries face significant food security challenges due to limited water resources and regional climatic changes that affect the stability of local agricultural production (FAO, 2024b). Regional climate changes are affecting rainfall and temperature patterns, reshaping local farming systems, crop productivity, livestock and fish farming systems, and affecting food distribution, food markets and access to food (FAO, 2024c).

At the local level, Saudi Arabia is one of the countries facing special challenges due to its harsh environmental conditions and high dependence on limited water resources, in addition to high temperatures and its direct impact on changing rain patterns (Food and Agriculture Organization of the United Nations, 2024d). Although global food production has increased in recent decades, global efforts to meet the Millennium Development Goals of halving hunger by 2015 have shown the difficulty of achieving this goal, with

the number of people suffering from chronic hunger increasing from less than 800 million in 1996 to more than 1 billion by 2009 (Food and Agriculture Organization of the United Nations, 2009).

Food security in Saudi Arabia depends on the abundance and access to local food, both for those who grow it as a source of livelihood, and for those who buy or exchange it (Food and Agriculture Organization of the United Nations, 2024AH). Therefore, the impacts of climate change on food security must be taken into account, including direct impacts on local food production and interactions with the entire food system (FAO, 2024f). Agriculture is very sensitive to climate changes, as high temperatures affect the stability of agricultural systems, as well as agricultural productivity and animal and fish breeding systems (Food and Agriculture Organization of the United Nations, 2024g).

This study reviews current scientific knowledge on the relationship between climate change, agriculture and food security, focusing on projected impacts, managing climate risks, accelerating adaptations to growing climate change, and addressing greenhouse gas emissions from various agricultural activities.

Research problem

In recent decades, the world has witnessed large-scale climate changes, the effects of which have been reflected in various economic and social sectors, most notably the agricultural sector and food security. Global studies indicate that rising temperatures, fluctuating rainfall patterns, and increasing severity of extreme weather events directly affect food production around the world, leading to lower agricultural yields, worsening water resource scarcity, and rising food prices, increasing the risk of food insecurity in developing countries and mainly agriculture-dependent economies (FAO, 2022; IPCC, 2023).

At the regional level, the countries of the Middle East and North Africa face significant challenges as a result of their desert environment and the scarcity

of water resources, as climate change is considered one of the most prominent threats to food production and the stability of food markets. It is estimated that water shortages and increased temperatures will reduce crop productivity by 10-30% in some regional countries by mid-century (World Bank, 2021; FAO, 2022).

At the local level, Saudi Arabia, being a country with a desert climate and few natural water resources, faces additional challenges in this area. The Saudi agricultural sector relies heavily on intensive irrigation to cope with limited rainfall, and national food security is a strategic goal within the Kingdom's Vision 2030. As climate changes continue, the productive capacity of local agriculture is expected to be affected, and the pressure on limited water resources increases, which may lead to a rise in the cost of food and exacerbate the Kingdom's dependence on food imports (Al-Ghamdi et al., 2021; FAO, 2022). From this standpoint, the research problem arises in the following main question: “What is the impact of climate change on agriculture and food security in Saudi Arabia, in light of increasing global and regional challenges?”

Research Questions.

1. What is the concept of climate change, its causes and manifestations, and how do these phenomena appear globally and regionally?

2. What is the concept of food security and its various dimensions, and how is it affected by climatic conditions?
3. What is the relationship between climate change and food security at the global and regional levels, and what are its implications for the Kingdom of Saudi Arabia?
4. How do agricultural activities affect climate change, and what are the implications of these impacts on the sustainability of agricultural production?
5. What are the most prominent manifestations of climate change in the climate of the Kingdom of Saudi Arabia, and how does it affect water resources and agriculture?
6. What are Saudi Arabia's current and future efforts in addressing climate change and achieving sustainable food security?

The research objectives:

1. Identify the concept of climate change, its causes and manifestations at the global and regional levels.
2. Clarify the concept of food security and its various dimensions, and analyze the impact of climate change on it.
3. Studying the relationship between climate change and food security at the global and regional levels, with a focus on the Kingdom of Saudi Arabia.
4. Analyze the impact of agricultural activities on climate change and assess their implications for the sustainability of agricultural production.

5. Identify the manifestations of climate change in the climate of the Kingdom of Saudi Arabia and its effects on water resources and agriculture.
6. What are Saudi Arabia's current and future efforts in addressing climate change and achieving sustainable food security?

Research Significance

Scientific importance: Enriches scientific knowledge in the field of the impact of climate change on agriculture and food security, especially in dry environments such as the Kingdom.

Practical importance: It contributes to highlighting the challenges facing the agricultural sector and decision-makers, which helps in developing more effective plans and strategies.

The research methodology:

Since the research is theoretical, it will be based on:

Descriptive analytical approach: To describe the manifestations and effects of climate change in the Kingdom.

Analysis of previous studies: by reviewing local and global research.

Relying on official reports: such as the reports of the Saudi Ministry of Environment, Water and Agriculture, and the reports of the Meteorological and Environmental Protection Authority, in addition to the reports of international organizations such as FAO and IPCC.

Research Boundaries

Spatial boundaries: Saudi Arabia.

Thematic Limits: Climate change and its impact on agriculture and food security.

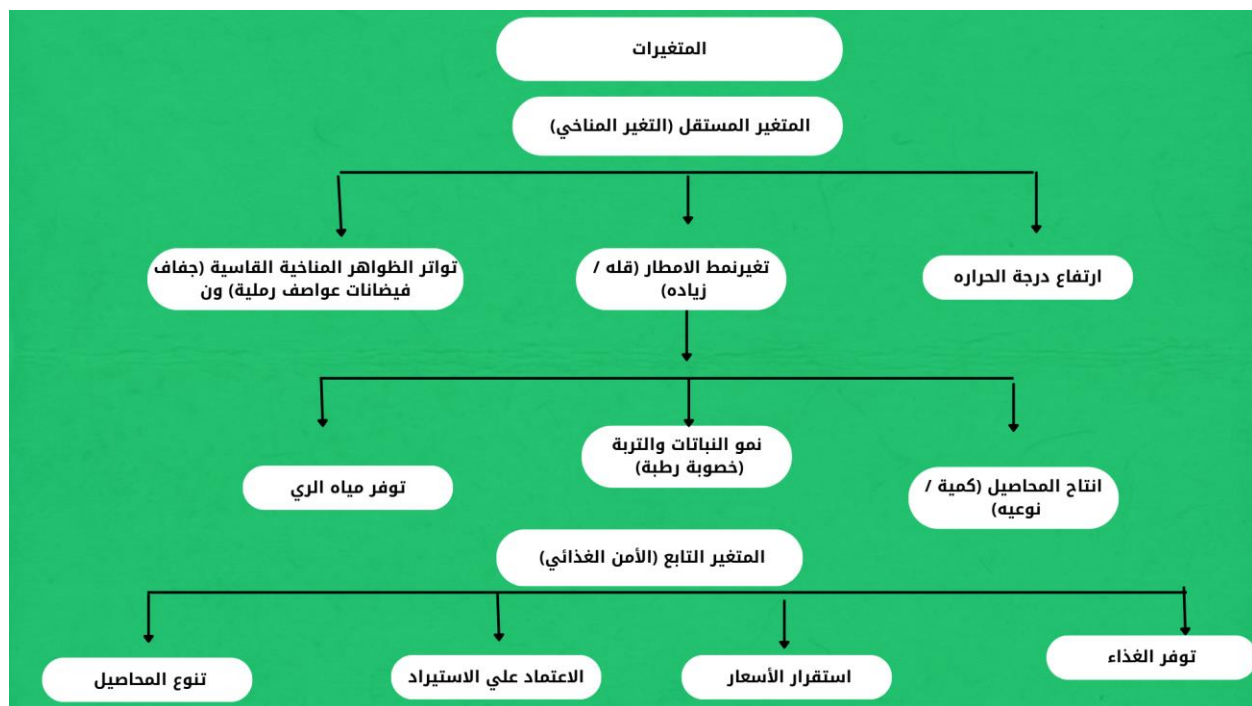
Time limits: Studies and reports issued during the period from 2000 to 2025.

Research variables:

Independent variable : Climate change (high temperature - change in rain pattern, less or more frequent extreme weather events, drought, floods and sandstorms)

Intermediate variables : crop production (quantity and quality) - plant growth and soil (moisture fertility) - availability of raw water.

Dependent variable : Food security: availability of food - stability of prices -



dependence on imports - diversity of crops.

A conceptual map showing the relationship of the research variables of the student's numbers

Concepts

The concept of climate change:

Climate change is the long-term change in the rate of weather over a period of time ranging from decades to millions of years. ومعدل حالة الطقس يمكن ان تشمل معدل درجات الحرارة، معدل تساقط الأمطار وحالة الرياح. These changes can occur due to the dynamic processes of the Earth, such as volcanoes, changes in the intensity of sunlight, and human activities.

The United Nations Framework Convention on Climate Change (UNFCCC) defines human-caused climate change as "climate change that is directly or indirectly attributable to human activity that alters the composition of the global atmosphere as well as natural climate variations

viewing across similar durations."(Al-Rubaie, 2011, p. 4)

It is also known that fluctuations in weather lead to fluctuations in climate, causing global warming over long periods (Tayr et al., 2024, p. 29)

The United Nations Convention defines it in its first paragraph as (change that is directly and indirectly attributable to human activity that leads to a change in the composition of the global atmosphere in addition to the natural variability of climate over similar periods of time) (Jawhar and Amin, 2023, p. 386)

It was defined by the Intergovernmental Panel on Climate " as a change in the state of the climate that can be determined through the use of statistical tests, for example, change on average and that this change lasts for a long period of decades " (Tayr et al., 2024, p. 29)

Food Security Concept:

FAO defined it as "ensuring adequate food supply for all individuals at all times" (AlajalandSharara, 2014. P3)

It is also defined by the World Health Organization as representing all the necessary conditions and standards during the production, manufacture, storage, distribution and preparation of food, with the aim of ensuring its safety and health quality, and ensuring its suitability for human consumption without harmful impact on the environment. (Tayr et al., 2024, p.29)

Chapter 1: General Framework for Climate Change and Food Security

The first topic: Previous studies

1-A study by Tair Mohamed, Yoazid Sayeh and Hawari Ali (2024) on the impact of climate change on food security in Algeria. It aimed to try to shed

light on the diagnosis of the reality of climate change and food security in Algeria, because this climate change has become one of the most prominent problems facing decision makers in the Algerian government, especially with the emergence of a clear impact on the sources of water and food dependent on its growth. The study concluded that Algeria is increasingly facing each year severe climatic phenomena that gradually increase its vulnerability, which reflected negatively on the decline in agricultural crops and food quality due to drought, heat waves and floods, which led to its inability to achieve food security for its population as well as an increase in pests and plant diseases. This is what the country witnessed in 2023 with a decline in various crops compared to previous years.

2-Suleiman's study (2019) This study aimed to know the expected effects of climate change on food security in Egypt by 2050 , by estimating its impact on the productivity and areas of the most important agricultural crops, namely: wheat, barley, maize, sorghum, soybeans, sunflowers, and rice. The study also seeks to analyse projected climate changes, including temperatures, precipitation rates and greenhouse gas emissions, and measure their reflection on agricultural production, consumption and the food gap. The study used the descriptive analytical approach by analyzing historical data for the period 1960-2016 , and building future scenarios to estimate the cultivated area, productivity, production and consumption until 2050 . The study concluded with a set of important findings that highlight the magnitude of the challenges that may face food security in Egypt, with the proposal to adopt climate-smart agriculture strategies to reduce negative impacts and achieve greater sustainability in agricultural resources.

3- The study of Jawhar et al. (2023) Climate change and its impact on achieving sustainable development in Iraq aimed to highlight the repercussions of climate change in the Garmian region, especially the drought situation that affected

in the natural environment, human activity and the economic and social aspects of the population of Al-Darsa area in recent years . It also aimed to put forward ways to address or reduce the negative effects of climate change in the study area and achieve sustainable development in it. It used the descriptive analytical approach and reached a set of results, including the impact of climate change, especially drought, on surface and groundwater resources, which negatively affected economic, agricultural and social activities in the study area. The phenomenon of drought and the fluctuation of the amount of rainfall also reflected negatively on the natural environment

in the study area. Population migration from rural areas in the study area and mobility to urban centers is largely due to

4- The study of Rajab Rana Ahmed and the ruling of Manasik Abdul Wahab (2025). Impact of climate change on the African environment.

The study aimed to analyze the extent of the impact of climate change on the African environment, focusing on its economic and social repercussions, in addition to highlighting the roles of African leaders in developing strategies to mitigate these effects and adapt to their repercussions. It used the descriptive analytical approach and concluded that Africa's contribution to global warming is relatively limited compared to other continents, and that it is one of the regions most affected by its results, as the continent faces major risks that threaten its national economies, infrastructure, water, food, health and agricultural systems, which negatively affect livelihoods and increase the likelihood of the spread of extreme poverty and high rates of migration and displacement. These changes also intensify conflicts over dwindling natural resources, necessitating the adoption of comprehensive adaptation strategies and effective response plans to ensure the continent's sustainable development.

5-Al-Abdali study (2024) The study aimed to clarify the impact of climate change and its recurring cycles on natural reserves, with a focus on Prince Mohammed bin Salman Royal Reserve in Saudi Arabia. The reserve extends along the northwestern coast of Doha Governorate

North to South Face Governorate during the period from 2018 to 2024. To achieve accurate results, the study relied on the use of the latest spatial perceptions of the region, analyzing these perceptions using the ArcGIS program, and applying the targeted classification to achieve a deeper understanding of spatial perceptions. In addition, the Vegetation Index

(NDVI) was calculated to determine changes in land cover over time. The study addressed changes in the vegetation cover and environmental characteristics of the reserve, to identify the main causes of vegetation degradation and to study the potential impact of climate change on biodiversity and ecosystems. The study also analyzed the reasons that contribute to the development of these reserves as focal points for cities, and the impact of this on improving environmental conditions and contributing to environmental sustainability in light of climate challenges.

The study relied on the scientific and analytical method in addition to the descriptive approach in the study of phenomena related to vegetation cover and climate change. Through the analysis of the vegetation index (NDVI) using satellite visualizations, the study reached the following results:

1. The percentage change in the distribution of vegetation cover during the study period was about 0.43%.
2. The rate of change in the area of desert land during the study period was about 1.47%, indicating an increase in desertification.
3. The vegetation in the study area extends from the northeast to the southwest.
4. Ecosystems are directly affected by changes in vegetation, as vegetation is a major source of food and shelter for many organisms. Its degradation, as a result of climatic changes or human activities, leads to the loss of natural habitats, which negatively affects the numbers and diversity of animals.
5. The results of Pearson's analysis showed that climate factors play a pivotal role in influencing biodiversity in the Prince Mohammed bin Salman Reserve. These findings are of great importance to planners and policymakers, as they highlight the need to take appropriate action

to protect existing species and ensure their sustainability in the face of ongoing climate change.

The second topic: Climate change causes and manifestations:

Climate change is a challenge facing humanity, as interest in this phenomenon began at the end of the nineteenth century. Scientists and researchers in the field of climatology and Earth science were able to confirm that the climate and Earth are constantly changing. Since that time, several definitions have been provided, including the United Nations Convention on Climate Change, and in its first paragraph, the definition of climate change (it is the change that is directly and indirectly attributed to human activity that leads to a change in the composition of the global atmosphere in addition to the natural variability of climate over similar periods of time) (Jawhar Wamin, 2023, p. 386). The topic of climate change has recently been of great interest to many researchers and organizations concerned with this, as researchers

have made serious attempts to determine the nature of climate changes and find out the reasons that lead to their occurrence, and the change is the transition from one state to another, it is different from the fluctuation that is about the rate of the state and for a short period, but the change represents an increase or decrease in the rate of the state and lasts for decades, and climate change has been defined by the International Panel on Climate " as a change in the state of the climate, which can be determined through the use of statistical tests, for example, the change in the average and that this change lasts for a long period lasting decades" (Tayer et al., 2024, p. 29)

Climate change is a phenomenon that is witnessing an increasing escalation in its pace and effects, which has not been witnessed in the world since the industrial revolution 250 years ago , as it led to the largest change in the atmosphere as a result of the escalation of greenhouse gases, especially chlorine oxide and carbon, which form a thick layer surrounding the atmosphere, which traps heat and thus high temperatures in the summer (Tayr et al., 2024, p. 28)

Causes of climate change

Climate change is a complex phenomenon resulting from the interplay of natural and human factors that directly and indirectly affect the Earth's ecosystem. These changes have led to global climate imbalances, causing changing weather patterns and rising temperatures, negatively impacting agricultural production and food security. The following is a breakdown of the most important of these reasons:

First: Natural Causes of Climate Change

Natural factors contribute to climate change, albeit with less influence than modern-day human factors. These include:

1-NaturalGaseous

Emissions

Some greenhouse gases are naturally emitted from environmental sources, such as the decomposition of organic matter in soils and swamps, the emission of methane from volcanic activities, as well as the production of nitrous oxide from some natural biological processes. Although these emissions occur without human intervention, their impact on the global climate system remains noticeable (Al-Rubaie, 2011, p. 4).

2-SolarFluctuations

Changes in solar activity play a role in influencing Earth's climate; variations in the intensity of solar radiation lead to long-term temperature changes.

3.Geological phenomena and natural disasters

Some natural phenomena, such as a large volcanic eruption, are factors that temporarily affect the climate, as volcanoes release huge amounts of gases and particles into the atmosphere, blocking sunlight and causing a change in global temperatures.

Second: Human Causes of Climate Change

Recent studies have proven that human activities are the main driver of climate change in the modern era, due to their excessive emissions of greenhouse gases and radical changes in ecosystems. The most prominent of these activities can be classified as follows:

GHG Emissions

Greenhouse gas emissions are one of the most influential factors in climate change, leading to warming in the atmosphere, which exacerbates global warming. Carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) are the main components of these emissions:

-Carbondioxide (CO₂)

It is mainly produced from the combustion of fossil fuels, such as coal, oil and natural gas, in the fields of transport, industry and energy production. Studies indicate that carbon dioxide accounts for about 76% of total global greenhouse gas emissions (Al-Rubaie, 2011, p. 5).

-Methane (CH₄)

It is mainly produced from agricultural activities, especially livestock breeding, as well as the decomposition of organic materials in landfills. Methane is several times more influential on global warming than carbon dioxide.

-Nitrousoxide (N₂O)

Nitrogen fertilizers are often used in agriculture and are highly effective gases in raising global temperatures.

These emissions are causing sharp changes in weather patterns and increasing droughts, leading to a decline in agricultural production and exacerbating the food security crisis.

2. Industrial activities and urbanization

Industrial activities and urbanization contribute to raising environmental pollution and significantly increasing carbon emissions. Energy production, heavy reliance on fossil fuels in factories, and the use of conventional vehicles are all accelerating global warming. Urbanization has also led to the removal of large areas of forests, which are considered a natural reservoir for absorbing carbon, weakening the ability of the ecosystem to balance greenhouse gases.

3. Agricultural Practices

Agriculture is an activity that has a double impact on climate change, contributing to increased emissions of methane and nitrous oxide, as well as the depletion of natural resources. Excessive use of chemical fertilizers and

pesticides creates an ecological imbalance, and unsustainable agricultural expansion increases deforestation to provide space for farming and grazing.

4. Consumption and Transport Patterns

A culture of excessive consumption and increased demand for industrial and food products are exacerbating environmental pressures. The increasing reliance on traditional means of transport, especially cars and aircraft, has also led to a rise in air pollution and increased carbon dioxide emissions.

Implications globally and regionally:

These factors have contributed to global warming, causing significant climate changes at the international and regional levels. Some regions have experienced significant temperature rises, while others have experienced recurrent droughts and floods, negatively impacting food security and water resources in multiple regions around the world (Jawhar and Amin, 2023, p. 387).

Manifestations of climatic changes:

Despite the efforts made in ways to reduce the negative effects of climate change around the world, the danger is still imminent for humans, and there have been many manifestations of this in recent years, and the following will be listed the most important manifestations of climate change that have appeared in many regions around the world, including the following (Tayr and others 2024, p. 29) :

A. Global warming: Global warming is one of the most important manifestations of climate change in modern times. This phenomenon indicates that the Earth's temperatures are gradually rising above their normal temperature. Studies indicate that the Earth's temperature has increased by approximately 1.2 degrees compared to temperatures before the outbreak of the industrial revolution in the eighteenth century. This

phenomenon constitutes the most dangerous manifestation of climate change at all, as it directly affects the environment and water resources and directly threatens human life.

B. Extreme heatwaves: Heatwaves sometimes hit some areas on Earth in an unprecedented way, and this is all the result of climate changes that are taking place on the planet, and these waves are manifestations that are in line with global warming that is hitting the entire planet. In some regions, the incidence of heatwaves has increased to more than thirty times than before, and the chance of these waves occurring in most areas on the surface of the Earth has tripled due to climate change.

C. Drought: Rising temperatures and heat waves hitting many regions, in addition to disrupting rainfall rates, lead to droughts in many regions around the world, although scientists still find it difficult to determine how climate changes affect

Droughts on the surface of the earth, many regions have suffered from continuous and prolonged droughts, as in the regions of East Africa.

D. Heavy rains and floods: Changes in climate have led to heavy rains in some areas and fluctuations in rainfall rates in many countries around the world, and they have often led to devastating floods, and this is at the expense of drought in other areas, so the bouts of heavy and intense rains have become more, and this may be due to warm air that retains moisture more.

e. Wildfires: Climate change and global warming have allowed violent heatwaves that have caused many fires in huge forests. In 2022, the number of fires has greatly increased around the world. In April 2022, a fire broke out in the state of New Mexico in the United States of America and burned approximately 1,380 square kilometers, as well as the fires that occurred in

America in 2024 and 2025, in addition to many fires that broke out in Europe and elsewhere.

F. Melting snow at the poles: Rising temperatures lead to the melting of frozen ice in the Arctic and Antarctica. Scientists have observed icebergs in Greenland and the Arctic as a result of rising temperatures. Satellite images have also shown the erosion and melting of ice on the summit of Mount Kilimanjaro in Kenya to more than 50% compared to what it was in the 1970s.

g. Sealevel rise: The sea level has risen as a result of melting ice at the poles due to rising temperatures, and scientists indicate that sea level rise is about 12 cm since 1880 ,and this as it continues will undoubtedly lead to the demise of many beach cities .

Some studies have shown, for example, that all of the Maldives is threatened with extinction.

The third topic: Food security and its dimensions

There is no unified definition of food security, as defined by the Food and Agriculture Organization as “ensuring adequate food supply for all individuals at all times” (Al-Ajal and Sharara, 2014). P3)

It is also defined by the World Health Organization as representing all the necessary conditions and standards during the production, manufacture, storage, distribution and preparation of food, with the aim of ensuring its safety and health quality, and ensuring its suitability for human consumption without harmful impact on the environment. (Tayr et al., 2024, p.29)

Based on this definition, food security is achieved by providing individuals with sufficient food to live, and this is either through local production, or by completing consumption needs by resorting to the international market. Attention to providing sufficient quantities of food and providing sufficient nutritional value for the needs of the body is no longer sufficient, but food must also be safe for consumption, and not pose a threat to the health of the consumer or the environment or contribute to increasing environmental pollution problems

Dimensions of food security

Achieves food security when the individual has at all times the financial, social,

This safety aims to provide an active and healthy life for individuals, and to obtain a more accurate and comprehensive vision of the food security situation in a particular country, its dimensions must be analyzed as follows (Tayr et al., 2024, p. 30) :

A- Availability of food: Availability is an important dimension of food security. The supply of sufficient food to the population is more necessary, but not sufficient. It is also a condition to ensure the appropriate access of food to individuals, in the sense of adequate food and of appropriate quality.

B- Access to food: Adequate and continuous access of food resources to individuals in order to acquire appropriate food according to a nutritious diet, that is, access to adequate food for individuals and families. Access to food is determined primarily through income, food prices and the ability of families and individuals to receive social support. In addition, access to food is also greatly affected by social variables, as it includes access to food physically given the availability of transport infrastructure such as the quality of railways and roads, and access to it economically represented by the local food price index, the prevalence rate of undernutrition.

C- Stability: The possibility of obtaining sufficient food at all times without facing the risk of losing this possibility due to a specific shock such as an economic crisis, environment or seasonal cycle, that is, in order for the population, families or individuals to reach the stage of food security, they must have the ability to access adequate food at all times, and there must be no risk of losing access to food as a result of one of the shocks (economic or climate crises) or periodic events (such as seasonal food insecurity). Thus, the concept of stability refers to both after availability and after access to food.

D- Utilization: The way individuals use food depends on the quality of food, and is divided after utilization into two groups, the first includes variables that determine the ability to benefit from food, especially the availability of appropriate household equipment, access to water and sanitation, while the second group includes the results of food utilization, especially with regard

to nutritional deficiencies in children under the age of five, such as wasting, osteoporosis and underweight, and other indicators of micronutrient deficiencies were added in 2013 from the publication of the State of Food Insecurity in the World report, namely the prevalence of anemia and vitamin A deficiency among children under the age of five and the prevalence of iodine deficiency and anemia in pregnant women.

The fourth topic: the relationship between climate change and food security: Climate and environmental changes, together with social and economic transformations, are posing a clear threat to food security worldwide and in various production sectors. Water scarcity and soil degradation and erosion are valued as one of the key factors affecting the agriculture and livestock sectors in different regions of the world. Extreme weather conditions, such as droughts, high heat waves and heavy rainfall, can result in unexpected production losses and fluctuations in crop production. These factors reduce the available agricultural space in key delta areas, such as the Nile Delta, which is vital for agricultural production. For example, sea level rise and soil collapse can reduce this area. In addition, parasites and mycotoxins that grow on plants in nature pose a threat to food safety, as their growth is highly correlated with climatic conditions, and threatens the safety of foods in storage.

According to a 2015 study by Ragar Entam International Studies, Nanyang University, Singapore, entitled "The Impact of Climate Change on Food Production: Options for Importing Countries" by Paul Teng, Milli Calibero Anthony, John Tian and Jonathan Lassa, this brief examines the potential impacts of climate change on agricultural crops and livestock by 2030, 2050 and 2050. During this time period, they highlighted the impact of food

production systems based on climate estimates in different regions around the world and focused on two main aspects during this study .

- The first is the degree of adaptation and the amount of flexibility in food production systems - The second is the geographical location. They pointed out the expected impacts as a result of climate estimates by 2030 to the following points:

1-Thermal stress, i.e. high temperatures affecting grain production;(crops)

2-Water stress as a result of lack of water (dehydration) or increased water High rainfall and flooding can cause erosion and soil erosion and thus lower yields. By 2050 , the resulting effects are(Tayr et al., 2024, p.30) :

-Continued water and heat stress.

-Reflection of temperature rise on wheat production in all countries

-Increasing ocean temperatures and ocean acidification as a result of ocean water absorbing carbon dioxide.

The most prominent challenges for food-importing countries are:

-Decrease in crop, livestock and fishing production.

-High food prices due to increased production costs

-Changing food production centers in the world (Tayr et al., 2024, p.31)

Projected impacts of climate change on agriculture and food security

Climate is one of the key factors determining the productivity of agricultural systems and the stability of food security. Despite technological advances in crop improvement, genetic engineering, and modern irrigation systems, climate remains the most influential factor in determining the quantity and quality of agricultural production. Studies indicate that the average surface temperature of the Earth has increased by about 1°F over the past century, which has led to significant changes in weather patterns, increased rates of droughts and floods, and instability of agricultural production.

First: Expected impacts on agricultural production

Climatic changes directly affect crop productivity, as increased temperatures and changing rainfall patterns result in reduced yields for many key crops such as wheat, maize and sunflower. During the years 1996-2003, cereal production was relatively stable at 1.8 billion tons, but the period 2000-2003 saw a decline of about 93 million tons due to droughts and high temperatures, as happened in India and the United States. In 2003, Europe suffered from very low levels of rainfall and unprecedented highs in temperature, which led to large losses of crops in France, England and Ukraine. (Al-Rubaie, 2011, p.6)

High temperatures also affect the duration of the crop growth cycle, as their rise accelerates the ripening process and reduces the period between planting and harvesting. For example, the growth period of corn can be reduced from four weeks to one week, which reduces productivity due to the short period of photosynthesis.

Second: Impacts on Livestock

The productivity of domestic animals is directly and indirectly affected by climate change.

- Direct effect: Increased temperatures lead to physiological pressures that reduce the productivity of meat and milk.

- Indirect impact: The change in the quality of feed and the rise in input prices, as well as the spread of animal diseases as a result of changing environmental conditions.

Third: Impacts on water resources and irrigation

Rising temperatures and changing rain patterns cause increased evaporation rates, leading to a shortage of water resources. Frequent droughts also increase the need for irrigation, even in areas where annual rainfall amounts remain constant.

Fourth: The Impact of Climate Change on Fisheries

Ocean warming affects the distribution of marine fish populations and species, reducing biodiversity in aquatic environments. It also reduces the productivity of fish farms, and affects food security in coastal areas that rely on fish as their primary food source.

Fifth: Impacts on Agricultural Biodiversity

Climate change disrupts the ecological balance of plant and animal communities, altering flowering and fruiting seasons, and increasing the chances of weeds and invasive species spreading. These changes also affect natural pollination processes, which negatively affects crop productivity.

Sixth: Agricultural Pests and Diseases

Studies show that climate change contributes to the spread and intensification of plant pests and diseases, as a result of rising temperatures and increased humidity. Animal diseases transmitted by insects and biological vectors are also expected to increase, posing an additional threat to food security.

Seventh: Effects on Carbon Pollination and Food Quality

High levels of carbon dioxide (CO₂) promote photosynthesis of some crops such as wheat and rice, which may raise productivity in some areas. At the same time, however, studies indicate a decrease in the protein content of grains and a decrease in the levels of some important nutrients such as iron

and zinc, which negatively affects the nutritional value of crops and the quality of food in general.(Al-Rubaie, 2011, p.7)

Eighth: Impacts on agricultural areas

Rising temperatures may contribute to the expansion of some agricultural areas in colder regions as a result of melting frozen land. In contrast, large areas of low-lying land are expected to be lost as a result of sea-level rise, particularly in areas such as Bangladesh, India and Vietnam, which could reduce the production of strategic crops such as rice.

Ninth: Global Food Security

The Intergovernmental Panel on Climate Change (IPCC) reports that climate change will lead to:

- High global grain prices.
- Reduced caloric abundance.
- Increasing malnutrition rates, especially among children.
- Decline in the ability to store and distribute food as a result of the recurrence of extreme weather events.

Tenth: Improving agricultural information management

Recent studies have shown the importance of developing climate information and data systems to support agricultural decisions. Contemporary efforts include:

- Improve remote sensing technologies to monitor climate changes.
- Use advanced models to integrate climate data with crop productivity.
- Adopting data analysis platforms such as AgMIP and HarvestChoice to study future agricultural production scenarios and improve food security management.(Al-Rubaie, 2011, p.9)

Impact of Agriculture on Climate Change:

The agricultural sector is one of the most important factors affecting climate change, due to its significant role in greenhouse gas emissions and land uses. Agriculture is one of the largest consumers of natural resources and relies heavily on fossil fuels, making it a major contributor to the increasing concentration of greenhouse gases. The Intergovernmental Panel on Climate Change (IPCC) points out that three main reasons behind the rise in greenhouse gas emissions over the past twenty-five years are (Al-Rubaie, 2011, p.10) :

1-Use of fossil fuels.

2-Changing land use patterns.

3-Agricultural activities.

Agriculture contributes to the emission of these gases through four main pathways:

-Emission of carbon dioxide (CO₂) as a result of deforestation.

-Emission of methane gas from rice farms.

-Emission of methane gas resulting from intestinal fermentations in livestock.

-Emission of nitrous oxide (N₂O) due to the use of nitrogen fertilizers.

The following table shows the percentage of methane emission from agriculture and livestock

Indicator	Ratio
Agriculture Emissions of Methane	40%
Livestock emissions	%32
Rice Cultivation Emissions	%8

Table No . (1) Source Arabic Blog

Together, these processes account for about 54% of global methane emissions and about 80% of carbon dioxide emissions from land uses. Deforestation, especially in temperate regions, also reduces carbon uptake processes, increasing the concentration of CO₂ in the atmosphere. Livestock-related activities, including agricultural processes based on the burning of fossil fuels, are responsible for 18% of total human greenhouse gas emissions, broken down as follows:

Source	Ratio
CO ₂	9
Methane	35- ≥40 ()
Nitrous oxide	64

Table 2: Percentage of greenhouse gas emissions from the Arab Blog

Improving information systems and databases and agricultural modelling

Many modern technologies have been employed to improve the quality and accessibility of agricultural information in the face of climate change. The most prominent of these techniques are:

- Develop remote sensing systems to monitor climate change and land use.
- Use systems like Google Earth and Wikis to track spatial data.
- Dissemination of information using smart phone technologies.

However, these technologies are bound to be integrated with ground-based observations rather than relying on them entirely. There is also an urgent need to gather more information on plant genetic sources and crop response to changing climatic conditions, as much of this data has yet to be compiled. Also, new ways of making accurate projections of the impact of climate change on agriculture have recently emerged in line with the needs of

decision-makers at the national and regional levels. The most prominent of these initiatives are:

1. AgMIP - Comparison and Improvement of Agricultural Models

Led by the Earth Institute at Columbia University, it aims to design climate scenarios similar to future conditions, with the aim of improving the diagnosis of food security resulting from climate change and enhancing the adaptive capacities of rich and developing countries.

2. Quantification-to-End Project

It is implemented by the University of Leeds in the UK via equip.leeds.ac.uk, combining climate modelling, statistical modelling, and community impact analysis. This project helps prepare more accurate projections of the potential risks of climate change.

Development of Global Agricultural Databases

Sophisticated agricultural models require the provision of accurate and reliable data on food production systems in targeted areas, as well as monitoring and evaluating the impact of climate changes over time. The most prominent efforts in this field are:

- Creation of the CGIAR Spatial Information Consortium via cgiar.csi.org , which provides advanced spatial databases.

- HarvestChoice project via harvestchoice.org , which contributes to improving the availability and analysis of information.

- International Household Survey Network via ihsn.org, which focuses on collecting disaggregated data at the level of agricultural households, especially in low-income countries, to support decision-making and improve agricultural policies.

Researchers have recently called for the establishment of a unified global system to monitor agricultural processes and technologies, facilitating the

adoption of promising innovations and technologies in various regions of the world.

Challenges and Adaptive Capacities in the Face of Climate Change

Researchers and decision-makers face complex challenges in understanding the mutual influences between the components of the agricultural system and the food system. The more interactions between these components, the higher the level of uncertainty in climate and agricultural forecasts. However, farmers' ongoing efforts to minimize damage may help improve forecasts and reduce the range of potential scenarios.

However, the ability of agricultural systems to adapt to climate change varies from region to region depending on the nature of environmental, technological and economic conditions. Adaptation mechanisms remain one of the key factors that will determine the future of food security in light of accelerating climate change, as effective adaptation strategies can contribute to reducing risks and reducing the level of uncertainty in future forecasts.

Chapter Two: Climate Change in Saudi Arabia and its Impact on Agriculture and Food Security

The first topic: Change in the climate cycle of the Arabian Peninsula region

Climate change is a natural phenomenon that occurs as a result of synchronized environmental and geographical fluctuations over time, such

as changing Earth's temperature, increasing levels of carbon dioxide, and changing rainfall patterns. These changes may be caused by natural factors, such as volcanic activity or changes in sunlight, but in recent decades they have become more pronounced due to human activities, such as the burning of fossil fuels and deforestation, which has accelerated the pace of this phenomenon.

In the Arabian Peninsula, the impact of climate change is evident, as the region suffers from rising temperatures and increasing rates of drought, which is reflected in the local environment, agriculture and groundwater. These changes require an in-depth study to understand them and direct efforts towards adaptation. This research aims to explore the effects of climate change on the Arabian Peninsula and how to deal with it in a sustainable way that contributes to achieving a balance between the region's growth and its environmental needs.

There have been many changes in the climate cycle of the Arabian Peninsula, where in the past it was characterized by a humid and fertile climate, and vegetation and water resources were more abundant and extensive than they are today. Over time, the climate gradually began to change, and the Arabian Peninsula became a dry and desert region. Professor Abdulaziz bin Abdullah Laboune studied these climatic changes and their impact on the environment and civilizations that have arisen in the Arabian Peninsula throughout history, and found that these changes had a significant impact on the lives of the ancient inhabitants and the development of the culture and economy of the region (Al-Khatib, Al-Ma 'ayah, 2020). Thanks to his deep and comprehensive studies, Professor Abdulaziz bin Abdullah Laboune was able to draw a clear picture of the history of the Arabian Peninsula and its development in terms of climate and environment,

and the impact on the lives of peoples and civilizations that flourished in this important civilizational region (Minale, 2013).

Amidst this dramatic change in the climate cycle of the Arabian Peninsula region, it was imperative to work on the development of wildlife, which is a key element for preserving the environment and ensuring the sustainability of its vital resources. Therefore, States shall protect natural areas and designate them as reserves in accordance with special laws and regulations. In the Kingdom of Saudi Arabia, Vision 2030 came up with many initiatives and strategies aimed at expanding and developing nature reserves in terms of their areas, enhancing their protection programs, and improving their performance at the environmental, economic, and social levels (Ghariani, 2017).

History of Climate in Saudi Arabia

The history of the climate in Saudi Arabia dates back thousands of years, as its climate was in the past wetter and cooler than it is today, allowing the presence of forests and water bodies in some areas. Over time, the climate gradually changed and deserts and dry areas came to dominate the landscape, especially in the central and northern regions of the country. The Arabian Desert is one of the largest deserts in the world, experiencing very high temperatures in summer and low temperatures in winter.

Despite these harsh conditions, the Kingdom is characterized by great ecological and natural diversity, including mountains, valleys, plains and beaches, which gives it climatic diversity that helps sustain life and economic growth (Abu Zeid, 2009).

The climate in the Kingdom dates back to prehistoric times, as the region has witnessed varied climatic changes throughout the ages. In ancient times, there were signs of significant changes in climate, such as the effects of

rivers and lakes in today's difficult desert areas. During the Middle Ages, the Kingdom was affected by seasonal climatic fluctuations that led to changes in weather patterns and rainfall, and some regions experienced wet and fertile periods that contributed to the development of ancient civilizations.

The forests and plant lifestyles of the Kingdom were different from what they are today, in some areas there were forests of palm trees and trees such as cypresses, cedars and pines, providing food and shade. Wet periods of regular rainfall have allowed for more natural water sources and more plant and tree growth (National Center of Meteorology, 2021).

These ancient forests and climates are a testimony to environmental changes and the evolution of plants and animals in the region over time, and by studying these ancient environments, it is possible to understand the impact of climate and environmental changes on life in the Kingdom over thousands of years.

In modern times, the Kingdom experiences very high summer temperatures of more than 50 degrees Celsius in some regions, while winter is cold, especially in the northern regions, and rainfall is low and concentrated in some southern and northern regions. Despite these harsh conditions, the Kingdom has a large biodiversity of plants and animals adapted to the desert and dry environment, which contributes to the sustainability of life (Gharyani, 2017).

The second topic : The impact of climate change on agriculture and food security in the Kingdom of Saudi Arabia

1. Increasing temperatures and frequency of droughts

Studies indicate that Saudi Arabia has seen a significant increase in the

frequency of agricultural droughts, with the frequency of droughts expected to increase by up to 88% by 2050 , threatening the sustainability of agricultural production and increasing pressure on limited water resources (G20 Climate Risks, 2023). The annual average temperature in the Kingdom of Saudi Arabia for 2023 was 26.1 degrees Celsius, which is higher than the average for the reference period (1991/2000) and 0.9m. The graph shows that

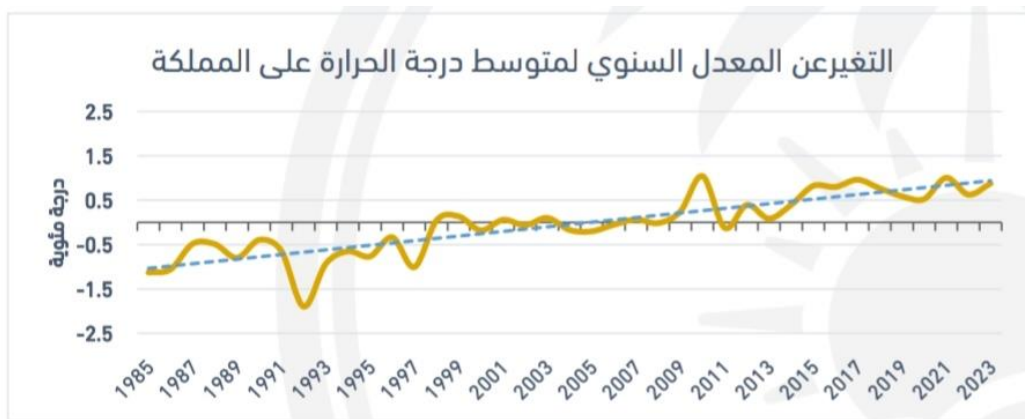


Chart No . (1) Source: National Center of Meteorology

2.Impact of climatic changes on crop productivity

Changes in temperature and precipitation have led to marked fluctuations in



crop production

Chart No. (2)Source National Meteorological Center

agriculture, including wheat, with some regions recording productivity declines of between 10% and 15% over the past years (FAO & MDPI, 2022).

3.Increasing demand for water

Climate change is expected to increase water demand by up to 34.2% by 2050 , even in low emission scenarios, further exacerbating the Kingdom's water crisis (G20 Climate Risks, 2023).

The third topic : The Kingdom's policy towards climate change

-Domestic policy towards climate change:

Saudi Arabia first participated in international climate-related agreements in 1992 through the United Nations Framework Convention on Climate Change. Despite being an oil country, the Kingdom is not a major historical contributor to greenhouse emissions. However, its economy's dependence on fossil fuels, which accounted for about 69% of government revenues in 2019 , imposes an additional responsibility on it both internationally and regionally (Lindzen, 2006, p. 1).

The Kingdom has adopted a cautious policy towards climate change, which has given it enough time to review the solutions offered and restructure some future projects based on renewable energy. In terms of effective participation, the Kingdom has led work efforts at the local, regional and international levels, launching several initiatives, most notably "Green Saudi Arabia" and "Green Middle East", with a plan to plant 40 billion trees in the region.

The Kingdom aims to reduce greenhouse gas emissions by 287 million tons of carbon dioxide equivalent by 2030 , double the previous target of 130 million tons, to achieve carbon neutrality by 2060 (BP et al., 2020, p. 15).Through the following:

Circular Carbon Economy

As part of the Kingdom's efforts to curb climate change, the Kingdom has adopted the Circular Carbon Economy (CCE) approach , which was proposed by the Kingdom during the G20 Summit in 2020 and endorsed by the Member States at the G20 Summit . This approach aims to manage greenhouse emissions using multiple options including carbon reduction,

reuse, recycling, and removal, shaping the circular carbon economy quadrant (BP et al., 2020, p. 18).

The Kingdom's measures include the implementation of carbon capture, use and storage (CCUS) and CO₂-enhanced oil recovery projects, along with boosting investment in renewable energy with the goal of producing 41 gigawatts of electricity by 2032 (Saudi Aramco, no page). According to the Saudi Renewable Energy Strategy, the 2023 solar target has been raised from 5.9 GW to 20 GW, with a total renewable energy target of 58.7 GW set by 2030 (Naguib, 2013, p. 45).

2-Renewable energy projects in the Kingdom

The Kingdom has launched two major renewable energy projects: Sakaka and Dumat Al Jandal.

-Sakaka Project: A 300 MW photovoltaic solar plant, covering an area of more than 6 square kilometers, and contributes to achieving the Kingdom's goal of producing 58.7 GW of renewable energy by 2030 (King Abdullah City for Atomic and Renewable Energy, 2024, p. 12).

-Dumat Al-Jandal Project: The project is the first of its kind in the Kingdom and the largest in the Middle East, with a production capacity of 400 megawatts, and an estimated construction cost of \$500 million (King Abdullah City for Atomic and Renewable Energy, 2024, p. 14).

Saudi Green Initiative

The Saudi Green Initiative was launched in 2021 as a comprehensive framework for the transition towards clean energy and combating climate change, and includes efforts to promote a green economy, accelerate the transition to clean energy, and protect the environment for future generations (Saudi Green and Middle East Green Initiatives, 2021, no page). One of the objectives of the initiative is to plant 10 billion trees during the current century.

using recycled water, and to rehabilitate about 40 million hectares of degraded land.

-Regional Initiatives

At the regional level, the Kingdom has promoted climate action through the Middle East Green Initiative, which aims to plant 40 billion trees in the region and reduce carbon emissions by 60% using clean hydrocarbon technologies. The Kingdom also announced the establishment of a number of regional centers and programs to support the circular carbon economy, extraction and storage, sandstorm warning, sustainable development, and cloud seeding (Al-Suraihi, 2021, p. 33). The Kingdom launched an investment fund to support regional initiatives with an investment of \$10 billion, 15% of which is funded by the Kingdom (Al-Suraihi, 2021, p. 35).

- The global role

At the international level, the Kingdom has participated in several initiatives to promote climate change efforts, including the Carbon Sequestration Leadership Forum (2005) and the Ministerial Committee for Clean Energy (2015), in addition to being one of the founders of the Oil and Gas Companies Climate Initiative. In April 2021, the Kingdom established the Zero Producer Neutrality Forum in cooperation with the United States, Canada, Norway and Qatar, accounting for 40% of global oil and gas production, and aimed to improve carbon neutrality strategies and reduce methane emissions (Al-Suraihi, 2021, pp.38-39).

It is clear from this that the Kingdom's position has evolved from a cautious approach to an effective and progressive participation, in line with the Kingdom's Vision 2030, which seeks to achieve an economy less dependent on oil, while continuing to benefit from national resources to promote economic development, as the Kingdom produces about 13 million barrels

of oil per day, of which about 4 million barrels are consumed internally, while the Kingdom's share of global carbon pollution is about 1.86% in 2019 (Lindzen, 2006, p. 2).

Kingdom's strategies to address climate change

Climate change has become one of the most prominent issues of concern to societies at the global, national and local levels in recent years, as scientists have agreed that sudden climate changes and rising temperatures have immediate and long-term risks to the urban and environmental composition of societies and citizens alike (Najat Aoun, 2023).

Evidence suggests that the main causes of environmental change are excessive land use, deforestation, urbanization, and intensive consumption of fuels. Among the most prominent manifestations of this environmental phenomenon are heavy rains, floods, droughts, and severe storms, as UN reports have shown that billions of people around the world are negatively affected by these phenomena (RT Arabi, 2020).

In Saudi Arabia, climate change affects both rural and urban areas, given the sensitivity of the Saudi ecosystem and the scarcity of water resources and its arid climate, making agricultural land vulnerable to environmental changes (Bilal Saghir, 2023).

Saudi Arabia has therefore taken proactive steps to address climate challenges, including international engagement by supporting the 2016 Paris Agreement , and partnering with a number of sister countries to plant an additional 40 billion trees in the Middle East, which is expected to reduce global carbon rates by 2.5% and restore 200 million hectares of degraded land (Al Yala, 2021).

The Kingdom 's Vision 2030 is one of the most important tools to confront climate change, as it aims to reduce dependence on oil and transform the economy into environmentally friendly, thus contributing to reducing harmful gas emissions. National initiatives also include increasing green spaces, as two initiatives have been launched to plant 10 billion trees over the coming decades, in addition to the

Saudi Green Initiative, which aims to enhance marine life and reduce carbon emissions (Abdul Hafeez, 2022).

The Kingdom is also adopting a new agriculture approach based on solar and hydraulic energy, to benefit from its natural resources and reduce oil and gas energy consumption. Given the scarcity of water, the Kingdom has resorted to the use of local climate-adapted trees, artificial rainfall techniques, and water desalination, in addition to recycling ablution water in mosques to support the green initiative (CNN in Arabic, 2022; Youm7, 2022).

The Green Middle East and Saudi Arabia initiatives represent the Kingdom's roadmap to overcome the crisis of desertification and climate change, while the Saudi authorities have issued severe penalties for logging, and the establishment of special environmental security forces to reduce logging and overgrazing (Middle East, 2022).

The fourth topic : The Kingdom's efforts in achieving food security and its strategy in facing climate challenges.

At the global level, humanity faces significant challenges in securing food as a result of the increase in population and the growing global demand for cereals and food, as the Food and Agriculture Organization of the United Nations indicates that the global demand for cereals will increase by 70% by 2050 compared to the current situation, with doubling in many low-income countries as a result of high per capita consumption and improved income levels in some societies, especially in Asia (FAO, 2009).

At the regional level, Arab countries face increasing challenges due to limited water resources and regional climatic changes that affect local food production, as changes in rainfall and high temperatures lead to significant fluctuations in agricultural crop production and breeding

Livestock and fish, which affect food distribution, food markets and access to food (Saudi Ministry of Environment, Water and Agriculture, 2022).

At the local level, Saudi Arabia is one of the countries facing great pressures in this context due to its desert environmental conditions, high temperatures, and high dependence on limited water resources. Despite the increase in food production globally, local challenges remain, as food security depends on the availability of food locally and the ability of citizens and farmers to access it, whether through direct production, purchase or exchange (Saudi Food and Drug Authority, 2024).

Agriculture in the Kingdom is very sensitive to climate changes, as any rise in temperatures can affect the stability of agricultural systems and change the productivity of crops, livestock and fish breeding systems, as well as affect food distribution and local markets. Therefore, it has become necessary to integrate climate change adaptation and climate risk management policies to reduce their impacts on food security (Saudi Ministry of Environment, Water and Agriculture, 2024).

Through its programs and policies, the Kingdom seeks to address these challenges by improving water resources management, enhancing local food production, stimulating investments in sustainable agriculture and renewable energy, in addition to adopting a circular carbon economy approach to reduce carbon emissions associated with agricultural and industrial activities (Saudi Ministry of Environment, Water and Agriculture, 2024; FAO, 2009).

Future Expectations

Estimates of advanced climate studies, including joint regional modelling between the Center for Complex Engineering Systems at King Abdulaziz City for Science and Technology (KACST) and the Massachusetts Institute of Technology (MIT), indicate that temperatures in the Kingdom and Middle Eastern countries could rise to 60 degrees Celsius within 30 years, with

serious health and environmental impacts if urgent action is not taken (RT Arabi, 2021).

The Kingdom's current initiatives are expected to contribute to modifying the radiative properties of the Earth's surface, increasing soil moisture, enhancing the absorption of carbon dioxide gas, and producing oxygen through photosynthesis processes, which reduces the concentration of one of the most important greenhouse gases. Renewable energy projects also aim to provide 50% of electricity by 2030, which will contribute to reducing more than 130 million tons of carbon emissions (Bilal Saghir, 2023).

RESULTS:

- 1.Climate change is caused by the interplay of natural and human factors, with modern human factors such as greenhouse gas emissions and industrial and agricultural activities dominating.
- 2.Emissions of greenhouse gases, especially CO₂ ,methane and nitrous oxide, contribute mainly to global warming and rising global temperatures.
- 3-Climatechange manifestations include: rising temperatures, extreme heat waves, frequent droughts, heavy rains and floods, forest fires, melting ice, and sea level rise.
- 4-Climatechange threatens food security through: decrease in crop and livestock production, deterioration of water resources, disturbance of natural pollination, spread of pests and diseases, and decrease in the nutritional value of some crops.
- 5-Agricultureitself contributes to climate change through deforestation, the emission of methane from rice and livestock, and the use of nitrogen fertilizers, which increases the concentration of greenhouse gases in the atmosphere.
- 6-Theeffects of climate change include low food production, high prices and changing production sites globally, which affects importing countries and increases malnutrition rates.
- 7.There is a need to develop accurate sensing and monitoring information systems and technologies to support agricultural decision-making and improve food security management in the face of climate change.
- 8-TheKingdom has developed its climate policy from a cautious stance to a leading role at the regional and international levels through initiatives such as "Green Saudi Arabia" and"Green Middle East", with goals to reduce emissions and achieve carbon neutrality by 2060 .9. TheKingdom has

adopted a circular carbon economy approach and expanded renewable energy projects, including Sakaka and Dumat Al-Jandal, to achieve 58.7 GW of renewable energy production by 2030 .10-TheKingdom faces climatic challenges, including rising temperatures, repeated droughts, fluctuating crop production, and increased demand for water, which threatens the sustainability of agriculture and food security.11- TheKingdom is working to address these challenges by managing water resources, enhancing local food production, encouraging sustainable agriculture and renewable energy, and increasing vegetation cover to reduce carbon emissions and improve environmental balance.

RECOMMENDATION:

- 1-Improving themanagement of agricultural and water resources and increasing the efficiency of water use, whether through modern irrigation techniques or benefiting from recycled water and desalination
- 2-Enhancing local food production by using drought-resistant crops and applying sustainable and modern farming methods.
- 3.Integrate climate change adaptation strategies such as circular carbon economy and renewable energy into agricultural and industrial activities, and increase green spaces and rangelands by continuing Saudi Green and Middle East Green initiatives to reduce desertification and enhance vegetation cover.
- 4-Developingresearch and technical capabilities to provide accurate data on the impact of climate change on food production and support decision-making,
- 5-Raisingawareness among farmers and the community about sustainable agriculture methods and climate risk management at the local, regional and international levels.

Afterword:

The research demonstrates that climate change is a real threat to agriculture and food security at the global and local levels. Rising temperatures and changing rainfall patterns have reduced crop productivity and increased the frequency of droughts, placing significant pressures on water resources and affecting the stability of food systems. Saudi Arabia shows a clear example of climate challenges due to its desert environment and limited water resources, but is proactively working to address these challenges through national and regional initiatives to promote sustainable agriculture, increase vegetation cover and achieve carbon neutrality.

National efforts such as Saudi Green and the Middle East Green and the expansion of renewable energy projects reflect the Kingdom's commitment to preserving the environment and ensuring sustainable food security. The research indicates that the integration of climate change adaptation strategies and effective resource management, along with the promotion of scientific research and awareness-raising, form the basis for ensuring the Kingdom's ability to face future climate risks and achieve environmentally, socially and economically balanced sustainable development.

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