

Global water security under climate change**Guendouz Aicha**

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Abstract:

This paper addresses two of today's biggest problems of water security and climate change and the impact of the latter on water security in the world, using the analytical descriptive approach to describe the phenomena and analyze their data while monitoring the implications of climate change patterns for water security in the world.

The study concluded that there is a two-way effect between climate change and water security, as climate change affects the amount of fallout, freshwater torrents, river streams, and the degree of salinity of groundwater... Causing water stress, while irrational consumption of water resources wastes natural water wealth and affects ecosystems, the study also recommended that international efforts to mitigate and adapt to climate change should be combined with strategies to reduce water stress, especially in developing countries.

Keywords: Climate change; Water security; Water stress; Water resources.
Jel Classification Codes : Q54; Q56; Q57; Q25.

ملخص:

هدفت الدراسة لدراسة أكبر المشكلات التي تواجه العالم اليوم، وهما الأمن المائي وتغير المناخ، وتأثير الأخير على الأمن المائي عالمياً. تعتمد الدراسة على النهج الوصفي التحليلي لوصف الظواهر وتحليل بياناتها، مع رصد انعكاسات أنماط تغير المناخ على الأمن المائي في العالم. خلصت الدراسة إلى وجود تأثير متبادل بين تغير المناخ والأمن المائي، حيث يؤثر تغير المناخ على كمية التساقطات، والسيول العذبة، وتدفقات الأنهار، ودرجة ملوحة المياه الجوفية، مما يؤدي إلى الضغط المائي. وفي الوقت ذاته، يتسبب الاستهلاك غير العقلاني للموارد المائية في هدر الثروات المائية الطبيعية ويؤثر على النظم البيئية. وأوصت الدراسة بضرورة تكامل الجهود الدولية للتخفيف من آثار تغير المناخ والتكيف معه مع وضع استراتيجيات لتقليل الضغط المائي، خاصة في البلدان النامية.

الكلمات المفتاح: تغير المناخ؛ الأمن المائي؛ الضغط المائي؛ الموارد المائية.

تصنيف JEL: Q54; Q56; Q57; Q25.

I. Introduction:

The issue of climate change has become a sensitive issue in this area of time. All continents have experienced major climate fluctuations in the past five years, and their severity and impact have been the subject of numerous studies on sustainability in the past and present; These climate disruptions have caused some devastating natural disasters, such as: B. hurricanes, ice melt, heavy rains, floods, landslides, severe droughts, etc. According to experts from the Intergovernmental Panel on Climate Change (GIEC), the earth is not only affected by "natural" climate change, but also by climate change caused by human activities. (IPCC, 2013) Climate change, increasing water shortages, population growth, demographic changes and urbanization have brought challenges to water supply systems. At least 2 billion people worldwide use sources of mit contaminated drinking water from human waste, mainly for industrial activities, followed by agricultural activities and excrement, transportation activities and the resulting toxic gas emissions; By 2025, half of the world's population will live in water-stressed areas. Repurposing wastewater for water, nutrient or energy recovery has become an important strategy. In developing countries, wastewater is increasingly used for irrigation. This accounts for 7% of irrigated land. (WHO)

Developing countries are not unaffected by climate change, but they are the most affected because they further exacerbate known water security issues due to the nature of their countries, the already prevalent dry climate and their large populations; climate change is one of the most important challenges facing water security in developing countries.

The considerations so far lead to the main question of this study: What are the effects of climate change on water security in developing countries? The research question can be developed in more detail by answering the questions "What is global climate change?", "What is water security and its dimensions?" and "What are the effects of climate change on water security in developing countries?"

The study is based on the following assumptions:

- Climate change is an extreme and atypical variation of natural phenomena;
- Traditional and other non-traditional water resources;
- Climate change has a negative impact on water systems, thus posing an obstacle to water security.

The importance of this study is reflected in the importance of the issues of water security and climate change. These topics are considered as current issues; the first issue concerns the issue of achieving water security for decision-makers in developing countries and the importance of addressing the negative impacts of climate change on water security and drought mitigation around the world.

Methodology: The descriptive and analytical method has been used to describe the topics, their dimensions and problems, then to analyse their requirements and the relation between them.

II. Literature review:

The most recent previous researches are the study by (Bouchenaf Faiza, 2023) describes the relationship between water security and food security as crucial. In fact, the future of a country's food security is closely linked to its ability to achieve water security. This is why the Algerian government is looking for the best way to achieve this goal. In this context, this study uses a descriptive analysis method to find that Algeria has several qualifications to implement water security projects, thereby guaranteeing the achievement of food security. While Mukhtar (2020) conducted a study on "Climate Change and Water Security in Pakistan" to analyze Pakistan's water security by examining water availability, climate patterns, and rainfall changes. The study looks at Pakistan's vulnerability index and suggests ways to address future water challenges. The researcher found that Pakistan is vulnerable in terms of water security. Countries like Pakistan along the Sindh River will suffer from a lack of water and potentially face conflicts over water resources. He suggested private sector funding for water and climate projects to support environmental protection and climate change adaptation. A nationwide evaluation of water availability, demand, and the future effects of climate change on the water industry is necessary. These initiatives need legal support and an institutional framework to meet adaptation strategy requirements. In 2009, Sadof and Muller presented a study titled "Water management, water

security, and adaptation to climate change: Early Impacts and Essential Responses." The study proposed investing in water resources management and natural infrastructure to adapt to climate change's impact on water supply and ensure sustainable water security. Proper utilization of available information, including storage, transport, and water treatment. Finding the right combination of information, institutions, and infrastructure is essential to achieving balance between equity, environment, and economy.

II.1. The conceptual frame of the water security:

Water security comes when water is managed effectively, sustainably, and equitably, both to take advantage of its productive potential and to limit its destructive potential.

UN-Water, the United Nations inter-agency coordination mechanism for all water-related issues, states that water security should be defined as: "The ability of the population to ensure sustainable access to sufficient quantities and acceptable quality of water for sustainable livelihoods, human well-being, and social and economic development, to ensure protection from water-borne pollution and water-related disasters, and to maintain ecosystems in a peaceful and politically stable environment (UNWATER, 2013). Water security is achieved through effective, sustainable, and fair management of water, balancing its benefits and risks.

Michel Garrow, a past Chairman of the United Nations Committee on Water and Secretary-General of the World Meteorological Organization, defined water security as: "Security now means human security and its achievement through development. Water is commensurate with this broader definition of security, which encompasses political, health, economic, personal, food, energy, environment and other concerns and serves as a central link between them" (SCO UN, pp. 24-25).

Beyond just considering water shortage, water security considers a nation's productive and preventive efforts to secure water in addition to its water resources. While some of the world's most water-rich countries are fighting to safeguard their citizens from water-related calamities and/or give access to better drinking water, some of the world's most water-scarce countries can also be considered among the safest in the world. (World Bank Group, p. 04)

However, security cannot be limited by using this idea alone. Water security encompasses not only the prudent management and preservation of existing water supplies, but also their non-pollution and sensible consumption. In order to maintain equilibrium between the supply of resources and the rising demand for them, efforts are being made in the areas of irrigation, industry, and watering, as well as the creation of new water sources and the upgrading of existing investment capacities. The following is a review of the topics that are connected to the idea of water security: Water is one of the most important resources on human security as a fundamental and required requirement. Life cannot be formed or sustained without it in addition to being a productive resource. Human security is the defense against unforeseen catastrophes that jeopardize human life and livelihoods. It poses the biggest threat to human security due to its destructive features of floods and droughts.

- When fresh water supplies are scarce, impoverished irrigation techniques—the most prevalent of which include the use of saltwater and improperly treated wastewater—become intertwined with human security, water security, and the environment. The Middle East and North Africa, which have the lowest percentages of arable land and the most limited water resources in the world, lose around one million hectares of agricultural area year due to salinized soil.

- Water balance is defined by The International Association of Hydrological Sciences as: "The process of balancing the total volume of conventional and non-conventional water resources (water supply) in a given period with the total volume of water requirements required to meet different needs (water demand) during the same period", in other words: "means the quantities of water entering and exiting any water system". (The International Association of Hydrological Sciences, p. 92)

- Water stress: Due to insufficient, erratic, or delayed rainfall, water stress is also known as water-scarce places. According to Henin* (1976) Water deficits measured at the plant tissue level indicate the presence of water stress, which has a negative impact on yield.

II.2. Water resources:

The amount of water on the planet is estimated at 1,408.7 million km³, the bulk of which is 97.5% of the saltwater that fills the oceans and seas, while the amount of freshwater represents only 2.5% (GUY, p. 103). Water resources are any source of natural water on the earth's surface physical condition, whether solid, liquid, or invasive of potential benefit to human beings, River water, seas, and oceans are the most widely used sources, and This is because of their growing need for water in the agricultural, industrial and recreational fields. Water covers 71% of the earth's surface, only 2.5% of which is fresh water, the rest is salt water, and water resources are classified into three main parts: salt water, groundwater, and surface water.

II.2.1. Surface water: with 63% of surface water used for sanitation, 58% for irrigation, and 98% for industrial purposes, Surface water is naturally replenished by Sedimentation*, Surface waters and associated ecosystems provide habitat for many plant and animal species. Because surface water is on the earth's surface, it is easy to develop for use and provides about 78% of all off-stream water use in the United States. Surface water includes streams, rivers, lakes, reservoirs, and wetlands. The term stream is used here to represent all flowing surface water, from brooks to large rivers. (American Geosciences, 2002)

II.2.2. Groundwater: accounts for 30% of the world's available freshwater. An additional 69% of freshwater is trapped within polar ice sheets, while river and lake water account for only 1%. Groundwater is often hidden in the vicinity of aquifers, permeable rocks, and sediments and

* Hénin Stéphane (1910-2003), 44 contributions from 1949 to 1974, Agronomist, Honorary Research Director, National Institute of Agricultural Research (in 1989). <https://www.persee.fr/authority/441574>

* Sedimentation is a process in which the heavier solid particles present in a liquid, settle down at the bottom of the container. It is the last of the geological processes and occurs after the erosion process. Sedimentation by running water: The faster the water stream the lower the sediment size.

extracted using pumping wells. Often, aquifers can be renewable water resources that are slowly replenished through rainwater spills over hundreds or even thousands of years (IAEA).

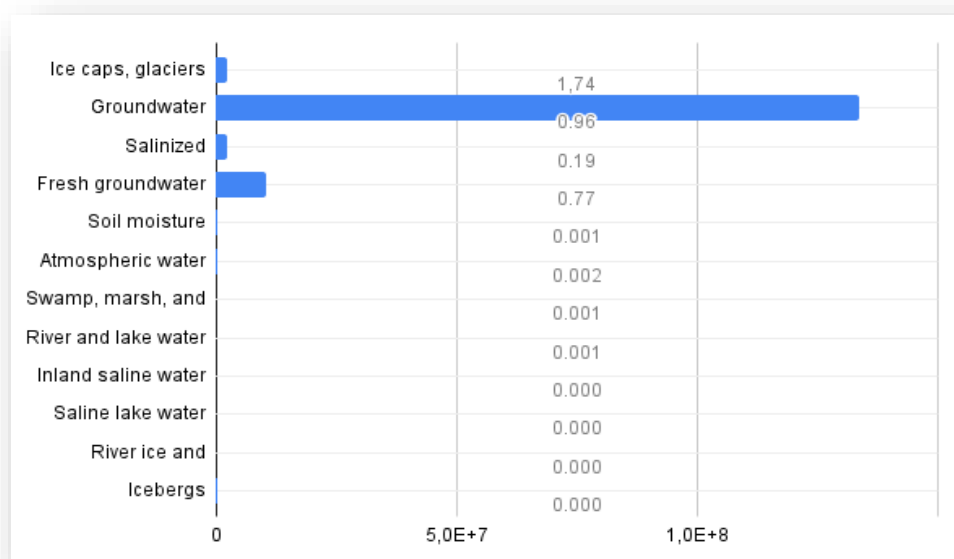
Table 1 Estimate of water volume and distribution on the earth's surface

Source of water	Amount of water	Percentage %
Oceans and seas and bays	96.5	-
Ice caps, glaciers, and ice	2406000	1.74
Groundwater	133800000	0.96
Salinized groundwater	2340000	0.19
Fresh groundwater	10530000	0.77
Soil moisture	165000	0.001
Atmospheric water vapor	300000	0.002
Swamp, marsh, and bog water	2120	0.001
River and lake water	1120	0.001
Inland saline water	85400	0.000
Saline lake water	12900	0.000
River ice and glaciers	11470	0.000
Icebergs	176400	0.000

Source: Khaled.M.Azouawi, *Water the blue gold in the Arabic world, group Nil Arabia, Cairo, 2004, p66.*

Oceans, seas, and bays contain the most water, followed by ice caps, glaciers, and ice. Groundwater is the third most abundant source of water, followed by soil moisture, atmospheric water vapor, and swamp, marsh, and bog water. River and lake water, inland saline water, saline lake water, river ice and glaciers, and icebergs are the least abundant sources of water.

Figure 1: Estimates of water volume and distribution on the earth's surface



Source: Based on the data in table 1.

The distribution of water sources on earth can be summarized as:

- Oceans and Seas: 96.5%, Ice Caps, Glaciers, and Ice: 1.74%, Groundwater: 0.96%
- Salinized Groundwater: 0.19%, Fresh Groundwater: 0.77%, Soil Moisture: 0.001%
- Atmospheric Water Vapor: 0.002%, Swamp, Marsh, and Bog Water: 0.001%
- River and Lake Water: 0.001%, Inland Saline Water: 0.000%, Saline Lake Water: 0.000%
- River Ice and Glaciers: 0.000%, Icebergs: 0.000%.

The world contains 1,400 million km³ of water and freshwater forms 5. Only 2% of this water is 35 million km³, the large quantities of freshwater found in ice blocks and ice debris as well as deep underground are not available for use. Freshwater available for use comes mainly from rainfall on the ground through nature's hydrological cycle or water cycle, and water is constantly recycled as a result of solar-driven evaporation. This shows that the energy consumed per day by nature's water cycle (hydrological cycle) exceeds that consumed by all mankind throughout its overall history.

II.2.3. Other sources: thanks to sophisticated technologies have opened up broad areas for States that lack or have water deficits to meet their growing needs, through several mechanisms, the most important of which are (Les Levidow & al, 2014, p85):

- **Desalination:** removal of dissolved salts from seawater and in some cases from the brackish (slightly salty) waters of inland seas, highly mineralized ground waters (e.g., geothermal brines), and municipal wastewaters. This process renders such otherwise unusable waters fit for human consumption, irrigation, industrial applications, and various other purposes (Britannica). There are several desalination methods, including Distillation, steam pressure, membranes, and reverse osmosis, the most common desalination processes are distillation and reverse osmosis. Desalination is currently expensive compared to most alternative water sources, and a very small proportion of all human water use is satisfied by desalination. The desalination process is usually only economical in the case of high-value uses (such as domestic and industrial uses) in arid areas. However, there is an increase in desalination for agricultural use, and in densely populated areas such as Singapore or California. However, the most comprehensive use of desalination is in the Arabian Gulf.
- **Reuse of wastewater:** The reuse of wastewater is one of the scientific methods used to develop water resources, Wastewater can be reused after being filtered with limited methods using modern technology to meet certain agricultural needs and other uses. This method generates 38.77 million m³ to irrigate 6,744 acres of agricultural land (Bouchenaf, p214) For example, approximately 20 million people in Chad, Niger, Nigeria, and Cameroon depend on Lake Chad alone, which has significantly diminished their waters. Given projections of population growth and water demand, global water data and figures reflect a water position that is not without embarrassment. Due to the uneven distribution of both population and water and unequal distribution, the situation has become critical in some countries and regions. There is an increase in different parts of the world that suffer from insufficient freshwater and increased competition among different users. (FAO).

About 80% of the world's population is exposed to high levels of threats in terms of urban areas and farming from water security. Two sources of water seed, threaten life in the water environment and puts pressure on freshwater ecosystems. In 2010, according to specialists' estimates, between 10 and 20,000 freshwater species were extinct or threatened with extinction. (UNESCO, 2019, p. 56), Latin America alone accounts for 31% of the world's freshwater resources, and its per capita is estimated to be 12 times higher than South Asia's per capita water share. Some places, such as Brazil and Canada, receive more water than they can use, while others, such as countries in the Middle East, do not have sufficient access to their

needs. We find that a water-stressed as Yemen (198 cubic meters per capita) is not assisted by a country such as Canada, which has an excess freshwater of over (90.000 cubic meters per capita). Similarly, water-stressed territories in China and India do not find assistance from Iceland with an abundance of water resources exceeding the limit of 700.1 cubic meters by 300 times. (water scarcity, risk, and vulnerability. 2006, p. 134)

A country like Peru is difficult to obtain, especially since its price is high. In the United States of America, a person consumes approximately 350 liters a day, much more than a person in developing countries. (Long, 2002, page 09).

III. climate change:

Climate is the range of atmospheric states (heat, air...) in a given place and in a specified time (month, year, millennium), it is a phenomenon occurring in the climate, and the term climate includes temperature patterns, precipitation, humidity, wind, and various seasons.

- In article, I, the 1992 United Nations Framework Convention on Climate Change (UNFCCC)* defined it as: "Climate change" means climate change directly or indirectly attributable to human activity leading to a change in the composition of the global or indirect atmosphere "Any direct response to natural fluctuations or human activity to any changes to human causes ". (UNFCCC), The Government's Climate Change Authority (GIEC) defined it as: "Changes in the state of the climate over time, whether caused by natural fluctuations or human activity". (Government Climate Change Authority, 2008, p. 78), Practical (procedural) definition of climate change: defined by the International Panel on Climate Change (IPCC) established by UNEP and the World Meteorological Organization (WMO) in 1988, which considered it "the set of changes in the state of the climate over time but human-induced". In 1995, it was declared that the human impact on climate change is clear and significant, through the emission of greenhouse gases such as carbon dioxide and methane... (greenhouse gases) that are adapted to climate change, and that the causes of these changes are considered only human activities, although nature may have a role to play. (Food and Agriculture Organization, page 02)

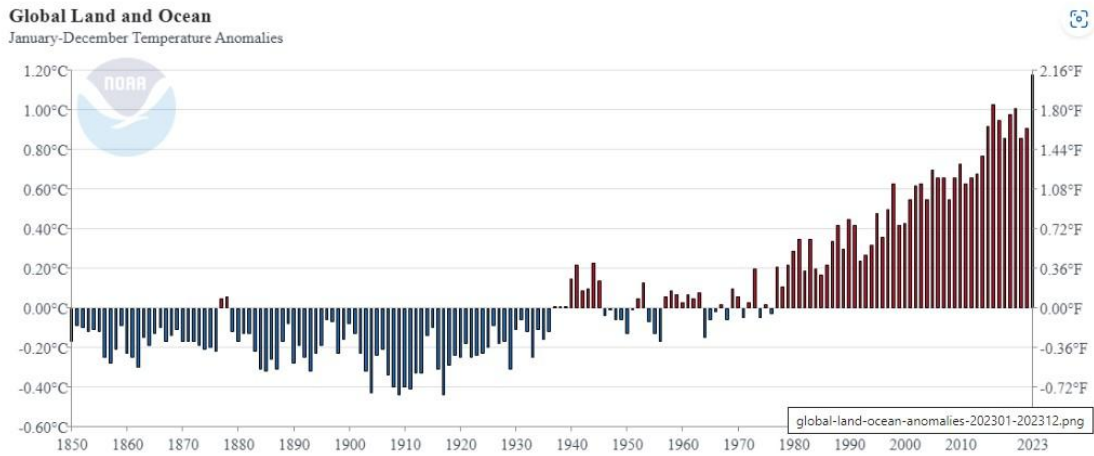
III.1. Difference between climate change and global warming:

People usually use the terms interchangeably, assuming they indicate the same. But there is a difference between the two: global warming indicates high average temperature near the earth's surface, and climate change refers to changes in atmospheric layers such as temperature, precipitation, and other changes measured over decades or longer periods. The term climate change is preferred when referring to the effect of factors other than high temperature. According to the United States Environmental Protection Agency, climate change may result from: (EPA)

- Natural factors such as changes in the density of the Sun or slow changes in the earth's circulation around the Sun,
- Natural processes within the climate system (e.g. changes in the ocean's water cycle),
- Humanitarian activities that change the composition of the atmosphere (e.g. burning fossil fuels) and the earth's surface (e.g. deforestation, reforestation, urbanization, desertification, etc.).

* The Intergovernmental Panel on Climate Change (IPCC) uses a similar definition, the main difference being that the IPCC covers all aspects of climate change.

Figure 2: High global average temperature 1850-2023



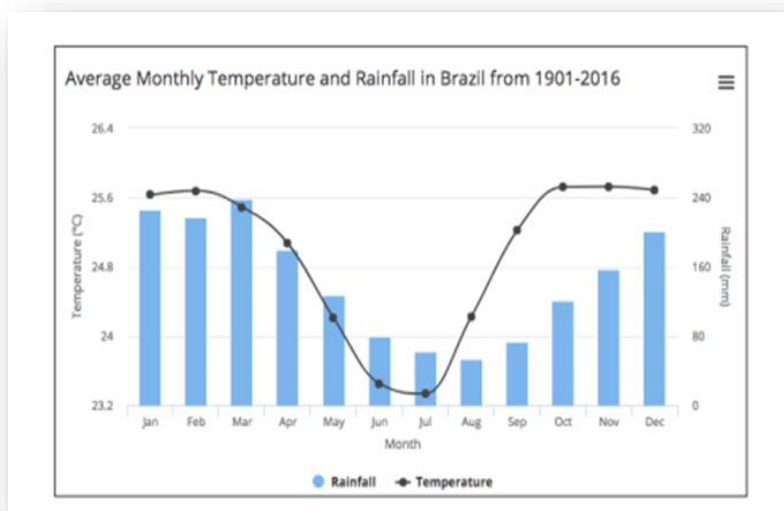
Source : <https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202313>

We note that the average temperature in the world has risen according to a range of sources over the last 170 years as the direction of the curve predicts that the average temperature will continue to rise over the coming decades as a result of changing climatic factors.

III.1.1. Greenhouse phenomenon: The greenhouse phenomenon is a reference to traditional greenhouses (greenhouses) in which glass walls reduce airflow and increase the temperature of the air that is trapped inside them. The earth's climate is mainly dependent on the Sun, where about 30% of sunlight is scattered back into space and the atmosphere absorbs some of it while the earth's surface absorbs the rest. The earth's surface also reflects part of the sunlight in a moving energy image called infrared radiation.

What happens is that infrared radiation is delayed by "greenhouse gases" such as water vapor, carbon dioxide, ozone, and methane, which make infrared radiation bounce back, raising the temperature of lower atmosphere layers and the earth's surface.

Figure 3: Average monthly temperature and rainfall in Brazil (1901-2006)



Source: metadata of the climate change knowledge portal.2018. P05

Over a century and 15 years, the average monthly temperature in the Brazilian region has fallen sharply between May and September, i.e. summer, while the average rainfall during the same season has decreased. This is explained by climate disturbances prevailing in the region, although greenhouse gases make up 1% of the atmosphere they form a cover around the floor or a glass ceiling for a glass house, This traps heat and keeps the globe's temperature at 30 degrees, which is as high as if that were not the case. (World Bank)

III.1.2. Causes of climate change:

We can divide the causal movements of the threat into natural factors on the one hand and human factors on the other. Although the symptoms of this phenomenon such as warming sea level rise, acidification of the oceans... They are natural phenomena but their causes are often human factors, and these causes in themselves are based on probability and not certainty, Natural causes: Most scientists agree that one of the most important causes is: volcanic eruptions and solar density...

Human causes are divided by scientists into three overlapping species: global warming greenhouse gas emissions, aerosols, and changes in earth's use: (UNEP, 2010)

- Greenhouse gas emission: the sources of these gases come from burning fossil fuels, power generation, transportation, and various industrial, agricultural, and household means. (United Nations Development Programme, p. 2007/2008).

- Aerosols: Solid particles and small liquids enter the atmosphere from land fires, forests, and the use of diesel fuel... these particles contribute to preventing solar radiation from entering the earth's atmosphere, making the earth's surface colder, or may increase its heat.

- Land-use changes: such as forest burning, logging, wetlands* destruction and replacement from the agricultural sector to other sectors, thus contributing to desertification that contributes to the emission of about 11 to 28% CO₂ gas according to the report of the International Panel on Climate Change. (UNEP, 2010, p. 34)

III.1.3. Climate change patterns:

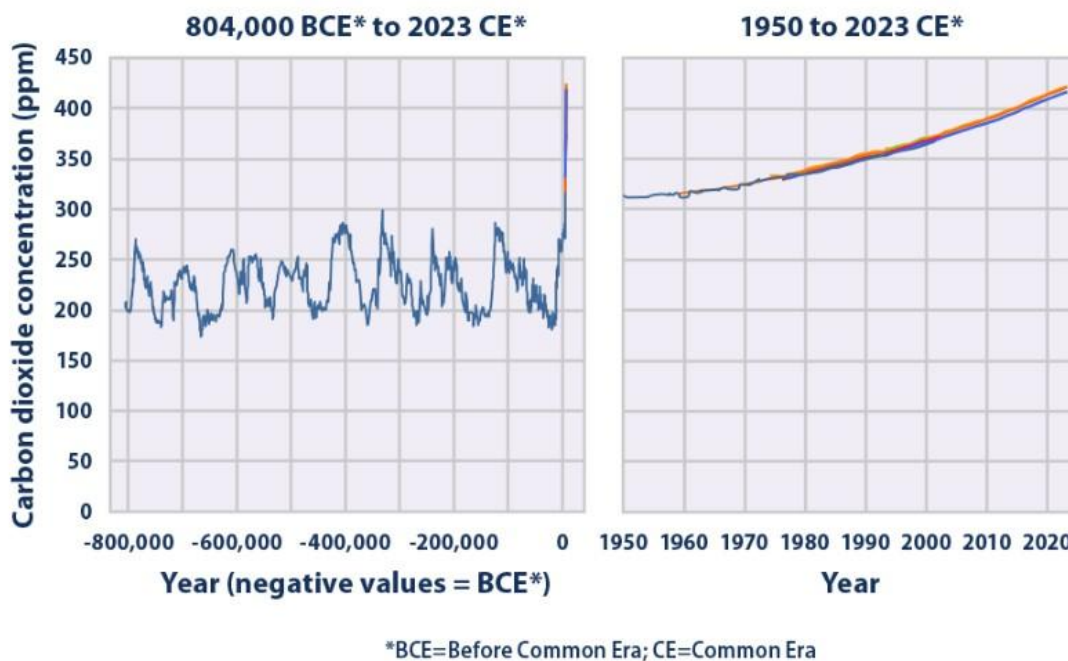
Climate patterns are climate changes that spread across the world's regions and regions, of which they are concentrated in nations but not others, while abnormal patterns are formed in places other than those that have written their existence, causing extreme weather events, including Hurricane Katrina in the United States in 2005. Cyclone Nargis in Myanmar in 2008, floods in Pakistan in 2010, Drought in the Arizona Basin region, Australia, and East Africa, and the decline of ice mass in the polar region.

III.1.3.1. Concentration of greenhouse gases in the atmosphere:

The greatest factor in global warming is due to the increased concentration of carbon dioxide in the atmosphere since the 1870s due to the Industrial Revolution. Atmospheric CO₂ concentration levels are now higher than at any time in the past 650000 years. In the northern hemisphere, the level of carbon dioxide concentration during the three spring months of 2015 exceeded the 400 ppm barrier for the first time in history (fig.4) the global concentration of greenhouse gases in the atmosphere: carbon dioxide, methane, and nitrous oxide.

* The Ramsar Convention defines wetlands (or ponies) as "marshland, peatland or water, whether natural, industrial, permanent or temporary, and whether they contain persistent, flowing, freshwater, stagnant or saline water, including navigational water areas with a minimum depth of six meters". (Article 1 of the Ramsar Convention on Wetlands, 1971). The present report has adopted this definition and thus covers inland wetlands (such as lakes, rivers, and marshes) and coastal wetlands (such as tidal flats, mangroves, salt marshes, and coral reefs).on: https://www.ramsar.org/sites/default/files/documents/pdf/Ramsar40_booklet/40thAnniversaryBooklet-7Feb2011.pdf

Figure 4: Global concentration of greenhouse gases in the atmosphere from 1970 to 2023



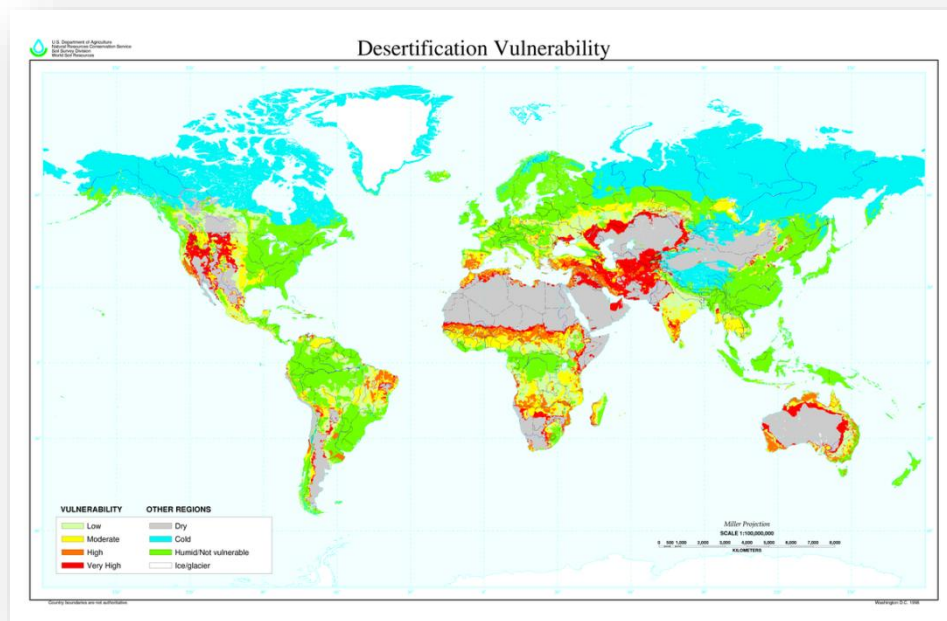
Source: https://www.epa.gov/system/files/images/2024-06/ghg-concentrations_download1-2024.png

III.1.3.2. Precipitation fluctuations:

Increased water vapor in warmer climates leads to more rainfall incidents and increased risk of both drought (where it does not rain) and floods (where it rains). Exemplary Russia and Australia-El Niño events cycle significantly affect the distribution and timing of floods and droughts, especially in the tropics and on most central latitudes of Pacific states. Overall rainfall on earth during the twentieth century in areas between the latitude 30 ° N and 85 ° N latitude ", however, there have been notable reductions in the past over the past 40-30 years and the latitude 30 ° N between latitude 10 ° S. Decreases in salinity in the North Ocean indicate similar changes in the Atlantic and south latitude 25 ° S over the ocean. Rainfall in the area between latitude 10 ° N and latitude 30 ° N increased markedly from 1900 to the 1950s but declined after 1970.

III.1.3.3.High drought and desertification factors:

defined as a decrease in the earth's biological production capacity or the degradation of productive land fertility at the rate it gains from conditions similar to desert climatic conditions. Desertification therefore leads to a decline in the production of plant life. The total desertification area in the world is about 46 million square kilometers for the Arab world, of which about 13 million square kilometers, or about 28% of all desertified areas of the world. Desertification affects the percentage of plant production of some crops and this is reflected in the prevalence of drought in many regions.

Figure 5: Proportion of the world's desertification prospects

Source: https://upload.wikimedia.org/wikipedia/commons/thumb/6/68/Desertification_map.png/1200px-Desertification_map.png

Climate change contributes to desertification as follows:

- High temperatures and low or rare rains help speed evaporation and build up salts in planted land (droughts);
- Floods also shovel soil and uproot crops, threatening soil fertility;
- dune crawl covering plowing and wind implants;
- Rising groundwater levels;
- Rain-dependent agriculture;
- The reliance on well water for irrigation, which has increased its salinity over time, thereby increasing the salinity and desertification of the soil;
- The wind leads to the speed of the plants' drying and permanent wilting especially if it lasts long. In addition, they tear and uproot plants, especially with shallow roots, leading to the removal of vegetation.

➤ **Sea warming:** Human activities, such as burning fossil fuels, cement production, and deforestation, have increased greenhouse gas concentrations in the atmosphere. The accumulation of carbon dioxide and other heat-pulling gases has increased atmospheric temperatures. The earth's temperature has risen $\sim 0.9^\circ\text{C}$ since 1880. It is expected to lead to further warming between $2\text{--}4^\circ\text{C}$ by 2100. Oceans, mostly due to human activity and this increase has resulted in a corresponding increase in ocean temperatures, especially in the ocean surface.

➤ **Sea level rise:** Changes in sea level occur for many reasons on different time and space scales. Tide gauges measure sea level variations with a fixed benchmark and thus record "relative sea level" change due both to vertical land movements and to real (eustatic) changes in the ocean level. Vertical land movements result from various natural isostatic movements, sedimentation, tectonic processes and even anthropogenic activities (e.g., groundwater, and oil extraction). In parts of Scandinavia, for instance, relative sea level is decreasing by as much as 1m per century due to isostatic "rebound" following the last major glaciation. In attempting to identify a globally-coherent. (Warrick & Oerlemans, p 263).

Figure 6: Sea surface rise

Mean sea level variation worldwide from 1993 to 2023
(in millimeters)



Source: <https://www.statista.com/statistics/603821/global-cumulative-sea-level-rise/>

Changes in storm patterns: Global climate change is likely to drive changes in storm patterns, future projections based on high-resolution models indicate that in 2100:

- Global tropical storms may be more severe;
- The frequency of severe storms may increase significantly in some areas;
- The number of tropical storms globally may decrease or change slightly.

➤ **Melting ice:** Global warming is melting parts of icebergs such as Arctic ice, resulting in the loss of meltwater amidst ocean salinity.

➤ **Ocean acidification:** High atmospheric carbon dioxide causes deposition in the surface ocean, lowering the pH of seawater (making seawater more acidic). Ocean acidification reduces the amount of calcium carbonate available to coral reefs and other calcified marine organisms to build their skeletons and shells. This process is called ocean acidification and reduces coral reef's ability to grow and resist stress.

➤ **Acid rain:** It is rain or any other form of deposition that is unusually acidic, meaning it contains elevated levels of hydrogen ions (low PH). It can have adverse effects on plants, aquatic animals, and infrastructure. Acid rain is caused by emissions of sulfur dioxide and nitrogen oxide, which interact with water molecules in the atmosphere to produce acids. Bad rains fall to poison fresh water and soil, destroy tillage and offspring, and their toxic metals kill humans through the water and food chain (USGS). Global warming comes through three factors: carbon dioxide 63%, methane 19%, and nitrous oxide 6%, agriculture contributes 12% of greenhouse gas emissions about 60% of total nitrous oxide emissions from fertilizer, and 50% of methane emissions from livestock. (WMO & IFAP, 2005)

According to the Intergovernmental Panel on Climate Change (IPCC), the earth's temperature rose 0.74%, causing a decrease in rainfall. It also caused the melting of glaciers, causing the feeding of major rivers to decline, which affects the water supply and at the end of the 21st century, the production of rainy crops such as rice is expected to decrease due to global warming, Increasing air temperature by 2 ° C also reduced the production of rainy rice by 5% to 12%. (AIACC, 2005), water stress poses a threat to food security in developing countries.

IV. Climate change Threats on water security:

Environmental threats affect and prevent water security from being built, and conversely, irrational exploitation of water security is affecting the sustainability of environmental resources.

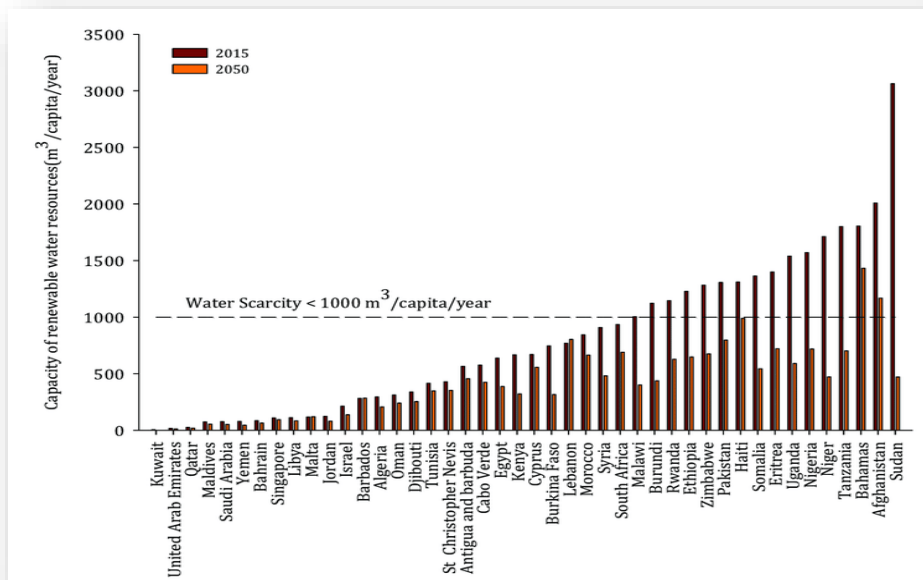
Water is the key element through which climate change affects ecosystems, livelihoods, and societies' well-being. Global climate change is expected to exacerbate current and future pressures on water resources due to population growth and land use and to increase the frequency and severity of droughts and floods. Climate change is also expected to affect the availability of water resources as a result of foreseeable changes in rainwater distribution, soil moisture, melting ice, ice and snow, and river and groundwater flows.

IV.1. Implications of climate change for water resources: (water systems)

Water-related hazards represent 90% of all natural hazards. There is a general increase in the frequency and severity of these risks, which has serious consequences for economic development. It should be noted that the extent of damage caused by natural disasters that affected several developing countries between 1990 and 2000 was between 2% and 15% of these countries' annual GDP. (UN, page 03), and \$7.13 billion (in drier cases) and \$2.19 billion (in wetter cases) are likely to be associated with the water sector, with the bulk being used to secure water supply and flood management. (United Nations, p. 04)

Wetlands act as carbon sinks that help reduce climate change, which is why their degradation (such as peatland consumption) can lead to very large emissions of greenhouse gases. Wetlands also regulate sediment transfer and thus contribute to land formation and coastal stability. (UN, page 06).

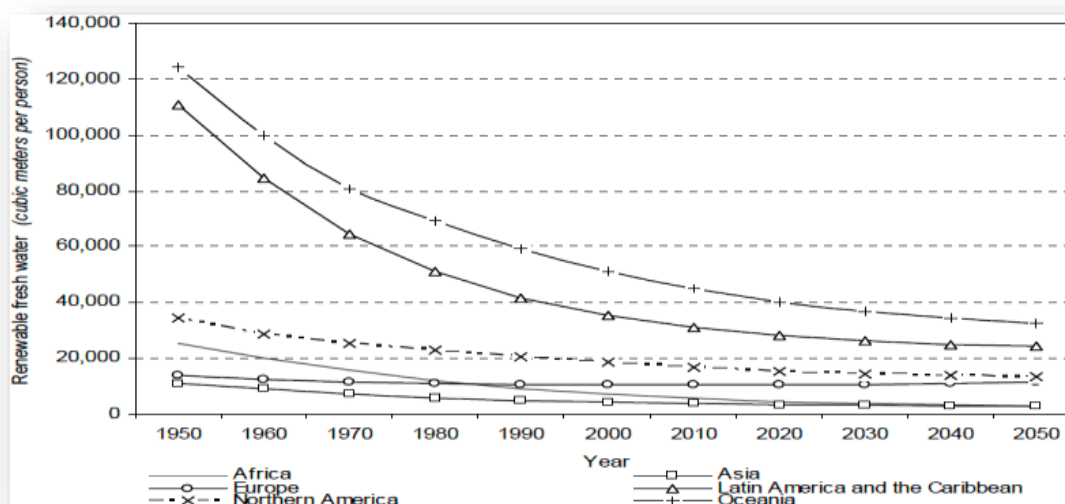
Figure 8: Water stress and water scarcity in the world (2015-2050)



Source: https://www.researchgate.net/figure/Countries-expected-to-be-water-scarce-by-2050_fig2_359654721

Fig 8 shows the concentration of water stress in South Asian and sub-Saharan African countries while water scarcity in Arab countries rises to address problems in the Middle East and North Africa region with average water availability falling by more than a quarter. By 2025, the average water availability is expected to be barely above 500 cubic meters per capita, with more than 90% of the region's population in countries with water scarcity. Water stress will increase in sub-Saharan Africa, slightly more than 2025 to 30%, and in South Asia, while the rest of the world does not have water shortages and projections for 85% and 2050. (Taking into account the latter's high population compared with that of African States, large-scale census countries such as China and India have joined the group of water-stressed countries globally).

Figure 9: Global water availability per capita(1950-2050)



Source: https://www.researchgate.net/figure/Water-availability-per-capita-in-major-world-areas-1950-2050-44_fig3_324912694

Global water per capita has changed dramatically owing to high population growth in countries already experiencing water stress water availability rates in wealthy countries in the 1970s, Those ratios continued to decline in developing countries, particularly in arid developing countries. The 2006 Human Development Report says that by 2025 there will be more than 3 billion people living in water-stressed countries - and 14 countries will fall from water stress to water scarcity.

Groundwater plays a critical role in ensuring the livelihoods and food security of more than 1 billion rural families in Africa's poorest regions and Asia, and in securing household water supplies for a large number of people in other parts of the world. The global rate of groundwater extraction has increased by at least three times in the last 50 years, greatly enhancing food production and rural development. Groundwater is today one of the most important sources of water for human consumption, securing nearly half of the world's drinking water. (United Nations, page 05) Benjamin Franklin, one of the authors of the American Declaration of Independence, said, "When wells dry, we realize the value of water." Today, the world's peoples and Governments are discovering the true value of water and the price of ignoring it in the past. The price of past practices that viewed water as a resource that can be exploited without limits is now driven by public policies that govern the world's people.

IV.2. Efforts to reduce climate impact on water security:

Climate change is ambiguous as extreme events are unpredictable. It is therefore difficult to control the outputs of mitigation or/and adaptation strategies that are designed to address the problem of climate change, while States resort to alternative solutions to water scarcity to reduce water stress caused by climate symptoms and variability. Solutions consisted of a range of non-traditional water sources. At the United Nations level, the United Nations World Water Development Report 2018, entitled "Nature-driven solutions to water issues", provided a vital means of overcoming business as usual to address many global water challenges while providing vital additional benefits to all aspects of sustainable development.

The conventional infrastructure constructed by human beings, often referred to as "grey" infrastructure, still plays a significant role in water management. However, the vast potential for leveraging solutions derived from nature remains largely untapped. These solutions encompass "green" infrastructure, which has the capacity to either replace, enhance, or complement grey infrastructure in a cost-effective manner. The goal is to establish the optimal combination of investments in green and grey solutions, thereby maximizing the benefits derived and the efficiency of the system, while also minimizing costs and concessions. (UN WATER, 2018, page 04)

The utilization of nature's solutions to address water-related challenges is pivotal to the execution of the 2030 Agenda for Sustainable Development. This approach not only yields mutual social, economic, and environmental advantages but also encompasses critical areas such as human health and well-being, food and energy security, sustainable economic expansion, employment opportunities, ecosystem restoration and preservation, and biodiversity conservation. Although nature's solutions may not serve as a universal remedy for every ailment, they are indispensable in the pursuit of a circular economy and the creation of a more equitable future for all.

By working in concert with nature, we enhance the management of water resources, facilitate the attainment of water security for everyone, and bolster essential components of sustainable development. (UNESCO), and considerable adjustments to the way water is distributed among the various sectors will be needed to ensure long-term economic growth. Increased water efficiency is required in tandem with the reallocation of up to 25% to 40% of water in water-problematic areas from activities with low to high levels of productivity and operation. This is due to factors such as population expansion, urbanization, industrial transformation, and climate change. Because agriculture uses a large percentage of water, it is assumed that this reallocation will come mostly from this sector; any water movement will need to be hypothetical and physical. Changes in the original distribution of surface and groundwater resources and the "sales" of water from agriculture to urban, environmental, and industrial users are the main ways that water physically moves.

Water traffic may also be hypothetical, with the production of large quantities of water-based food, goods, and services concentrated in water-abundant areas and exchanged with water-scarce areas. (WHO)

V. Conclusion:

As stated in Goal 6, the Sustainable Development Goals prioritized protecting water resources and attaining water security for all peoples. One aspect of the environmental dimension of sustainable development is protecting the climate from extreme changes. As a result, the two goals merge into one, with the goal of maintaining ecosystem stability and managing water resources sustainably by investing in grey infrastructure in tandem with green infrastructure for the best possible outcomes.

Suggestions: The research makes several recommendations:

- Increasing water prices and implementing integrated, sound management strategies for water resources serve as a catalyst for careless water use and pollution;
- Improving water management to maximize social welfare and equitable economic output while avoiding endangering the sustainability of important ecosystems.
- The adoption of modern and sophisticated waterproofing methods in the uses of agriculture and industry;
- Develop national plans through which developing States will work to create non-traditional sources of water based on technological development and innovation;
- The optimal, sustainable, and equitable use of water by increasing environmental awareness and combining the principles of sustainable development;
- Adhering to the rules of international conventions on environmental protection and climate change to increase water supply;
- Invest in water resources management infrastructure to achieve water supply;
- Take advantage of States' experiences in the desalination of seawater, river conversion, regulation of groundwater extraction, and recycling of wastewater.

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