Climate change Adaptation in West-Asia Region: Case study of Jordan

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Abstract
Undoubtable, climate change has become a reality on earth causing a variety of consequences. Glacier melts, changing weather patterns, extreme weather events and higher sea level are conclusive evidences implying extraordinary conditions on earth. Furthermore, measurements of weather variables provide additional proof by noticing trends of temperature and rainfall as well as climate models projections. Carbon dioxide levels after industrialisation period have reached unprecedented levels based on scientific evidences. The impact of climate change is noticeable at global scale; however, some regions are more affected. West Asia is one of the highly affected regions due to the predominant arid to semi-arid climate and limited rainfall rates. Jordan in particular, is a West-Asia's country inside west Asia boundary that is highly affected by climate change consequences as a result of its limited water resources. Jordan's climate models predict higher level of temperature and lower levels of rainfall.

Fortunately, many global initiatives are making great efforts towards dealing with climate change, however, it is not a simple mission as long as many developed and rising economies compete to grow faster. Therefore, it makes sense to follow a realistic approach that aims to respond to climate change within possible limits. This can be done through adopting adaptation and mitigation strategies. Nature-based solutions represent one of the adaptation options, if mainstreamed in policy, will definitely support response and adaptation to climate change.

Keywords: Climate change, Indicators, Greenhouse gases, Adaptation, Nature-based solutions.

Introduction

Climate change is a real threat to earth and all its natural and human systems; therefore, it becomes an urgent need to take actions that help to control the acceleration of climate change, mitigate its causes and adapt to its impacts.

The international community has paid attention to climate change consequences decades ago and created many initiatives to unify international governments' efforts to overcome this global issue. One of the milestones of the international endeavours was initiated by creating the Intergovernmental Panel on Climate Change (IPCC) in 1988. IPCC was created by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) with the objective of providing governments at all levels with scientific information that can be used to develop climate policies. After two years of IPCC's establishment, its first assessment report was issued in 1990.

Following IPCC formation, the United Nations developed its own entity with the mission of supporting the global response to threats of climate change known as UNFCCC, which stands for the United Nations Framework Convention on climate change. UNFCCC is well known for two significant events in the trip of global actions to respond to climate change: the Kyoto protocol treaty in 1997 and Paris agreement in 2015.

Kyoto Protocol aimed to design global commitment towards limited greenhouse gases' emissions, especially from the side of industrialized countries and rising economies, Paris agreement targeted to keep a global average temperature increase very close to 1.5^0C.

Currently, IPCC is working on three different working groups. The first one assesses the physical science of climate change. At the same time, the second group assesses the vulnerability of socio-economic and natural systems to climate change, the negative and positive consequences of climate change and options for adapting to it. Group 3 focuses on climate change mitigation, assessing methods for reducing greenhouse gas emissions and removing greenhouse gases from the atmosphere. Figure 1 illustrates the primary missions for each of the three groups of IPCC.

Climate change adaptation and mitigation are two important domains for the global efforts to effectively react to the effects of climate change with the least possible losses. Whilst adaptation to climate change is the process of adjustment to actual or expected climate and its effects, mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gasses.

This study aims to follow the scientific interpretations of climate change causes, indicators (on a global, regional and country-level) and impacts as described in available literature and data, in addition to present some nature-based solutions and techniques that can help to support climate change adaptation in urban areas.

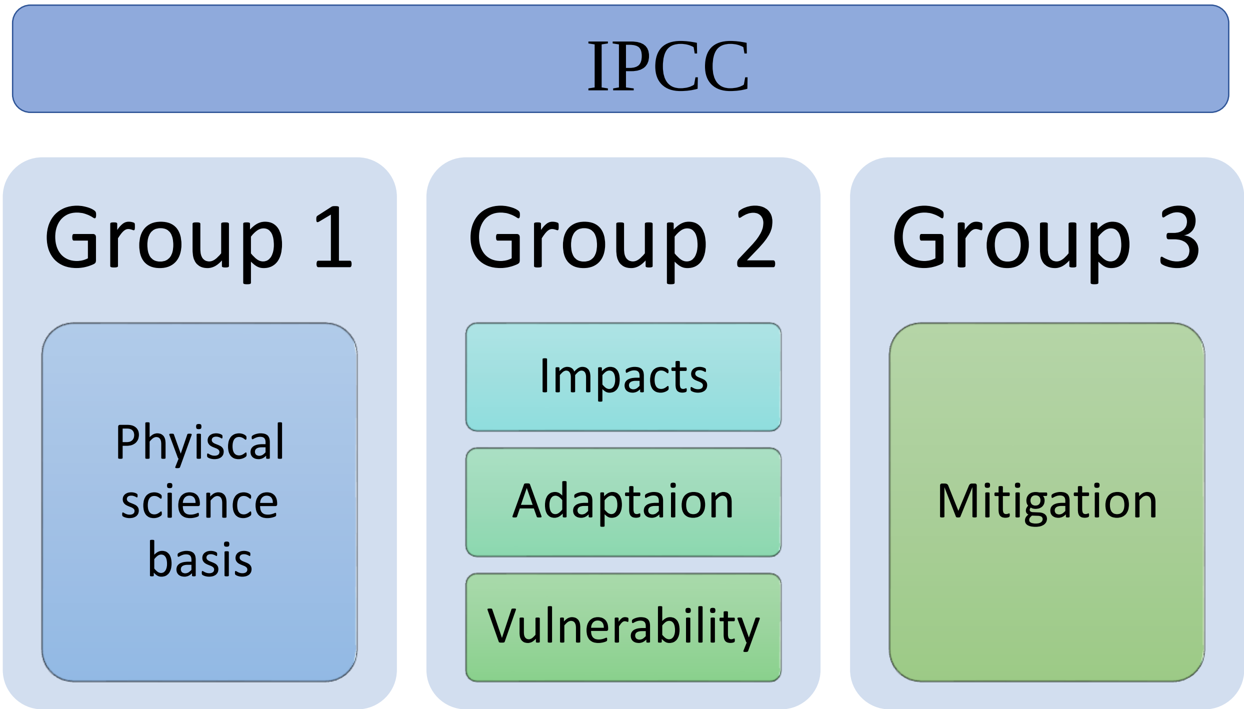

Figure 1: IPCC Working Groups

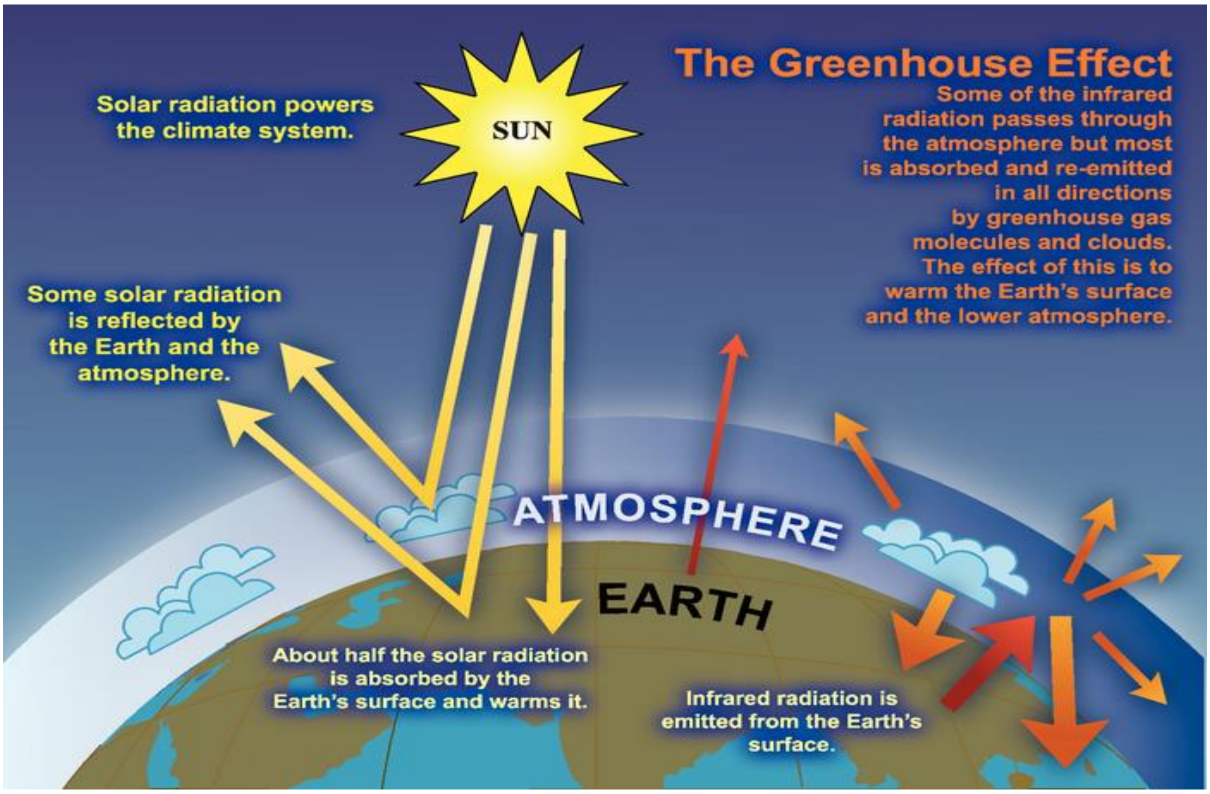

Figure 2: Greenhouse gases effect process[12]

Climate change causes

It is widely believed that greenhouse gases are the main contributors to climate change because they can trap heat into the atmosphere resulting in the greenhouse effect. The process starts when sun radiation falls on the earth; part of it is absorbed by the earth's surface whereas the rest are reflected back to the atmosphere. As the heat of the radiation is released back to space, greenhouse gases absorb a part of the reflected heat. Greenhouse gases radiate the trapped heat either back to the earth's surface, another gas particle, or space. Figure 2 illustrates the greenhouse gases effect.

Many daily life activities to meet human demands result in releasing gases into the atmosphere. Activities such as generating electricity, driving cars, flights and operating factories lead to releasing greenhouse gases causing the earth to warm. Although CO_2 emission is frequently mentioned as the main cause for global warming, yet other gases might have worse effect if released in similar amount compared to CO_2. Agriculture and fossil fuel burning activities result in releasing methane which can trap 84 times as much heat as CO_2[18] and about one-fifth of the global warming since the middle of the eighteenth century.[22] Nitrous oxide is another greenhouse gas that can capture 300 times heat compared to what can be capture by CO_2.[28]

Is climate change driven by human activities?

The major scientific consensus predominantly emphasizes that human activities are held mainly responsible for climate change. For instance, several articles in peer-reviewed journals assure that majority of 97% of climate scientists agree that human activities are the main reason for global warming.[8] Additionally, eighteen significant scientific organizations announced statements approving similar positions[21]. Furthermore, scientific researches by NASA have supported the evidence of anthropogenic driven climate change through reporting that atmospheric CO_2 levels for 800,000 years did not exceed 300 parts per million (ppm); however, since the industrial revolution, a persistent increase continued to override 400 ppm. Consequently, these levels cannot be attributed to natural causes. Projections' models predict 1.5 °C for most simulated scenarios by the end of the 21st century compared to the second half of the nineteenth century.[19]

On the other side, another group of scientists published debates to argue for a different point of view. For instance, ice core sample measurements during some climatic cycles indicated global warming coming ahead of CO_2 global increase.[5] Lindzen raised a contradicting fact of IPCC report stating, they have interpreted the past 17 years without warming as a result of heat hiding in the deep ocean. This explanation approves a failure of climate models to simulate the exchange of heat between the ocean's surface and its deep layers.

Material and Methods

Temperature: The increment in the global mean surface temperature since the 19the century is definite; for instance, the average global combined ocean and land temperature data over the period 1988-2012 demonstrate warming of 0.85 °C. Furthermore, the increment of the minimum and maximum land temperatures worldwide since 1950 is certain. Likewise, the upper part of the oceans (above 700 m) has wormed in recent history.[24]

I. Precipitation: Interdecadal and interannual variability are well pronounced in entire precipitation evaluations caused by The El Niño-Southern Oscillation (ENSO) and North Atlantic oscillations (NAO). The hydrological cycle is mainly controlled by the total energy of the atmosphere and the interactions with the clouds; therefore, due to the combination of fast and slow atmospheric responses to climate change, the overall mean precipitation varies.[1,13]

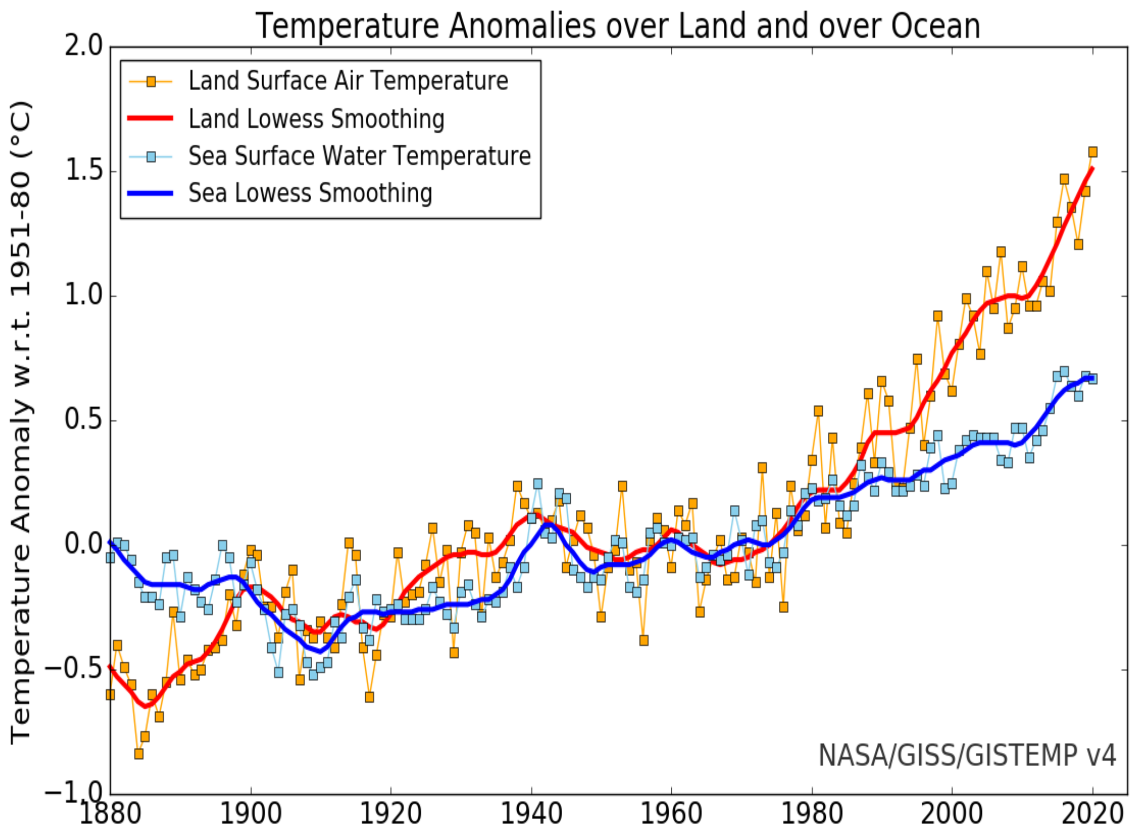

Figure 3: Temperature anomalies over land and ocean

Extreme weather events: The alterations in the duration, magnitude and frequency of extreme weather events are one of the most significant impacts of climate change. Extreme weather events comprise a set of events such as intense precipitation events and high-temperature events; other examples are exhibited in figure 4. As a whole, observing the trends in intensity and frequency of extreme weather events by studying the trends in the long run is quite challenging; such an observation is restrained by the limitation in spatial and temporal observational datasets.[23,29]

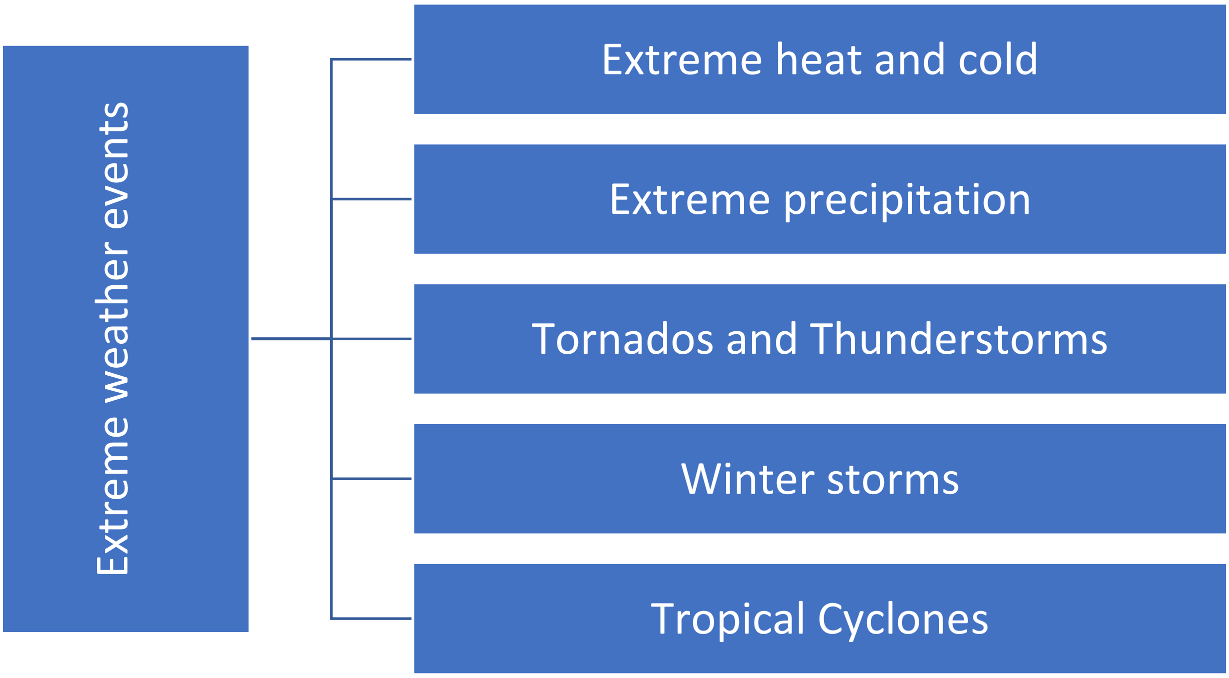

Figure 4: Examples on extreme weather events

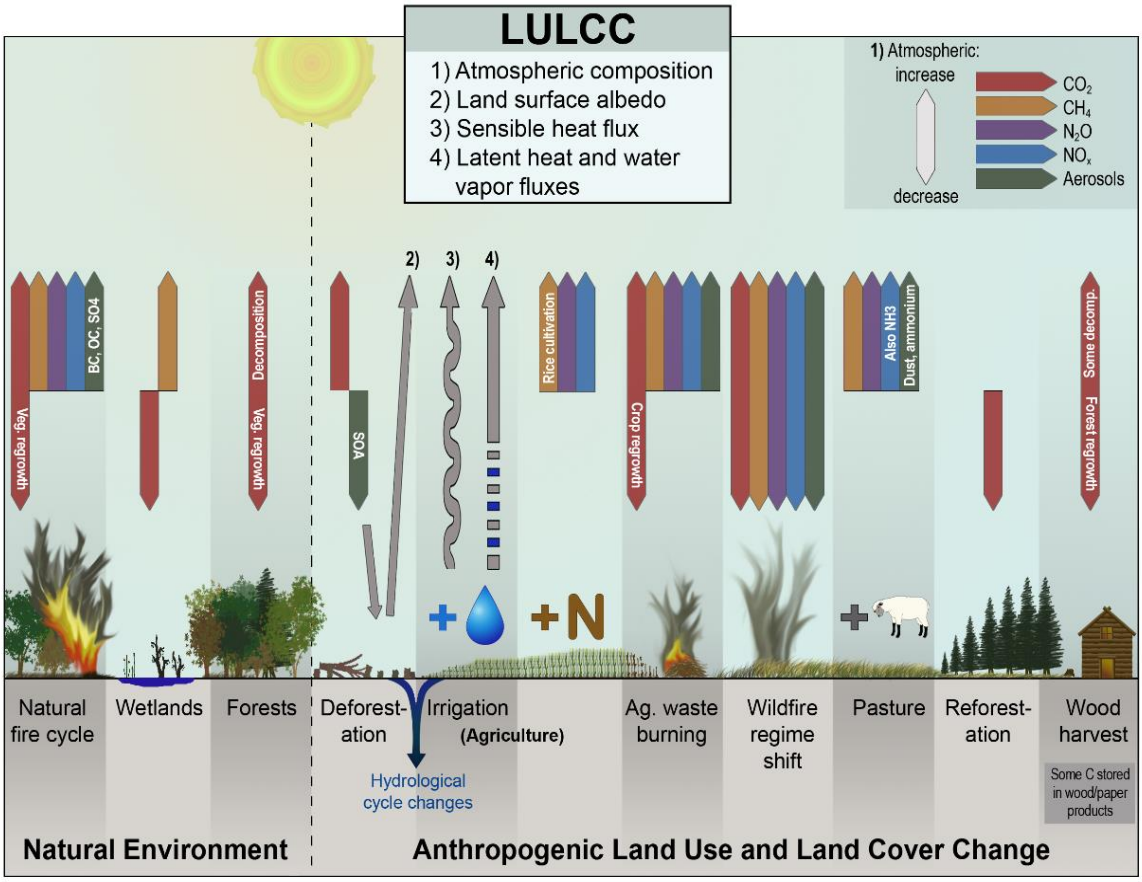

Figure 5: Land-atmosphere interactions from natural and anthropogenic land-use and land-cover change[30]

Changes in Land processes: Although climate change considerably affects land cover, direct land-use changes by humans affect the climate. More specifically, direct land-use changes by humans alter the landcover and consequently albedo. Hence, anthropogenic land-use changes contribute to climate change. On the other hand, climate change is reshaping land ecosystems' biogeochemistry; reshaping includes but not limited to the alteration in growing seasons, in addition to alteration in the productivity of forested as well as agricultural systems. As a whole, land cover and land use changes reach out to the climate processes. As a response, the ecosystem alters the carbon cycle, atmospheric aerosols and earth's albedo, forming a combination of negative and positive feedbacks to climate change as shown in the figure.[13,27,29]

Changes in glaciers, sea ice and land ice: Observations continuously demonstrate diminishing snow cover in the Northern Hemisphere, Arctic sea ice thickness and extent, continental ice sheets and the volume of mountain glaciers,[4,13] as exhibited in the figures.

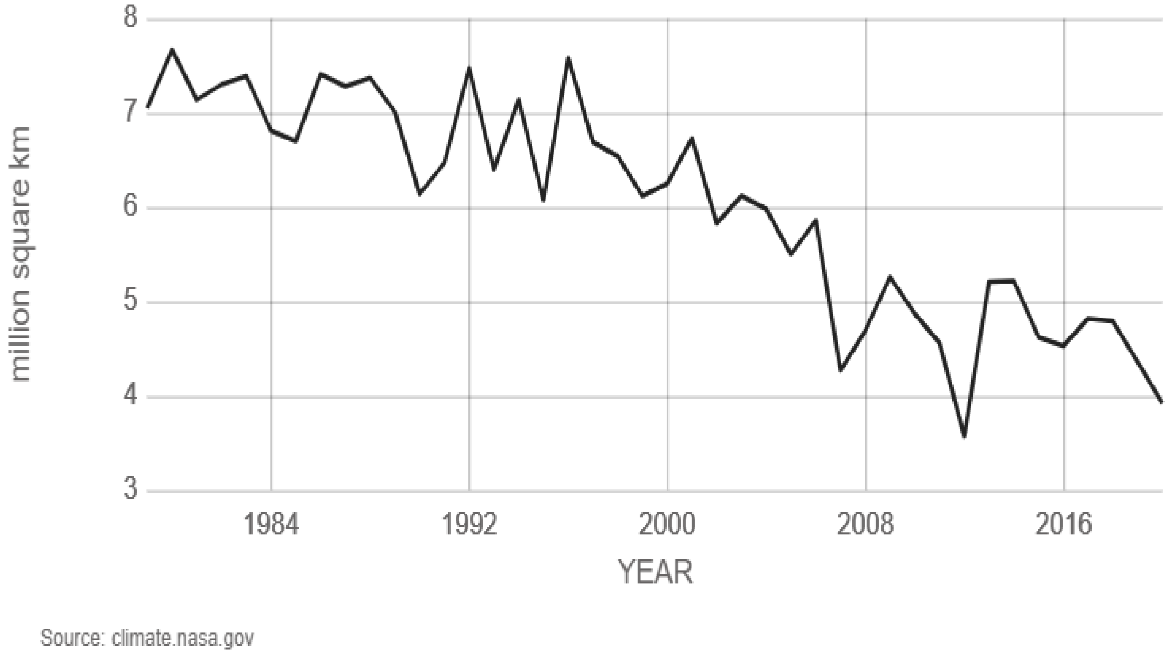

Figure 6: The volume of arctic sea ice over time

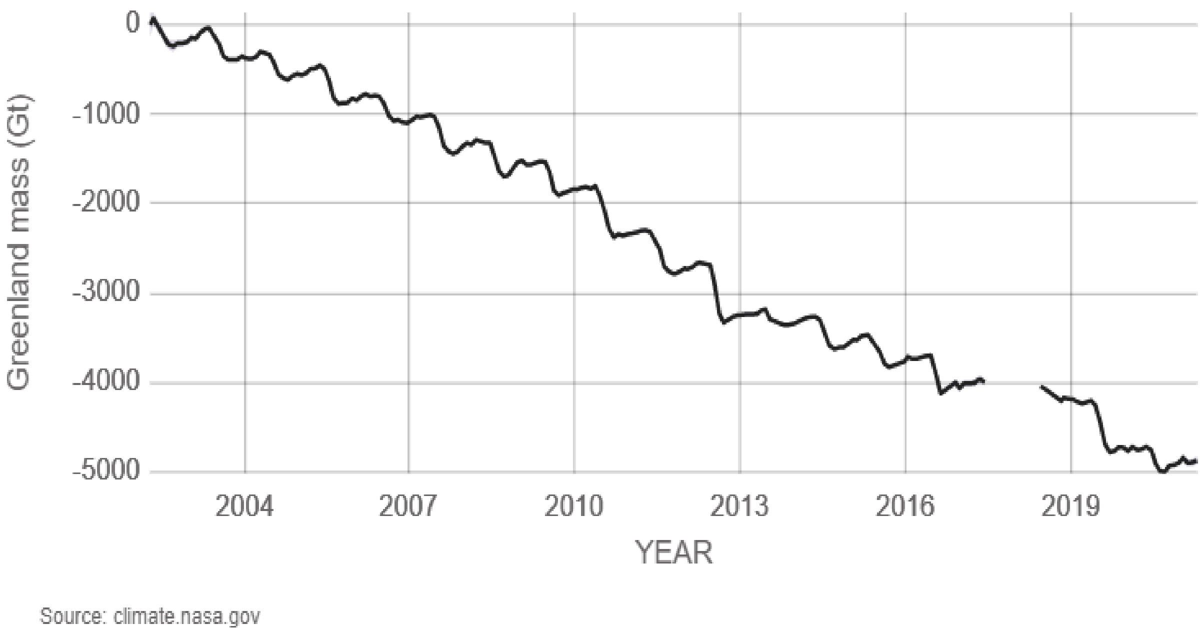

Figure 7: Greenland ice mass diminishing over time

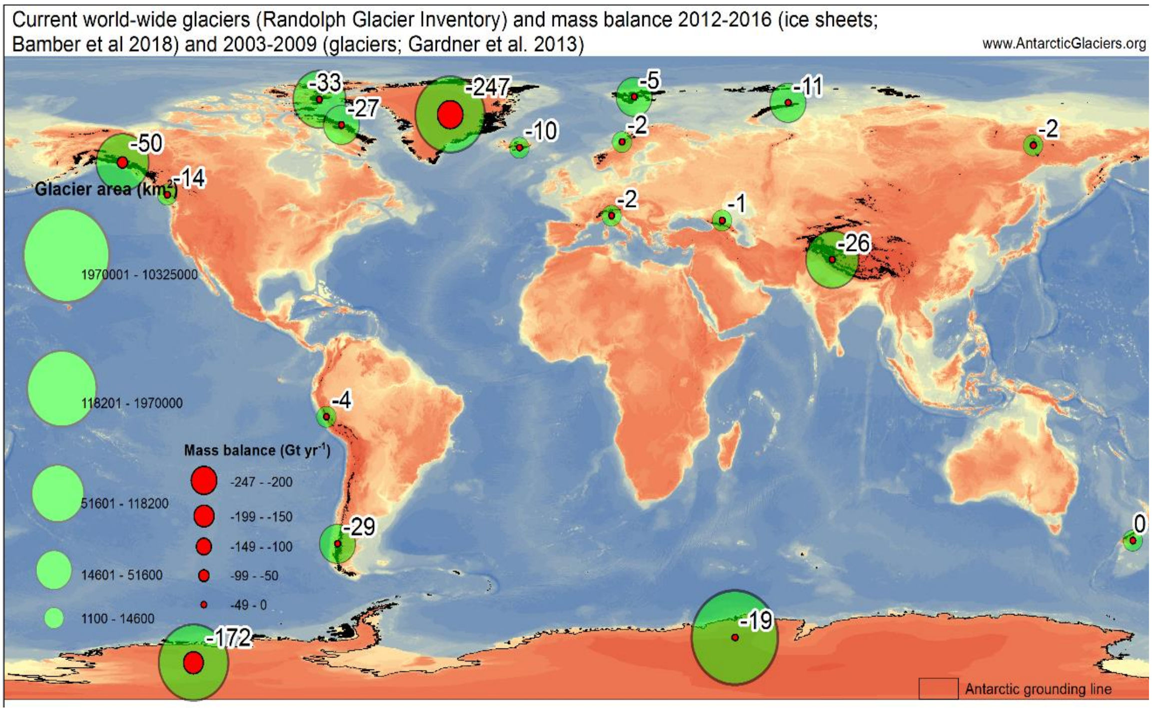

Figure 8: World glaciers' mass nowadays

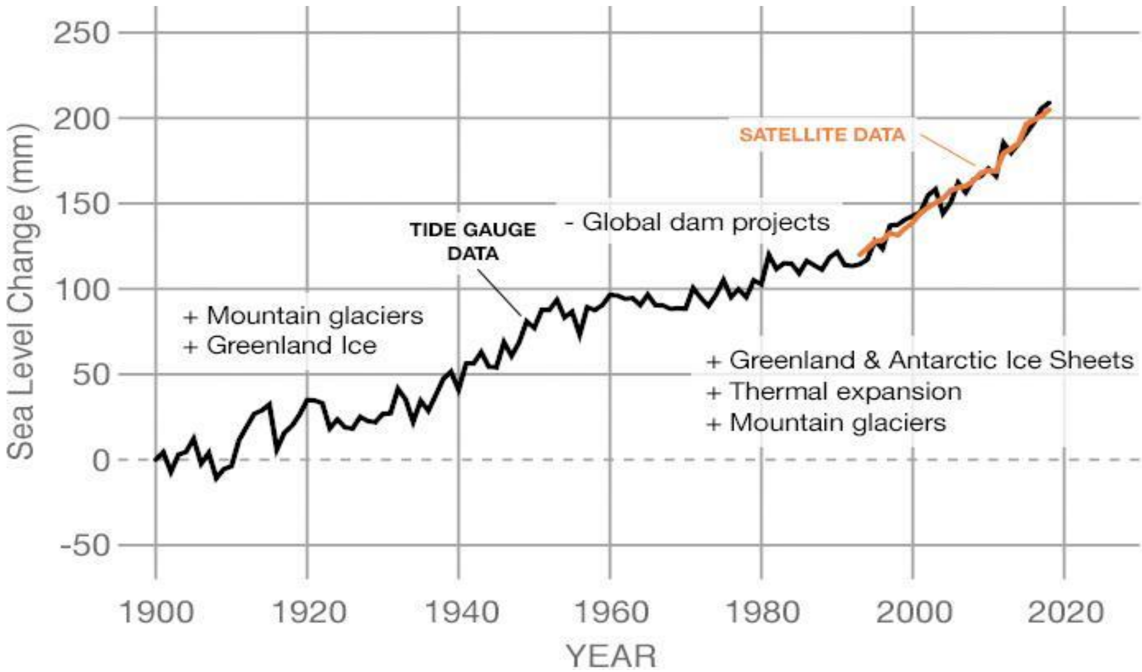

Figure 9: Sea level rise over time[21]

Changes in sea level: Rising sea level is intimately related to the increment in temperatures. Although uncertainties exist on the expected sea-level rise values during the current century, sea-level rise progressively threatens the infrastructure, ecosystems, coastal communities, erosion of coastal landforms, saltwater intrusion and coastal flooding. Statistically, since 1900, the rise in the global mean sea level is 16-21 cm.[29]

Climate data indicators for the Middle East region: Figures 10 and 11 illustrate the average monthly temperature and precipitation on a monthly basis for the middle east based on two historical periods, one represents the first three decades of the twentieth century (1901-1930) and the second period represents the last three decades (1991-2020).

Figure 10 depicts increase in average monthly temperature for the last 3 decades in comparison to the period of 1901-1930. The increase is noticeable for all months but the increased values vary from month to month. For instance, relatively higher increase of temperature is witnessed for 5 months (April to August) with 1.3-1.4 °C. Lower increase of 0.9-1.2 °C for the rest months, however, in November has the least change of temperature with a rise value of 0.4 °C.

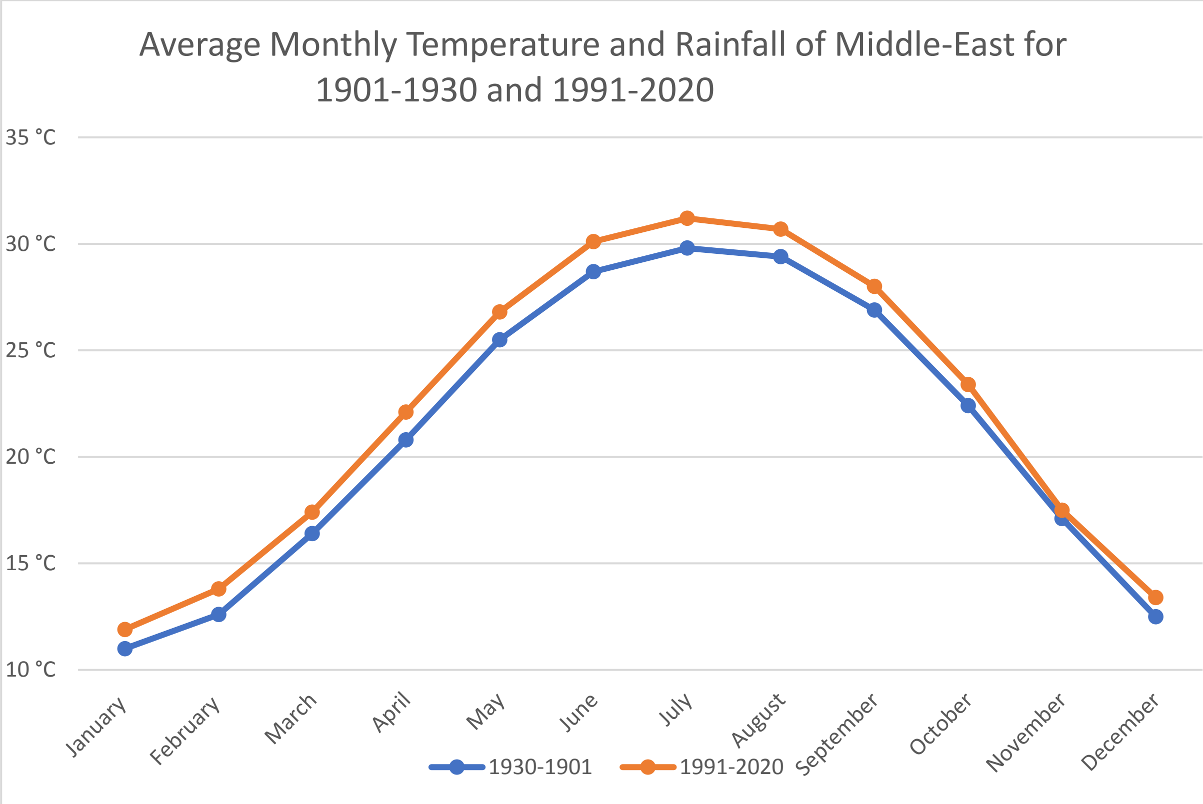

Figure 10: Average Monthly temperature of Middle East for 1901-1930[31]

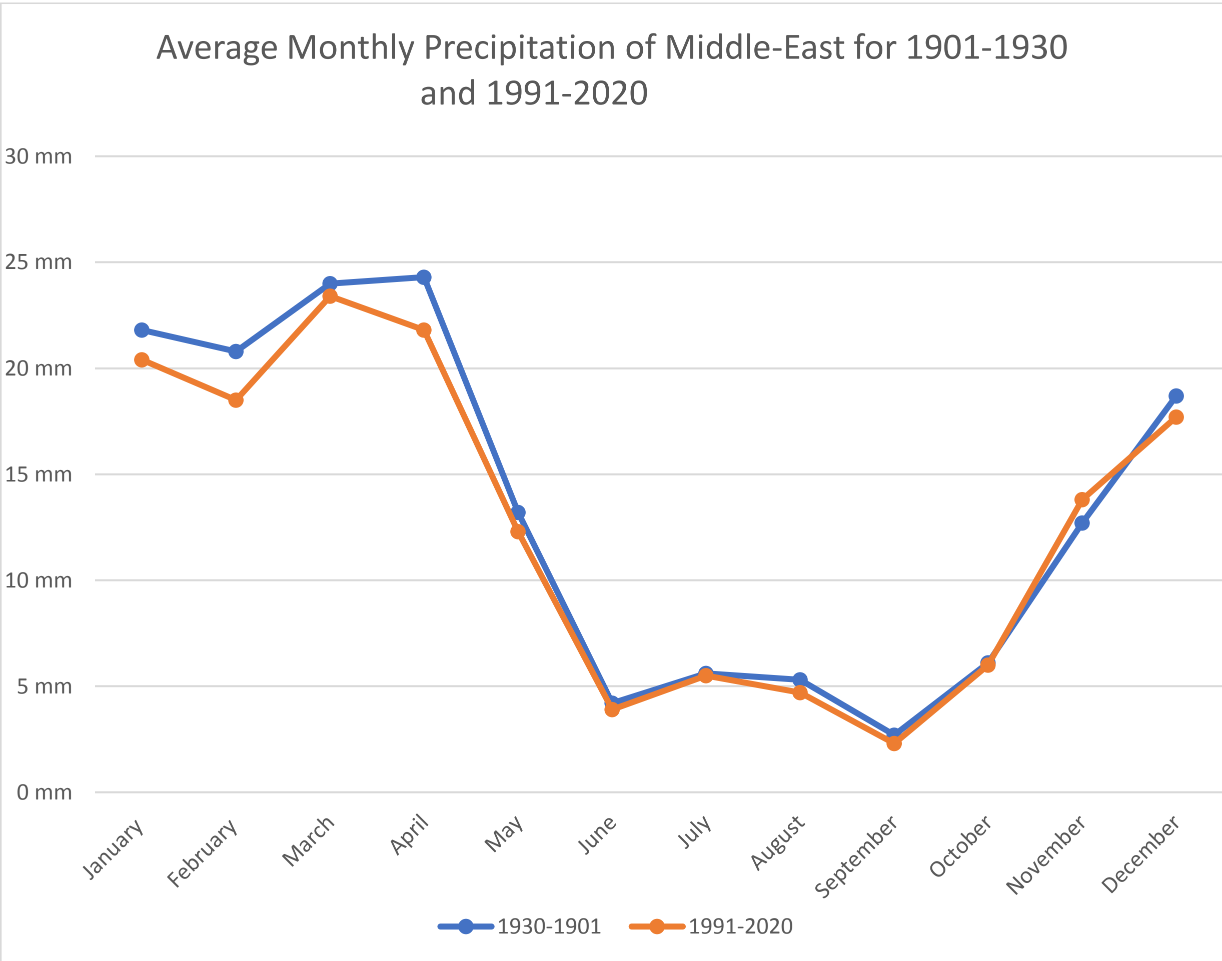

Figure 11: Average Monthly temperature of the Middle East for 1991-2020[31]

Precipitation historical data in figure 10 reveals less precipitation for recent decades compared to 1991-2020; this is the case for all months except in November where higher precipitation rates are recorded. April is the month for highest drop in average precipitation for the middle east by 2.5 mm followed by winter months (February, January and December) with a drop of 2.3, 1.4 and 1 mm. All other months have witnessed drop in average precipitation value in the last three decades compared to the period 1991-2020 where the values of drop vary between 0.1 – 0.9 mm.

Generally, the comparison of temperature and precipitation for the Middle East using records of 2 different periods indicates trends of higher temperature and lower precipitation average in the last three decades.

Results and Discussion

Climate data indicators for Jordan: Jordan's climate models denote that annual precipitation tends to decrease with time at a rate of 1.2 mm per year.[20] On the other hand, mean, maximum and minimum atmosphere temperatures tend to increase significantly by 0.02, 0.01 and 0.03 °C per year. Future projections denote that warmer summers compared to other seasons are more likely to happen including heatwaves. Furthermore, a higher number of dry days is predicted to increase. A higher overall humidity level is predicted. However, the quantity of days of dust storms is projected to decrease significantly.[20]

Jordan suffers water stress with its limited water resources; thus, many sectors such as agriculture and industry are likely to be affected by the scarce water resources and the additional threats raised by climate change. Hence, economic growth could be under real risk. According to a downscaling exercise conducted in the context of the Third National Communication of Jordan,[20] the following findings were stated:

a. Freshwater resources in Jordan are exposed to climatic hazards such as an increase of temperature, decreased precipitation, increased drought and evaporation. Identified sensitivity factors in the water sector include inter alia reduced groundwater recharge, streamflow reduction and increased water demand.

b. Agriculture in Jordan is exposed to the same climate hazards such as the water sector plus the anticipated shift in the rainy season. Most sensitive sectors exposed to these hazards are cropping systems, livestock production, natural resources (forests and rangelands) and food security and livelihoods, directly and indirectly, dependent on agriculture production.

Based on world bank data (Figure 12), rainfall was analysed between 1991 to 2020 to project a linear trend for January. Although the curve is fluctuating from a very low rate in a dry year such as 2009 to more than 40 mm in a rainy year such as 2013, the general linear trend depicts a falling pattern for rainfall rates over the 30 years period.

Temperature analysis for four different months (January, April, July, October) representing the four seasons (winter, spring, summer and autumn), indicates increasing average temperature throughout the different seasons of the year. By observing the trend lines' slopes for the four graphs, it can be clearly noticed that a higher slope for July compared to other months reflects a higher change of average temperature over the 30 years period.

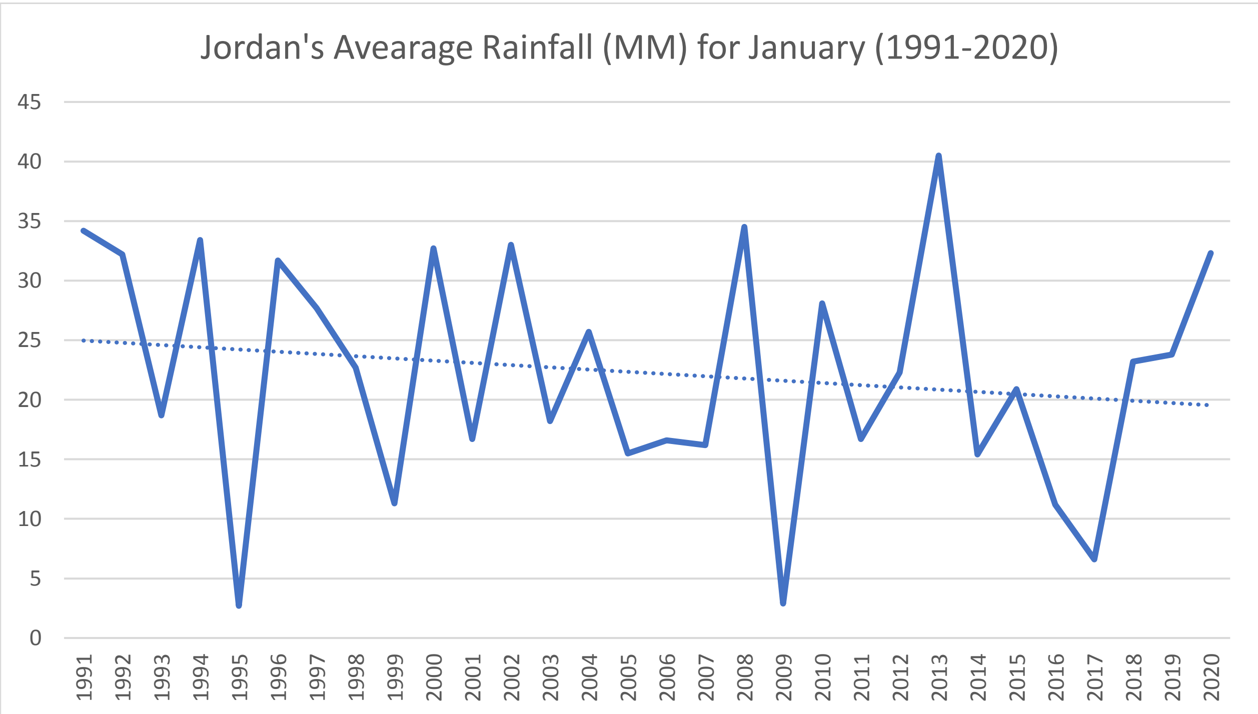

Figure 12: Jordan's Average Rainfall for January 1991-2020[31]

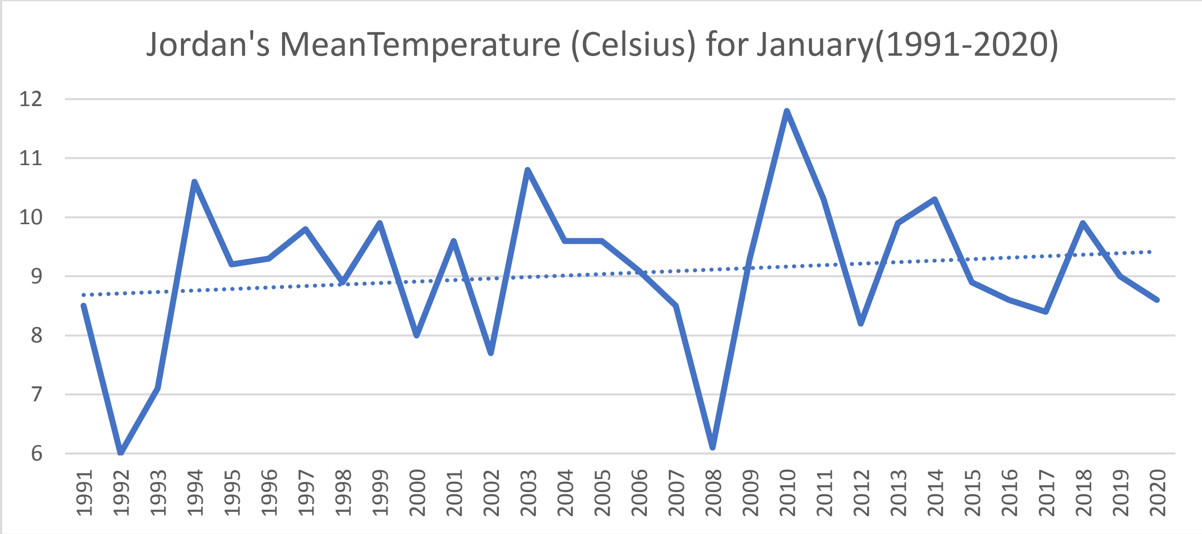

Figure 13: Jordan's Average temperature for January 1991-2020[31]

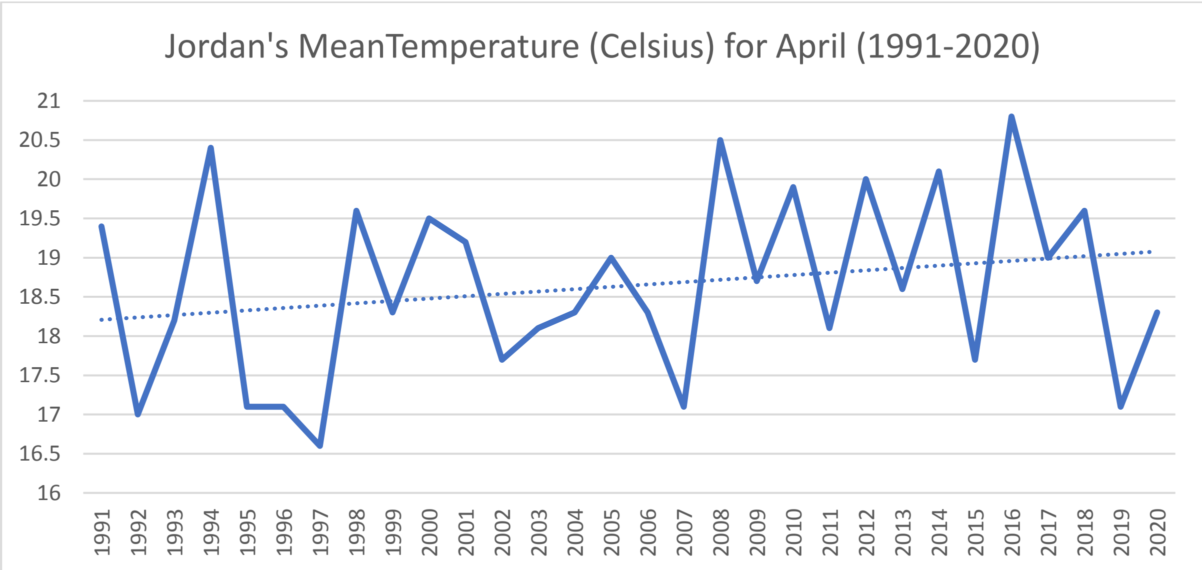

Figure 14: Jordan's Average temperature for April 1991-2020[31]

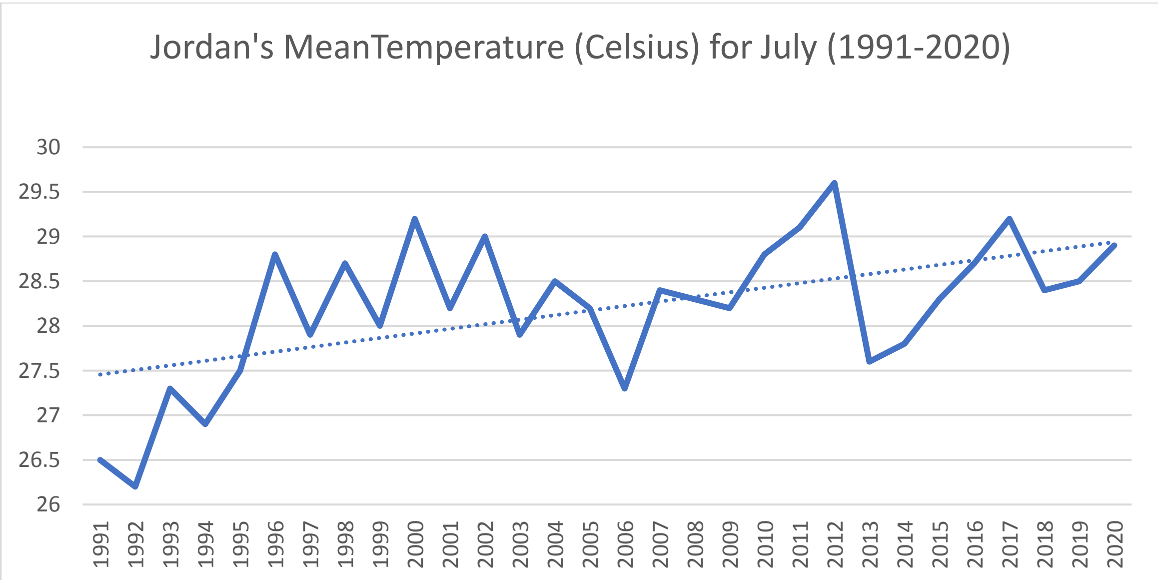

Figure 15: Jordan's Average temperature for July 1991-2020[31]

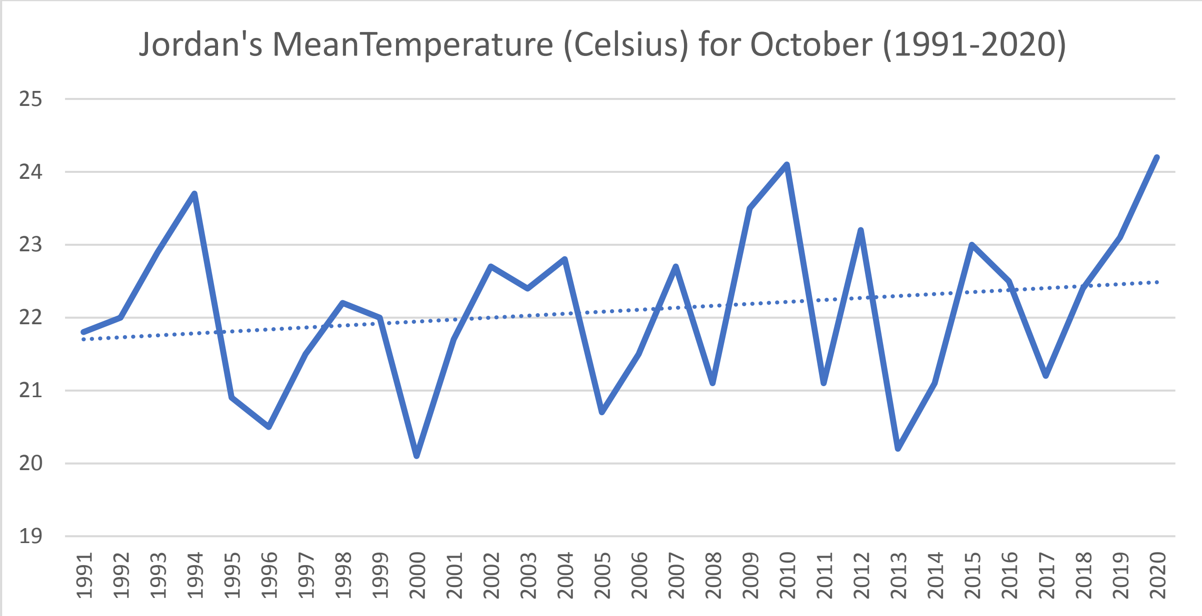

Figure 16: Jordan's Average temperature for October 1991-2020 (World Bank Group, 2021)

Impacts of climate change on the water and agricultural sectors: Worldwide, around 2 billion people are living in a water-stressed area. Likewise, almost half of the world's population does not have access to safe sanitation facilities. Accordingly, the water deficiency is likely to reach 40% by 2030, jeopardized by COVID-19 pandemic and climate change. Generally, the impacts of climate change disrupt the water supply chain and increase the operational costs of water supply.[2,15] As a whole, the impacts of climate change on the water sector are:

1. Minimized water availability: Climate change is expected to escalate seasonal variability resulting in an insecure water supply intensifying the water stress worldwide.[2]

2. Increased frequency of extreme weather events: Worldwide, over the past decade, extreme rainfall events have risen by almost 50%. In addition, the existing infrastructure is at risk of failure due to extreme weather events. As a whole, the frequency of floods and droughts is increasing due to climate variability.[2]

3. Saline intrusion: Due to sea-level rise, coastal groundwater aquifers are under the threat of saline intrusion.[10]

4. Changes in River flow: Stream flow temporal variability is likely to affect river beds' deposition and erosion patterns. Intense rainfall provokes further sediments. Therefore, climate variability causes variation of sedimentation and erosion in river beds in comparison with their past patterns.[16,17]

5. Other impacts: The impacts of climate change on the water sector are many; other impacts comprise but are not limited to surface water acidification, water quality-related impacts and groundwater recharge rate.[2]

In a similar manner, climate change is threatening food security by way of varied precipitation patterns, rising temperatures and a higher frequency of extreme weather events. However, negative effects of climate change on crop yields were only observed in certain regions, for instance, the yield of certain crops in low-latitude regions. Likewise, impacts of climate change threaten the pastoral systems; for instance, lower animal productivity and pastures were observed in Africa. As such, minimized water availability complicates entire farming activities.

However, the impacts of climate change on agriculture are not confined to the productivity stage; the four pillars of food security (availability, access, utilization and stability), in addition to their interactions, are negatively affected. As a result, catastrophe consequences are anticipated to jeopardize the economics, particularly in the regions that highly depend on agriculture.[14]

Nature-based Solutions (NBS) for climate change adaptation in urban sittings

Earth's climate is changing; as evidence, there has been approximately one degree Celsius of warming since pre-industrial times causing glaciers to retreat, ice caps to melts and sea levels to rise. Moreover, there is evidence that this warming is increasing the frequency and intensity of droughts, floods, crop failures of fires and storms right across the globe. How do we adapt to rapid environmental change? How do we thrive against these challenges? And how do we adapt and thrive in a way that slows down further change in many parts of the world? The dominant approach to deal with climate change hazards has static engineered interventions such as sea walls and irrigation infrastructure;

these can be very expensive but very effective at least in the short term.

However, in many situations', nature can provide a more affordable long-term solution. People have harnessed nature to mitigate the impacts of climate variability for millennia; however, it is only recently that awareness has grown that the restoration and protection of nature could safeguard biodiversity and support people's adaptation to the effects of climate change. Nature-based solutions can slow further warming on a global scale by absorbing and storing carbon.

IUCN defines nature-based solutions as actions to protect, sustainably manage and restore natural or modified ecosystems which address societal challenges (e.g. climate change, food and water security of natural disasters) effectively and adaptively and simultaneously provide biodiversity benefits. NBS appeared as a result of international organisations efforts to find new ecosystem-based solutions that help to adapt and mitigate climate change effect instead of the conventional engineering solutions. A range of approaches falls under NBS including ecosystem restoration approaches (e.g. ecological restoration), issue-specific ecosystem-related approaches (e.g. ecosystem-based adaptation), infrastructure-related approaches (e.g. green infrastructure), ecosystem-based management approaches (e.g. integrated water resources management) and ecosystem protection approaches (e.g. area-based conservation approaches).[7]

Although rural areas typically inhabit more vulnerable people to climate change impact, especially in developing countries, yet urban areas are the most changing circumference and usually can take more actions for natural requalification.[9] Around two-thirds of the world population is predicted to settle in urban areas. Urbanisation is usually correlated to environmental degradation. Combined with the climate change effect, both could potentially cause severe challenges, particularly in developing countries that have fewer resources to respond.

Therefore, the focus here is oriented towards introducing nature-based solutions in urban areas. Eventually, some NBS systems are presented below. These systems can be applied to buffer the environmental degradation resulting from the dual impact of urbanisation and climate change.

Infiltration trenches: Shallow excavations are filled with rubble or stone. Basically, infiltration trenches help to reduce rates and volumes of run-off. They function to improve soil drainage characteristics by allowing water infiltration to near soils beneath and near the trench, thus supplement groundwater and conserve the base flow of rivers. They treat run-off by filtration through the substrate in the trench and subsequently through soil.

In spite of having the merit of effectively removing pollutants, Infiltration trenches are not intended to function as sediment traps and must always be designed with an effective pre-treatment system. Unless very effective pre-treatment is included in the design, they work best as part of a larger sustainable drainage treatment system.

Permeable pavements: Paved surfaces have parts that allow water to infiltrate through them such as previous concrete porous asphalt, permeable interlocking concrete paving units, or grid-type systems over an open-graded base/subbase layer(s). Permeable pavements infiltrate stormwater, reduce peak flows, filter and clean contaminants and promote groundwater recharge. In North America, permeable pavement is more commonly used as the primary part of stormwater management and its best management practices.

Several design factors should be taken into consideration for effective functioning design pavements, such as appropriate capacity to accommodate vehicle loadings and managing inflow and outflow stormwater of the surface and different pavement layers.[11]

Rainwater Harvesting: It can be conducted to collect water from different urban installations such as rooftops, parking lots, or roads. Rainwater harvesting system typically consists of a basin surface that is favoured to be impermeable, transporting system from the collection surface and appropriate storage tank. Additionally, residential rainwater harvesting systems could contain screening and flush diverters. Nevertheless, global scale harvesting systems comprise of roof, gutter, pipes and a storage tank.[3]

Retention basin: A pond is to hold storm water and filter out sediment. The purpose of installing a retention basin is to detain run-off water as well as for settling a considerable amount of sediments of run-off water. Installation of retention basin should consider selecting a suitable location to effectively achieve its function i.e. the location should be installed at low-level site or in the path of natural drainage. Retention basins should be used with other management practices to trap sediments such as mulching and diversion dykes.

Green roofs: A building element in concept does not follow a specific standard; however, the currently available commercial green roofs are equipped based on customised construction properties and layers as well as vegetation selection.

Typically, a green roof consists of a lightweight soil mixture and a drainage layer. A fabric filter keeps these layers separated and a special layer under the drainage protects the underlying structure from the vegetation roots. Building a green roof can help to achieve several benefits such as energy conservation for heating and cooling; reduction in the urban heat island effect, absorption of air pollutants and dust, attenuation of stormwater run-off, an extension of life for waterproofing layers, attractive open space (aesthetic benefits), replacement of vegetation and habitat lost during an urban expansion.[26]

Conclusion

The global issue of climate change has increased focus by experts, politicians and even common people since decades. Many physical and scientific evidences reflect the growth of the issue. Human activities produce tremendous amounts of greenhouse gases that lead to implications on sea level rise, glacier melt, weather fluctuations and extreme events like floods and droughts. Many sectors are affected and many people are vulnerable to the consequences of climate change. Climate models and historical date prove the change in climate in multiple levels. For instance, in this study, we have investigated results of data at global, regional (middle east) and country (Jordan) levels.

Nevertheless, the global community interest is oriented towards quantifying the problem and creating innovative solutions to get over climate change. Mitigation strategies are needed through conducting negotiations between countries to create innovative technical solutions that help to mitigate greenhouse gases emissions as well as limiting the amount of emissions released by every country on earth. Additionally, adaptation strategies are needed to assist getting over the climate change challenge. Nature base solutions are compartment of the adaptation strategies which conclude several options that help to preserve the nature and taking advantage of its services. The authors suggested several options for nature-based solutions applicable for urban areas. Nevertheless, other solutions are available in literature but should be selected based on the nature for a specific area.

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