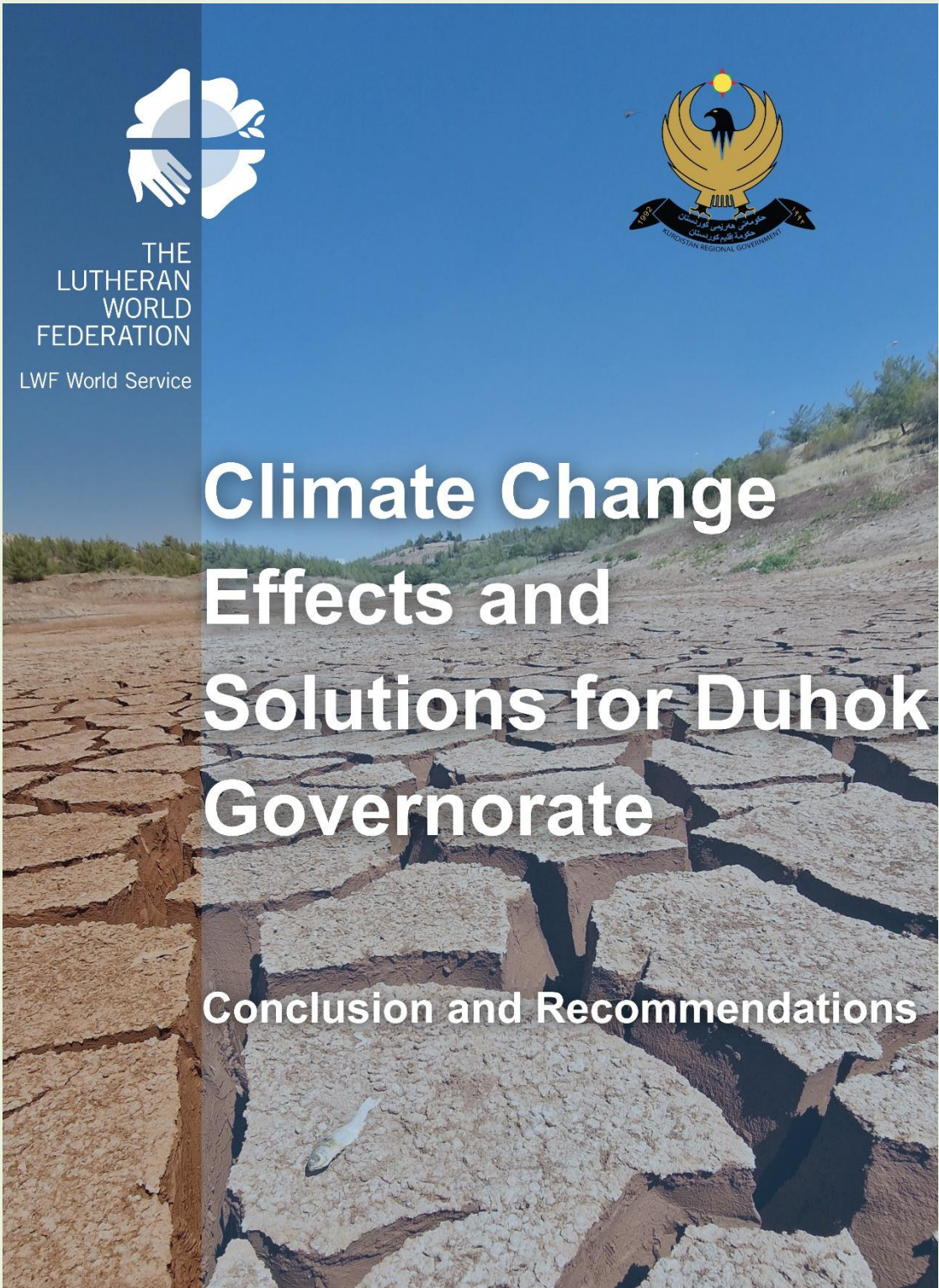

THE LUTHERAN WORLD FEDERATION

LWF World Service

KURDISTAN REGIONAL GOVERNMENT

Climate Change Effects and Solutions for Duhok Governorate

Conclusion and Recommendations

Acknowledgment

This booklet, developed in 2025, aims to provide valuable insights into the impact of climate change on agriculture, forestry, and water resources in Duhok Governorate. It represents the collective efforts of multiple departments and experts who have contributed their knowledge, data, and resources to deepen our understanding of the climate-related challenges facing the region—and to highlight potential solutions.

We extend our sincere gratitude to the following institutions for their invaluable contributions: the Directorate of Water in Duhok, the Directorate of Environment in Duhok, the Agricultural General Directorate, the Forestry and Rangelands Directorate, the Irrigation Directorate, the Directorate of Ground Water, the Directorate of Water Resources (Irrigation), and the Directorate of Water Outskirts. Their technical input and collaboration have been critical in compiling the data and analysis presented in this publication.

This booklet explores the growing impacts of climate change on vital sectors such as agriculture, forestry, and water resources. It presents an overview of observed changes in temperature, rainfall patterns, and water availability, while also proposing practical, locally tailored adaptation strategies. Designed as a resource for policymakers, practitioners, and the local community in Duhok, it aims to support efforts toward sustainable development and climate resilience.

We hope this publication will serve as both a reference and an inspiration—encouraging greater awareness, informed planning, and meaningful action to protect Duhok's natural resources and safeguard the well-being of future generations.

Table of Content:

Duhok Governorate Map

Duhok Governorate is situated in the northwestern part of the Kurdistan Region of Iraq, bordering Turkey to the north and Syria to the west. It shares internal borders with Erbil Governorate to the east and Nineveh Governorate to the south. Covering an area of approximately 10,956 square kilometers, Duhok is one of the four governorates that constitute the autonomous Kurdistan Region, according to Wikipedia.

As of 2023, the population of Duhok Governorate was estimated at 1,772,367, with the capital city, Duhok, serving as the administrative and economic center.

The governorate is home to a diverse population, predominantly Kurds, along with minorities such as Assyrians, Yazidis, Armenians, and Arabs. The main religious groups include Muslims, Yazidis, and Christians.

Duhok has experienced significant population growth in recent years due to internal displacement and the influx of refugees, particularly during and after the ISIS conflict. As of March 2024, the Kurdistan Region hosted 631,174 internally displaced persons (IDPs), with 40% residing in Duhok Governorate. Additionally, there were 251,475 Syrian refugees in the region, with 131,700 residing in Duhok Governorate as of 2022, according to Wikipedia.

The economy of Duhok is primarily based on agriculture, trade, tourism, and cross-border commerce with neighboring countries. The governorate's strategic location and demographic diversity make it a focal point for humanitarian and development programs.

Administratively, Duhok Governorate is divided into several districts, including Duhok, Zakho, Summel, Amedi, Akre, Bardarash, and Sheikhan. Some of these districts, such as Akre, Bardarash, and Sheikhan, are disputed and under de facto control of the Kurdistan Regional Government.

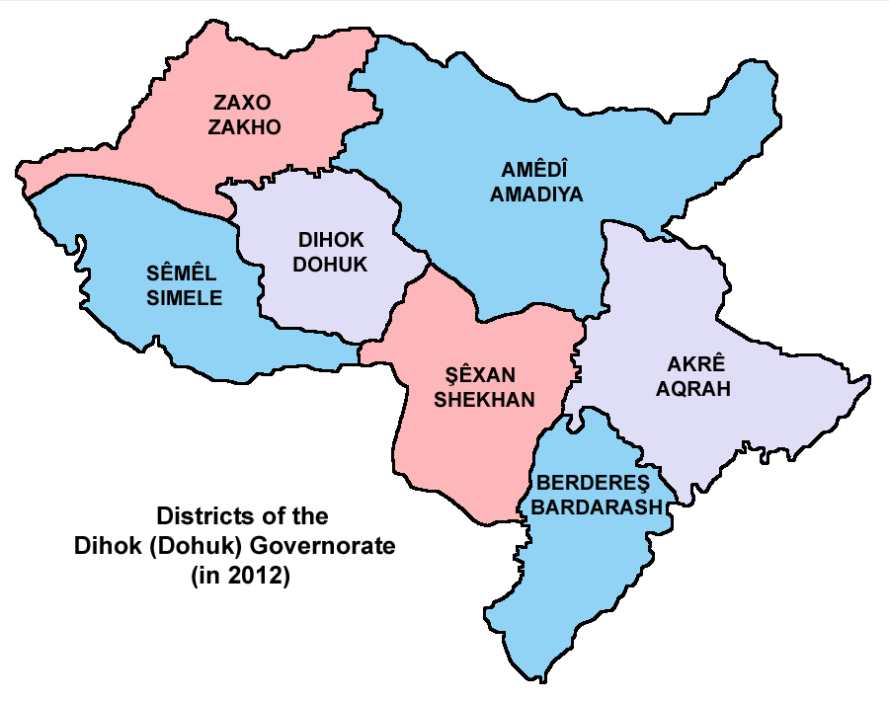

Figure 1: Duhok Province Map

1. Introduction:

An Overview of the Lutheran World Federation (LWF):

LWF World Service is LWF's humanitarian and development arm dedicated to promoting social justice, human rights, and environmental protection, with a strong focus on humanitarian assistance and sustainable development. Established in Sweden in 1947, the federation today includes 150 members across 99 countries. The General Secretariat of LWF is based in Geneva, Switzerland, where it fosters collaboration with other international organizations.

On a regional level, LWF commenced its operations and activities in Iraq in 2014, providing support to internally displaced persons (IDPs), host communities, and Syrian refugees. Its programs in Iraq align with LWF's strategic plan for 2025-2031, which aims to work with displaced populations, host communities, and returnees to claim their rights by implementing the following activities:

Livelihoods: Increasing opportunities for men and women through business rehabilitation programs, vocational training, etc.

Quality Services: Improving access to water, sanitation, and hygiene (WASH) facilities while promoting hygiene awareness.

Protection and Social Cohesion: Raising awareness and building the capacities of affected populations regarding discrimination and exclusion, empowering women socially and economically as leaders and decision-makers within their families and communities, and fostering peace-building through a participatory, grassroots approach.

This strategic framework has transformed LWF's role in Iraq from providing short-term humanitarian emergency response to functioning as a long-term development organization committed to standing in solidarity with affected communities as they claim their rights and rebuild their lives.

"In alignment with the LWF World Service Strategy 2025–2031, LWF contributes to enhancing the capabilities of individuals and communities

worldwide, dedicating its efforts to achieving sustainable development, social justice, and addressing environmental and humanitarian challenges." (LWF World Service Strategy 2025–2031).

In recent years, LWF has focused on building resilient communities capable of adapting during times of crisis. Through its programs, LWF has implemented several interventions aimed at mitigating the effects of climate change. These include raising awareness, advocating for climate-related issues, and providing training and capacity building for government officials. Furthermore, it has carried out integrated and multi-sectoral programs such as Climate-WASH, Climate-Livelihoods, Climate Justice, and sustainable solutions to combat and mitigate the catastrophic impacts of climate change, including desertification, floods, water scarcity, and agricultural resource depletion, encompassing both vegetation and livestock.

LWF implemented a series of interventions, including a five-day intensive training program for 35 government employees on climate adaptation and sustainable resource management. Additionally, two discussion and knowledge exchange sessions were held, engaging 59 government officials from relevant institutions to address climate change challenges such as water scarcity, deforestation, and their impact on agriculture, while fostering intergovernmental collaboration in this domain. Furthermore, LWF supported three youth-led initiatives to promote climate awareness and advocacy. These included awareness campaigns in primary schools about environmental conservation, a public tree-planting campaign titled "Green Community," and environmental advocacy sessions at the University of Duhok to enhance youth engagement in climate-related issues. Climate considerations were also integrated into other programs through a comprehensive approach that links climate with water and sanitation, livelihoods, and climate justice to ensure resource sustainability and mitigate the adverse effects of climate change.

These efforts align with LWF's vision to strengthen individuals and communities in confronting environmental challenges and to create a more sustainable future by fostering collaboration among government institutions, youth, and civil society.

2. Climate Change:

2.1 Climate: An Overview

Climate describes conditions over the long term and over an entire region. Climate is the big picture of temperatures, rainfall, wind, and other conditions over a larger region and a longer time than weather. The field of Climatology focuses on studying the characteristics of these natural elements in the lower atmosphere, examining their temporal and spatial variations, and analyzing their effects on human life, the environment, and productivity.

Weather refers to short-term variations in atmospheric elements like temperature, rainfall, and wind, often changing daily or even hourly. Climate, in contrast, represents the long-term average of weather patterns typically measured over a 30-year period or more. These distinctions help scientists understand both immediate and prolonged environmental changes (National Geographic, 2024; IPCC, 2021).

Meteorology is the scientific discipline concerned with measuring, analyzing, and presenting the characteristics of natural atmospheric elements in a specific location or region. It serves both climatology and weather forecasting by providing the necessary methodologies and tools for studying and analyzing atmospheric elements. (National Geographic, Weather vs. Climate, 2024)

Table No. (1): The differences between Climate and Weather

Basin for Comparison	**Weather**	**Climate**
Meaning	The weather is the everyday atmospheric condition of a particular region, as regards temperature, humidity, wind speed, etc.	Climate refers to the standard pattern of weather of a particular place, taken over more than 25 years.
What is it?	Minute-by-minute state of the atmosphere in an area.	Average weather in a region.
Represents	What are the conditions of the atmosphere in a geographical location, over a short period.	In what way atmosphere act over a typically long period.
Assessment	For a short term.	Over a long period.
Study	Meteorology.	Climatology.

The atmosphere is a multi-layered system of gases encasing the Earth, playing a crucial role in maintaining life by filtering harmful radiation, regulating temperature, and supporting the water cycle. These layers—ranging from the troposphere to the exosphere—help maintain the Earth's climate and enable weather patterns (NASA, 2024)

The atmosphere allows beneficial solar radiation to reach the surface while blocking harmful ultraviolet (UV) rays through the ozone layer and burning up meteoroids before they can impact the Earth. It plays an essential role in regulating the planet's temperature, making it habitable by trapping heat and preventing extreme fluctuations between day and night.

Additionally, the atmosphere drives the hydrological cycle, enabling processes like evaporation, condensation, and precipitation that sustain water availability. Composed primarily of nitrogen (78.08%), oxygen

(20.95%), and trace gases such as argon, carbon dioxide, and water vapor, it also provides the air we breathe, and the pressure needed for liquid water to exist. According to **NASA**, "The atmosphere contains the oxygen we need to live. It protects us from harmful ultraviolet solar radiation. It creates the pressure without which liquid water couldn't exist on the planet's surface, and it warms our planet and keeps temperatures habitable" (***NASA, 2024***).

The atmosphere consists of five primary layers: the Troposphere, Stratosphere, Mesosphere, Thermosphere, and Exosphere.

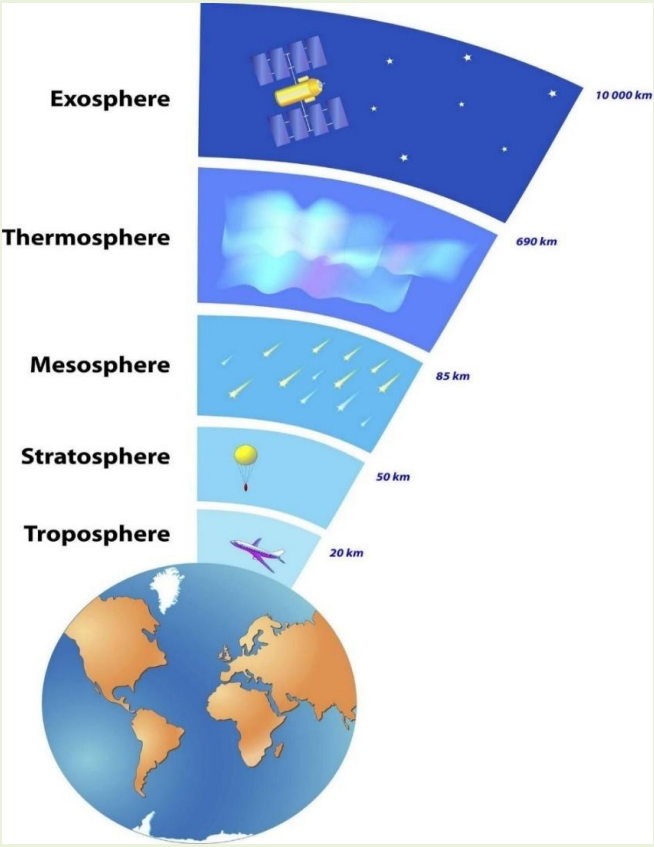

Figure 2: Atmospheric Layers

Furthermore, the ozone layer absorbs most of the Sun's high-frequency ultraviolet radiation, particularly UV-B and UV-C rays. This natural shield protects humans and ecosystems from harmful radiation. Depletion of the ozone layer was largely caused by substances like chlorofluorocarbons (CFCs), but international agreements like the Montreal Protocol have helped reduce these emissions, leading to a gradual recovery (*UNEP, 2023; WMO, 2022)*

While stratospheric ozone is beneficial, ground-level (tropospheric) ozone is a harmful air pollutant and a greenhouse gas. It forms when nitrogen oxides (NO_x) and volatile organic compounds (VOCs)—emitted by vehicles, industrial activities, and fossil fuel combustion—react in sunlight (U.S. Environmental Protection Agency (*EPA, 2023*). Unlike the protective stratospheric ozone, excess ground-level ozone contributes to respiratory diseases, smog, and climate warming.

Human activities, particularly the release of chlorofluorocarbons (CFCs) and other ozone-depleting substances (ODS), have historically damaged the ozone layer, leading to the formation of the Antarctic ozone hole (*NASA Ozone Watch, 2023*). Thanks to the Montreal Protocol, a landmark international agreement signed in 1987 to phase out the production and consumption of ozone-depleting substances, the ozone layer is on a path to recovery. Scientists project that, if current policies remain in place, the ozone layer will return to pre-1980 levels by the middle of the 21st century.

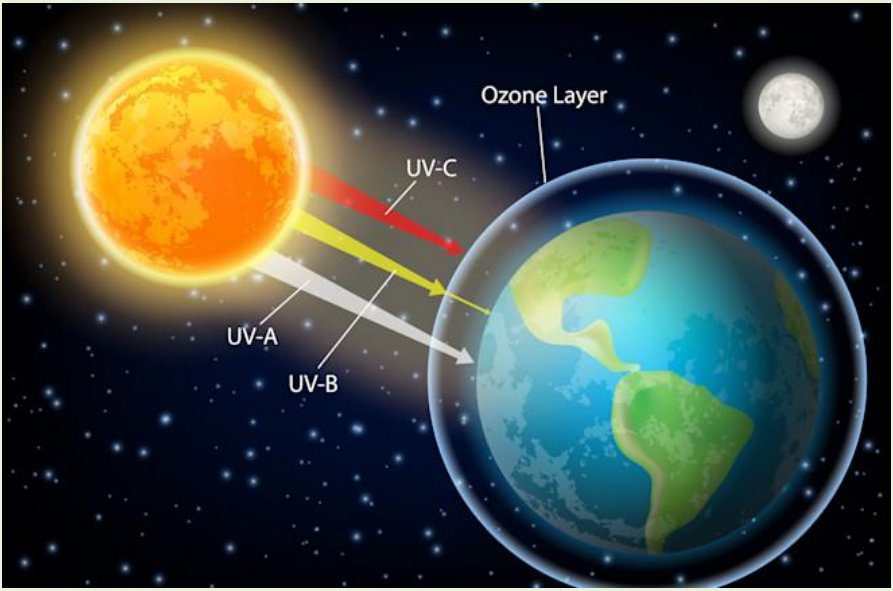

Figure 3: Ozone Layer and how it works with UV and green gases mechanism.

2.2 Climate Change:

In fact, there are various definitions of climate change, and these definitions are subject to disagreement in this field. Here, we will focus on the most prevalent ones, which are used locally and internationally and, on many occasions, at events and conferences.

According to the IPCC AR6 Report (Chapter 2), Climate Change refers to any process that causes adjustments to a climate system, which could be described as creating "climate change". These processes include volcanic eruptions to a cyclical change in solar activity. The planet's climate has constantly been changing over geological time.

Climate change in IPCC- Intergovernmental Panel on Climate Change refers to any change in climate over time, whether due to natural variability or as a result of human activity.

However, the current period of warming is occurring more rapidly than many past events. Scientists are concerned about the rapid human-induced

warming because of the serious implications for the stability of the planet's climate.

Nowadays, however, the phrase is most often used as shorthand for anthropogenic climate change – in other words, climate change caused by humans. The principal way in which humans are understood to be affecting the climate is through the release of heat-trapping greenhouse gases into the air.

Climate change is usually characterized by rising global temperatures, significant changes in natural phenomena, continuous degradation of vegetation cover and biodiversity, and the emergence of new climate patterns. These changes can result from natural phenomena such as variations in solar activity and volcanic eruptions, or from human industrial activities. Climate change affects the Earth's temperature regulation, the cycle and balance of environmental phenomena, and poses a threat to human health. Several natural factors influence climate change, including:

- **Proximity to the sea:** Coastal areas tend to have a warmer climate compared to inland regions, which are drier and experience higher temperatures.
- **Ocean currents:** The movement of water masses influences the climate by exchanging energy with the atmosphere.
- **Wind direction:** Winds coming from seas bring rainfall, while those originating from dry and hot areas contribute to higher temperatures, and those from cold regions bring cooler weather.
- **Topography:** Higher elevations receive more rainfall due to cooler air.
- **Distance from the equator:** The farther from the equator, the lower the angle at which sunlight reaches the Earth's surface, resulting in cooler temperatures.

In national context, the climate change in Iraq is experiencing escalating climate-related challenges, including rising temperatures, recurring

droughts, and irregular rainfall. These impacts are leading to desertification, reduced agricultural productivity, and increased socioeconomic pressures, despite Iraq contributing minimally to global emissions (UNEP, 2021; World Bank, 2022).

Iraq ranks among the world's five most climate-vulnerable countries (UNEP, 2021). According to the World Bank (2022), the country's average temperature has already risen by 0.7°C since 1980, while rainfall has decreased by approximately 10% per decade—trends that are projected to intensify by 2050

While in the Kurdistan Region, the effects of climate change are even more pronounced. The region has seen a temperature increase of approximately 2°C over the last few decades, while winter temperatures in areas such as Duhok and Erbil have risen by 0.5 to 1°C (KRG Meteorological Directorate, 2023). Rainfall has become increasingly irregular and sparse, threatening agriculture, water availability, and rural livelihoods. Furthermore, the number of extremely hot days exceeding 50°C has grown significantly in recent years (FAO, 2023). These shifts signal a substantial transformation in the region's climate and are consistent with projections from the IPCC's Sixth Assessment Report, which anticipates worsening climate conditions across semi-arid zones like northern Iraq (IPCC, 2021–2023).

3. Climate Change Adaptation

According to the Climate Justice Guidelines in 2021 by LWF, Climate adaptation is defined as the modification of natural or human systems to respond to actual or anticipated climate influences and their impacts, with the goal of reducing harm or taking advantage of beneficial opportunities. Climate change has become a reality. We must adapt to the consequences of climatic phenomena in order to protect ourselves and our communities, in addition to doing everything we can to reduce emissions and slow the pace of global warming. The impacts vary depending on where you live. These impacts could include fires, floods, droughts, higher or lower temperatures than usual, or rising sea levels.

There are several ways to adapt to what is happening now and what will happen in the future. Individuals can take simple actions, such as planting or maintaining trees around their homes to keep indoor temperatures cooler. Additionally, reducing bush clearing can decrease the risk of wildfires. If you own a business, start considering and planning for potential climate risks, such as hot days that prevent workers from performing outdoor tasks.

Everyone should be aware of the increased likelihood of natural disasters in the areas where they live, as well as the resources available to them in case these events occur. This could mean to getting insurance in advance or knowing where to find information about disasters and relief during a crisis.

Gaining greater resilience against climate impacts will require broad efforts, and governments will need to coordinate many of them. We may need to build roads and bridges designed to withstand high temperatures and stronger storms. Some coastal cities may need to create flood prevention systems in streets and underground transportation facilities. Mountainous regions might need to find ways to reduce landslides and floods caused by glacial melting.

Some communities may need to relocate because it will be very difficult for them to adapt to these phenomena. This is already happening in some island nations suffering from rising sea levels.

3.1 Stakeholder Commitments to Addressing the Impacts of Climate Change:

All parties to the 2015 Paris Agreement committed to enhancing the global response to climate change by increasing the ability of all to adapt, build resilience, and reduce exposure to climate impacts. At COP26 in 2021, the Glasgow Climate Pact was adopted, urging countries to double financing to support developing nations in adapting to climate change impacts and building resilience. Glasgow also established an action plan to identify a global goal on adaptation, which will outline collective needs and solutions for the climate crisis that is already affecting many countries.

3.2 Key Adaptation Measures to Address Climate Change and Its Impacts:

3.2.1 Early Warning Systems:

Early warning systems are a key adaptation measure for climate change, utilizing integrated communication systems to help communities prepare for climate-related hazards. These systems allow for real-time monitoring of weather conditions on land and at sea, effectively forecasting future weather and climate events using advanced numerical models. Early warning systems for floods, droughts, heatwaves, and storms are integrated systems that enable people to prepare for extreme weather events and guide governments, local communities, and individuals in minimizing the impending negative impacts.

3.2.2 Combating Desertification:

Climate change, coupled with poor land management, is leading to the formation of new deserts, a process known as desertification. This can be countered through restoring mangrove forests along coastlines. Mangroves are short woody trees that thrive in salty soil near rivers and coastlines. They have adapted to grow in saline soil. Desertification can also be mitigated through better long-term management of drylands—regions facing severe water scarcity, which cover more than 40% of the Earth's surface.

Additionally, reforestation, or planting trees in areas where natural forest cover has been cleared, can help combat desertification.

Figure 4: Tree planting in Iraq-KIR- Duhok, Summel, Khanke.

3.2.3 Reducing Exposure to Floods:

Addressing land degradation and adapting infrastructure to become flood-resistant involves investing in improved drainage systems, sustainable agriculture, weather and climate services to help communities prepare, and water security to protect not only against water shortages during droughts but also to ensure access to clean water during floods. Climate-resilient infrastructure refers to buildings, roads, and bridges designed to withstand extreme weather events. Research conducted by the World Bank in 2016 found that climate change poses a threat to all three types of buildings (residential, commercial, and industrial) due to the increased likelihood of floods, storms, droughts, and heatwaves.

3.2.4 Agriculture Adaptation:

Staple crops are already at risk of degradation due to climate change, and hence threaten food security. Some actions that farmers can take to adapt include improving food processing techniques, cultivating crops better suited to changing weather patterns, and growing drought-resistant crops in areas receiving lower rainfall.

Figure 5: Climate Smart Agricultural Practices by planting drought resistant culture (on the left) and by using Protective cultivation. (on the right)

3.2.5 Securing and Improving Access to Freshwater

Access to freshwater is essential for the survival of communities and the sustainability of agriculture, yet it is increasingly threatened by droughts, shifting rainfall patterns, glacial melt, and contamination from floodwaters. These stressors often lead to water scarcity, which can force communities to migrate, disrupt livelihoods, and increase the risk of conflict and instability (IPCC, 2022).

To address these growing challenges, a combination of adaptation strategies must be implemented. These include rainwater harvesting, the rehabilitation of springs, efficient irrigation systems such as drip and sprinkler technologies, and improved water storage infrastructure. Integrated water resource management (IWRM) and community-based water governance are

also essential to enhance resilience and ensure long-term water security (UNESCO & UN-Water, 2020).

In parallel, improving access to freshwater requires the adoption of innovative technologies and social strategies. Technological approaches include the purification and reuse of wastewater, desalination of seawater, particularly in coastal regions, and responsible mining of deep underground aquifers. Social measures such as seasonal water-use restrictions and public education campaigns can help manage consumption during dry periods and promote equitable access (FAO, 2021).

3.2.6 Protecting Human Health:

The World Health Organization (WHO) has identified climate change as the greatest threat to global health in the 21st century, already contributing to tens of thousands of deaths annually through extreme weather events, floods, and the spread of vector- and water-borne diseases such as malaria, dengue fever, and cholera. These impacts are intensified by floodwater contamination, rising temperatures, and expanding habitats for disease-carrying insects. A key component of adapting to climate change is strengthening health systems—through early warning systems, better planning, and disease prevention methods. To address these threats effectively, public health systems must adopt adaptive measures such as enhancing disease surveillance, improving water and sanitation infrastructure, increasing community awareness, and integrating climate risks into health planning and emergency preparedness. These steps are crucial to prevent avoidable deaths and reduce health vulnerabilities in the face of a changing climate (WHO, 2021).

3.2.7 Food Security and Malnutrition:

Climate change significantly threatens food security and contributes to rising malnutrition rates, particularly among vulnerable populations. Rising temperatures, shifting rainfall patterns, prolonged droughts, and extreme weather events disrupt agricultural productivity, reduce crop yields, and threaten livestock and fisheries. This, in turn, limits access to nutritious food and increases the risk of malnutrition, especially in children and low-income

communities. According to the IPCC (2022) and FAO (2021), climate-induced food insecurity is already observable in many regions.

To adapt, governments and stakeholders must invest in climate-resilient agriculture, diversify food systems, strengthen social safety nets, and build early warning systems for food shortages. Strengthening health systems is also critical—ensuring better disease prevention, nutrition programs, and emergency preparedness. In parallel, mitigating greenhouse gas emissions is essential to minimize long-term disruptions in food systems by reducing the frequency and severity of climate-related shocks.

3.3 Global Case Studies on Climate Adaptation:

Many efforts are currently being made to help people adapt to climate change. One of these efforts is the Adaptation Fund, which finances leading initiatives in developing countries. Here are some examples of how adaptation is being achieved in different regions:

Kiribati: A small island, highly affected by climate change, Kiribati is one of the first countries to adopt climate adaptation strategies. The country is working on improving fishery management to protect livelihoods and food security, as well as enhancing disaster early warning systems.

Ghana: Female farmers in Ghana are adapting to increasing rainfall variability by diversifying their livelihoods. After acquiring new skills, they now produce agricultural products like soy milk and shea butter, which have seen rising market prices.

Bosnia and Herzegovina: Farmers in Bosnia and Herzegovina have adjusted their crop choices to adapt to drought, such as planting peach trees instead of apples to cope with warmer weather.

Maldives: Due to decreased rainfall and rising summer temperatures, people in the Maldives have built larger tanks to collect rainwater, as well as desalination facilities to process seawater. They have also implemented systems to track water usage tightly and issue early warnings for drought periods. Sri Lanka is also repurposing an old water tank system to maintain water flow to farms and homes.

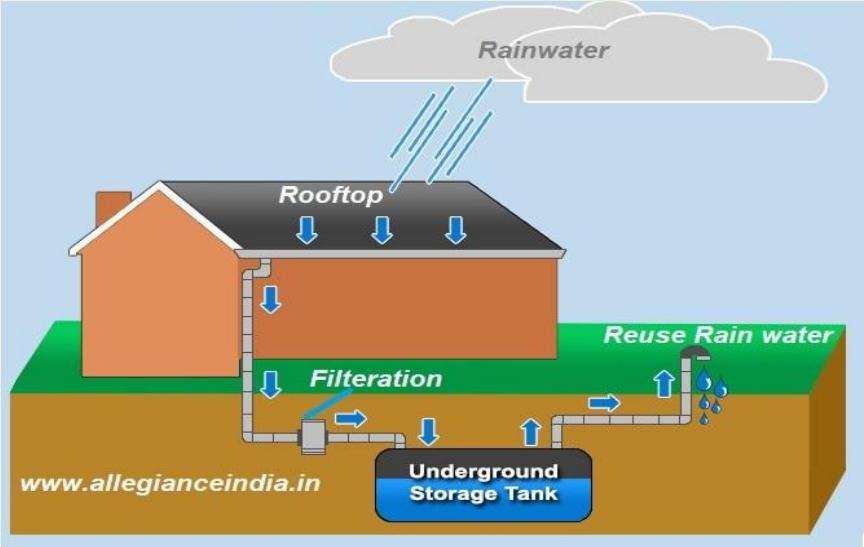

Figure 6: Precipitation Water Storage, Buildings collect rooftop rainwater and store or divert it to recharge wells, widely spread in India.

Djibouti: In Djibouti, people are staying safe by building flood barriers and replanting mangrove forests, which provides protection from rising sea levels, provides food for the population, and is a refuge for plants and animals. In Vietnam, coastal farmers have shifted from gathering increasingly scarce marine resources, such as shells and crabs, to developing beekeeping, which helps restore mangrove forests.

Figure 7: In Djibouti, Building flood barriers by replanting mangrove forests

Albania: One of the European countries most affected by coastal erosion, Albania is helping repair the vegetation in the Kune-Vain Lagoon to protect coastal communities and preserve a globally recognized migratory bird corridor. While nature-based solutions may seem to focus mostly on rural areas, cities are also currently working on boosting resilience by turning to nature.

In **El Salvador**, the capital city of San Salvador is working towards becoming a "sponge city" by restoring the surrounding forests to reduce landslides and flooding, while also improving drainage systems in ways that mimic natural streams and rivers.

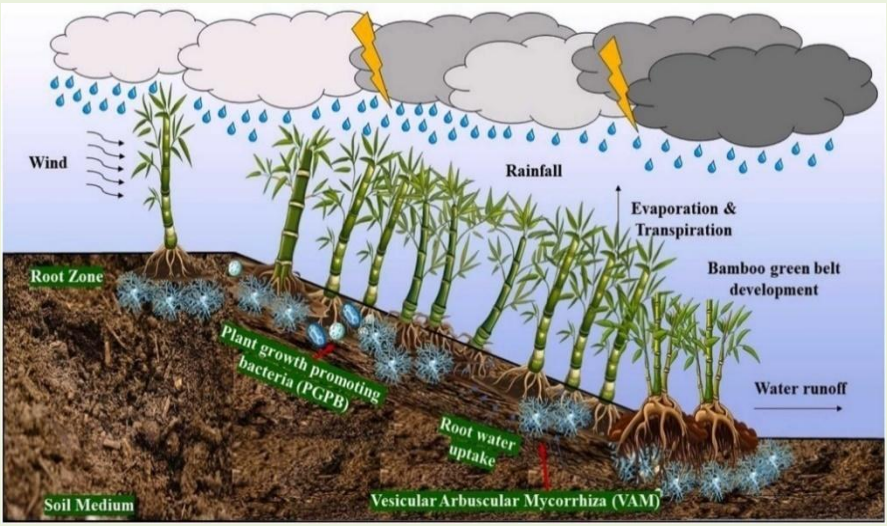

Figure 8: Flood Control by Reforestation

In the United States, the coastal city of Miami is raising street levels and developing green infrastructure, alongside implementing ambitious plans to reduce greenhouse gas emissions.

Figure 9: Miami city and higher street level against sea level raising

3.4 Improving Climate Change Adaptation Strategies:

The countries of Climate south have expressed interest in strengthening climate services to adapt to climate change. As a result, some national activities are expected to be implemented to showcase the enhanced use of climate information for managing climate-related risks on an operational basis.

Other actions are needed to address long-term issues that require careful monitoring and infrastructure development, if necessary. Examples of such issues include rising sea levels and related challenges in managing coastal areas, which involve increasing risks associated with coastal flooding. It is essential to establish monitoring systems to assess long-term developments in coastal situations, as well as to provide the ability to manage flood risks in near-real-time.

Increasing efficiency, such as water and energy use efficiency, is another example of actions that can result in a community capable of adapting to climate realities in the 21st century. This illustrates how climate change adaptation and mitigation can be viewed as two sides of the same coin, with strong synergies. Ultimately, climate change adaptation and mitigation are seen as complementary processes that lead to a low-carbon economy and a climate-resilient society.

Figure 10: Climate Smart Agricultural Practices in India

Ways to Address Global Warming with Resilience and Preparedness:

The world is addressing the climate crisis through two complementary strategies: mitigation, which focuses on reducing greenhouse gas emissions to limit global temperature rise, and adaptation, which aims to minimize vulnerability to climate impacts. According to the United Nations, nearly two billion people, mostly in low-income or climate-sensitive regions/communities, are already severely affected by climate change, a number expected to grow even with current mitigation efforts, as emissions cannot be halted overnight (UN, 2023).

Despite their interdependence, adaptation has historically received far less attention and funding than mitigation. While mitigation is critical to curbing temperature rise, adaptation is equally vital to cope with unavoidable impacts, from extreme weather to rising seas. The only way to survive the crisis is through preparedness—combining both strategies to build resilience while transitioning to a low-carbon future.

Developing nations face a dual challenge: they urgently need adaptation funding to protect vulnerable communities, but often lack resources due to

economic constraints. This imbalance has made adaptation a top priority in global climate negotiations. At COP27 (2022), efforts focused on elevating adaptation in climate action, securing balanced funding between adaptation and mitigation, and scaling up financial support ahead of COP28 (UNFCCC, 2022). This shift followed decades where mitigation projects dominated climate finance (OECD, 2021).

Additionally, COP27 reinforced demands for wealthy nations to fulfill their unmet $100 billion annual climate finance pledge, originally made in 2009 to help poorer countries adapt and mitigate (Copenhagen Accord). Accountability for this pledge remains critical, as vulnerable nations cannot face the climate crisis alone.

3.5 Local Climate Change Adaptation in the Kurdistan Region

The Kurdistan Region of Iraq faces increasing vulnerability to the impacts of climate change, particularly in key sectors such as water, agriculture, and ecosystems. In response, the Kurdistan Regional Government is preparing a Local Climate Adaptation Plan with the goal of building a region capable of proactively addressing climate risks. The plan aims to ensure the resilience of its population, institutions, natural ecosystems, and vital resources, while guiding the region toward sustainable and climate-resilient development.

Supported by national and international partners, this strategic effort fosters climate-smart development and is rooted in a participatory planning process, involving local sectoral experts in vulnerability assessments and the design of targeted adaptation programs. This section outlines that participatory approach, presents findings from climate risk and vulnerability assessments, and introduces key adaptation actions tailored to mitigate the region's climate challenges.

3.5.1 Participatory Approach:

A participatory approach was adopted in preparing the local adaptation plan, with local sectoral experts involved in assessing vulnerabilities and designing adaptation programs. The plan aims to build a region capable of

adapting to climate change through effective strategies that strengthen community stability, ecosystem resilience, and sustainable economic growth.

3.5.2 Historical Climate Conditions and Future Projections:

Historical climate data reveals an increase in the annual average temperatures, with a slight decline in average rainfall across the region. Future projections indicate significant climate changes that will have major impacts on the region, particularly on water resources and agriculture.

3.5.3 Climate Risk and Vulnerability Assessment:

A climate risk assessment (Climate justice Guidelines 2021 by LWF and Act Alliance) is a means of assessing the susceptibility of a project to climate change-related risks and their potential impacts, including through future trends. The hazard assessment analyses the type, frequency, and magnitude of climate extremes. The resulting project risk is not only defined by the hazard, as the climate stressor, but also by the level of existing vulnerability (e.g., exposure, fragility, and resilience) to the hazard. Climate risk assessments can be conducted for localities, projects, countries, or programs. They are an important part of risk management in the planning process, aiming at reducing risks and thus avoiding disasters or severe losses. They should be applied if a project has been classified as highly climate sensitive in the course of climate proofing, in case of climate adaptation projects, or for programs in climate-vulnerable countries.

Vulnerabilities in the Kurdistan Region were assessed at the governorate level, focusing on three main sectors:

- **Ecosystem**: The most vulnerable sector due to the complex interaction between climate change and sensitive natural resources.
- **Water Resources**: The second most affected sector due to the region's reliance on limited water resources, making it susceptible to changing climate patterns.

- **Agriculture**: Highly dependent on stable climate conditions for crop production and livestock management. Changes in temperature, rainfall, and growing seasons could have a significant direct impact on agricultural production and food security.

3.5.4 Adaptation Action Plan:

The local adaptation plan suggests a series of adaptation programs and measures, in addition to the three main sectors. There are two comprehensive programs: community-based adaptation and ecosystem-based adaptation. The plan also includes a timeline, budget, and financial strategy for implementing these programs.

Objectives of the Local Adaptation Plan:

Identification of Strategic Adaptation Measures: Strategic adaptation programs are identified, prioritized, and implemented to enhance the region's resilience, and adaptation plans will be integrated into planning systems and sectoral budgets.

Incorporation of Gender and Vulnerable Groups: The plan focuses on enhancing the ability of the most affected groups (such as women and children) to adapt economically and socially, contributing to stability in the region.

Providing an Effective Coordination Framework: This aims to guide national stakeholders and partners in making decisions regarding climate change mitigation.

Encouraging Strategic Investments: Facilitating climate-resilient development through the mobilization of national and international public and private finance, following flexible financing strategies.

Developing a Baseline Analysis: This strengthens the ability to monitor and review progress, ensuring that desired outputs, results, and impacts are achieved, and adjusting the local adaptation plan based on lessons learned.

Supporting Iraq's National Priorities: The plan supports achieving Iraq's Nationally Determined Contributions (NDCs) and Sustainable Development Goals (SDGs).

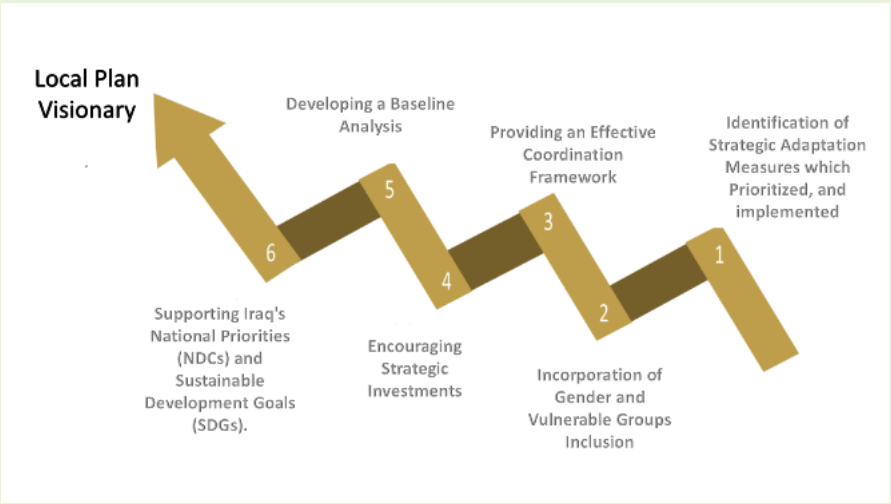

Figure 11: Local Adaptation Plan Visionary

According to the report by the Local Climate Change Adaptation Plan in the Kurdistan Region of Iraq for the year 2024, key indicators for climate change adaptation and the ability to adapt to climate change were identified through affected government sectors and adaptation mechanisms, as detailed in Table 2 on the following page.

Table No. (2): Climate Change Adaptation Capacity

Biodiversity and Ecosystems	Agriculture and Food Security	Water Sector
Protection of key ecosystems	Economic capacity of the sector	Access to water resources
Availability of necessary economic resources to maintain the ecosystem	Social capital (Community cooperation in adopting climate-smart practices)	Poverty levels (Impact of socioeconomic conditions on water affordability and accessibility)
Available or developed technologies and innovations to maintain ecosystems	Physical infrastructure (potential expansion of surface water projects)	Availability of funding for infrastructure projects
Availability of infrastructure to support ecosystem maintenance	Institutional capacity and governance structures in the sector	Capacity for development in current springs and wells
Institutional capacity and governance structures	Available groundwater and surface water resources, and treated wastewater resources	Sector governance structures

Adaptation Programs within the Local Adaptation Plan in Kurdistan Region. This section outlines adaptation programs for the water resources sector, the agriculture and food security sector, as well as biodiversity and ecosystems. Additionally, there are two cross-cutting programs on gender-based adaptation and ecosystem-based adaptation. Table 3 summarizes all

adaptation programs, indicating their timelines, budgets, and financing strategies. For planning purposes, the following time frames are proposed:

- **Short-term**: 1-3 years
- **Medium-term**: 3-5 years
- **Long-term**: More than 5 years

Table No. (3): Climate Change Adaptation Programs in Kurdistan Region for the Three Main Sectors

Sector	Objective	Program Name	Timeframe	Financing Strategy
Water Resources	Enhance water resource management and preservation to address the impacts of water scarcity and climate change	Construction of water infrastructure, such as reservoirs, dams, and water treatment plants	Medium-term	• Allocate funding from government budgets and climate funds • Partner with the private sector for water conservation technologies • Implement water tariffs to cover operational costs
Water Resources		Adoption of integrated flood management systems	Short-term	
Water Resources		Implementation of water-saving practices (e.g., drip irrigation)	Short-term	
Water Resources		Water demand management strategies	Medium-term	
Water Resources		Raise awareness on efficient water use	Short-term	

Agriculture and Food Security	Promote climate-resilient agriculture and ensure food security	Climate-smart agriculture (e.g., crop diversification, agroforestry)	Short-term	• Fund extension services and training • Public-private investments in infrastructure • Access international agriculture funds
Agriculture and Food Security		Farmer training on climate-resilient methods	Medium-term	
Agriculture and Food Security		Early warning systems for droughts and floods	Short-term	
Agriculture and Food Security		Resource-conserving agriculture	Long-term	
Biodiversity and Ecosystems	Protect and restore biodiversity-rich ecosystems	Protected areas and wildlife corridors	Medium-term	• Access international biodiversity and ecosystem restoration funds
Biodiversity and Ecosystems		Reforestation and afforestation programs	Short-term	• Partnerships with NGOs and agencies • Charge for ecosystem services
Biodiversity and Ecosystems		Sustainable land/forest management practices	Short-term	

All Sectors	Enhance resilience of vulnerable sectors via nature- and ecosystem-based adaptation	Strengthening climate resilience in the Kurdistan Region of Iraq	Short-term	• Mix of local/international funds, public-private partnerships, and community contributions
All Sectors	Promote gender equality in climate adaptation efforts	Gender-responsive integrated adaptation program	Medium-term	• Government and international funds • Women's empowerment initiatives • Community contributions

These programs are funded through various local and international financial sources, including government allocations, grants from international organizations, private sector partnerships, and community contributions.

3.6 Climate Change Impact (Kurdistan Region):

Climate Change Impact on Temperature Rising and Rainfall Rate in Kurdistan Region-Duhok Province:

Over the past decade, summer temperatures in the Kurdistan Region have increased by more than 2°C. In July 2009, the average temperature in Erbil province was 33.75°C, in Sulaymaniyah it was 31.55°C, and in Duhok it was 32.6°C. By July 2021, the average temperatures had risen to 35.7°C in Erbil, 35.3°C in Sulaymaniyah, and 34.7°C in Duhok. This represents an increase of 1.95°C in Erbil, 3.75°C in Sulaymaniyah, and 2.1°C in Duhok, with an overall regional warming of 2.6°C.

Climate data for Duhok Governorate, derived from the government report in collaboration with the United Nations Development Program (UNDP), indicates a clear trend of climate change over the period from 1901 to 2021, reflected in a gradual increase in the annual average temperature. The graph shows that annual temperatures ranged between 14°C and 15.5°C during the first half of the 20th century, with relative stability and limited fluctuations. Starting in the 1950s, the average temperature began to rise gradually, accompanied by more frequent fluctuations, especially after the 1990s, when a noticeable acceleration in the warming trend was observed. Annual temperatures peaked in recent years, particularly in 2016 and 2020, exceeding 17.5°C.

According to the general trend in the data, the rate of temperature increase in Duhok is estimated at 0.7°C per century, as illustrated in Figure 12. This significant rise reflects the growing impacts of climate change on the Kurdistan Region, highlighting the need to strengthen adaptation efforts and develop strategic environmental planning to protect key sectors such as water resources, agriculture, and public health.

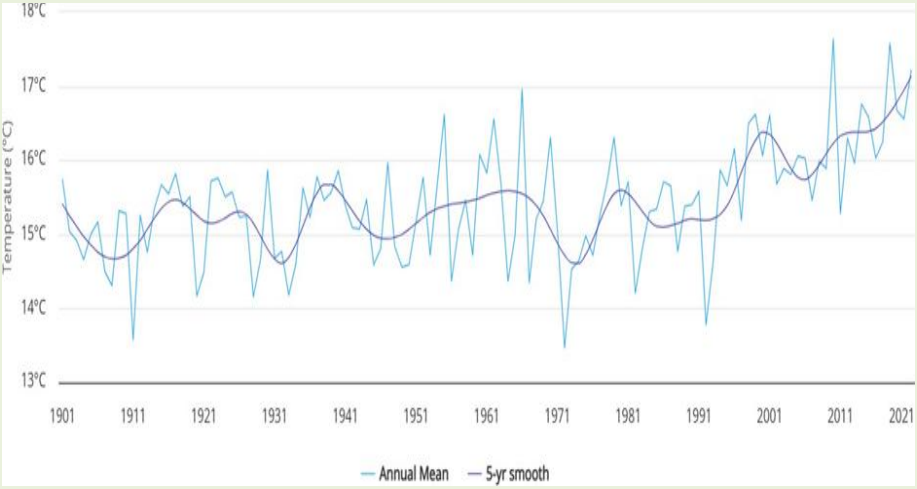

Figure 12: Annual average temperatures recorded in Duhok gov (1901-2021)

Another source which data were collected from Meteorological Department, another notable change is the rise in the annual average of maximum and

minimum temperatures in the Kurdistan Region, indicating that winters have become warmer. For example, in 2009, the average minimum annual temperature was 15.3°C, but by 2021, it had increased to 15.6°C, reflecting a 0.3°C rise in winter temperatures. Refer to table 4 for details on annual temperature average.

Table No. (4): Average minimum and maximum temperatures in the governorates and the Kurdistan Region between 2009-2021:

Year	Temperature / Level	Average Annual Temperature in Erbil	Average Annual Temperature in Sulaymaniyah	Average Annual Temperature in Duhok	Average Annual Temperature in Kurdistan Region
2009	Lowest	17.0°C	14.3°C	14.6°C	15.3°C
	Highest	26.0°C	24.7°C	25.6°C	25.4°C
	Average	21.5°C	19.5°C	20.1°C	20.4°C
2021	Lowest	16.8°C	14.9°C	15.1°C	15.6°C
	Highest	28.8°C	28.6°C	27.9°C	28.4°C
	Average	22.8°C	21.8°C	21.5°C	22.0°C

In fact, this increase in temperatures also corresponds with a notable decline in annual rainfall. According to data from the General Directorate of Meteorology and Seismology in the Kurdistan Region for the Duhok City Center, rainfall levels over the past two decades (2004–2023) have shown a marked downward trend, with wide annual fluctuations. While some years, such as 2018 and 2019, recorded exceptionally high rainfall (953.0 mm and 909.4 mm respectively), recent years have seen significant reductions, dropping to only 231.7 mm in 2021.

The average rainfall over the last decade (2014–2023) has declined by 289.6 mm compared to the previous decade (2004–2013). This trend underlines a growing water scarcity concern for the region, where rainfall variation between the driest and wettest years reached as high as 953 mm, highlighting the unpredictability and volatility of precipitation patterns linked to changing climatic conditions (see Figure 13).

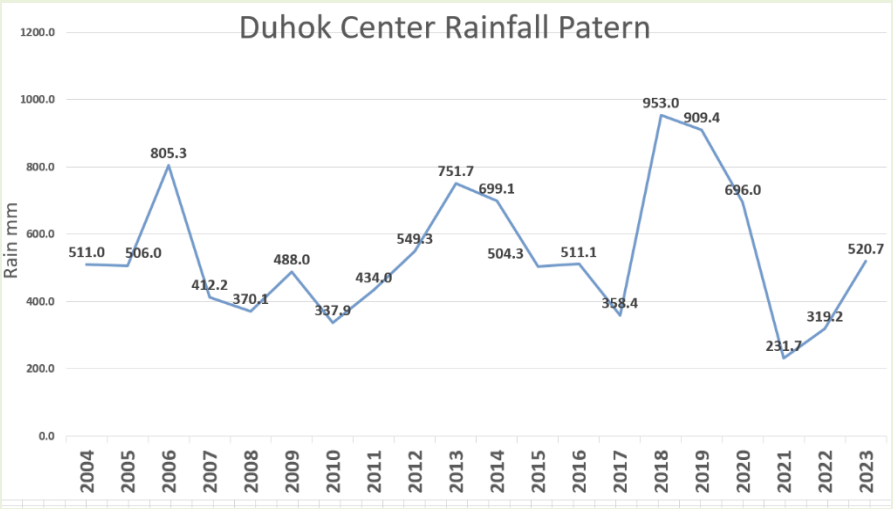

Figure 13: Duhok Center Rainfall Pattern (2004–2023)

Climate data from Duhok Governorate, analyzed in a recent study published in the International Journal of Research in Environmental Science (IJRES), reveal significant climate variability over the past five decades, marked by increasing fluctuations in annual rainfall. The data show that annual rainfall ranged between 158 mm (1974–1975) and 1,199.3 mm (2018–2019), with a long-term average of 533.7 mm. While the mid-20th century saw relatively stable precipitation, the latter half exhibited sharper oscillations, particularly after the 1990s. Recent years have witnessed intensified extremes, including the wettest year on record (2018–2019) and severe droughts (e.g., 2007–2008 and 2020–2022).

Referring to Figure 14, the rainfall trends in the Kurdistan Region and Climate data extracted from a government report in cooperation with the United Nations Development Programme (UNDP) indicates that the annual precipitation levels in Duhok Governorate have experienced significant fluctuations from 1901 till 2021 which shows that annual rainfall averaged between 400 mm and 450 mm during the early 20th century, with relative stability until the late 1940s. Starting in the 1950s, precipitation levels began to rise, reaching their peak during the 1960s and 1970s, with some years exceeding 600 mm. However, this increase was not consistent, as it was

followed by a period of decline and variability, especially from the late 1990s to the mid-2000s, where annual rainfall in some years dropped below 300 mm. The most recent data reveal substantial fluctuation in rainfall patterns, without a clear upward or downward trend, unlike temperature patterns. This indicates increasing irregularity in the rainy seasons, which directly impacts water resources, agriculture, and food security in the region. This evolving climate reality highlights the urgent need to adopt water management strategies and enhance climate resilience across vital sectors.

The coefficient of variation (38.79%) underscores growing unpredictability, consistent with global climate change patterns. This trend threatens water security and agricultural sustainability in the Kurdistan Region, necessitating adaptive strategies such as improved irrigation systems and climate-resilient infrastructure to safeguard vulnerable sectors.

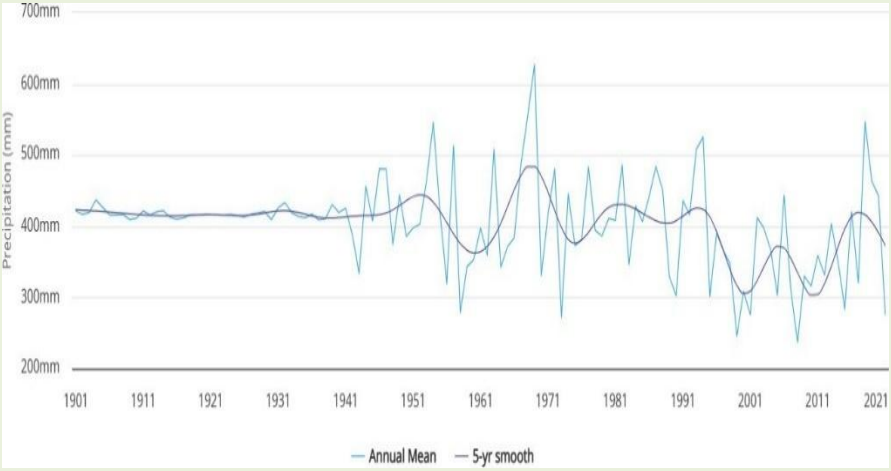

Figure 14: Annual average precipitation recorded in Duhok gov (1901-2021)

All indicators suggest that the consequences of climate change on Iraq, including the Kurdistan region, will not only lead to record-high temperatures, depletion of water resources, marshland disappearance, and forest fires, but also mass internal migration, village desertification, and increased urban congestion in future years. While there is no infrastructure to accommodate the large population and meet their needs, the population is

expected to double in the coming years, with temperatures exceeding 50°C and 90% of days experiencing dust storms.

Although Iraq and the Kurdistan Region are minor contributors to climate change, they face disproportionate consequences—from extreme heat and prolonged droughts to intensified dust storms. To mitigate these effects, Iraq must strengthen its agricultural resilience and WASH infrastructure with support from international partners. Investments in drought-resistant crops, efficient irrigation, and groundwater management can safeguard food security, while upgraded water and sanitation systems will protect public health amid worsening climate conditions.

Beyond environmental risks, climate change threatens Iraq's economy, with projected damages in the hundreds of millions of dollars to agriculture, industry, and critical supply chains. Without intervention, shrinking water supplies and soil degradation will exacerbate instability. By mobilizing domestic resources and global aid, Iraq can reduce dusty days, stabilize temperatures, and build long-term climate resilience for its people.

3.6.1 Impact of Climate Change on the Agricultural Sector and Water Scarcity

i. Climate Change and Agriculture

Climate change and agriculture are closely interconnected global processes. Climate change affects agriculture in several ways, including changes in temperature, rainfall, extreme fluctuations (such as heat waves), shifts in pests and diseases, alterations in atmospheric CO2 concentrations and near-surface ozone levels, modifications in the nutritional quality of certain foods, and rising sea levels (IPCC, 2019). Future climate change is expected to negatively impact crop production in low-latitude countries, whereas the effects in northern latitudes may be either positive or negative (IPCC, 2022).

Despite technological advancements such as improved crops, genetically modified organisms, and irrigation systems, climate remains a major factor in agricultural productivity, along with soil characteristics and natural ecosystems (FAO, 2021). The impact of climate on agriculture is more

closely tied to local climate variations than global climate trends. The Earth's surface temperature has increased by approximately 1.5°F (0.83°C) since 1880 (NASA, 2023). Therefore, agricultural experts stress that any assessment must consider each geographical region separately.

Global warming may lead to an increase in insect pest populations, harming staple crops such as wheat, soybeans, and maize. While warmer temperatures extend growing seasons and accelerate plant growth, they also increase metabolic rates and reproductive cycles in insects (Deutsch et al., 2018). For example, insects that previously had only two breeding cycles per year may gain an additional cycle if warm growing seasons are prolonged, causing population surges. Temperate and high-latitude regions are expected to experience significant changes in insect populations (IPCC, 2022).

ii. Drought and Climate Change Impacts

Droughts have become more frequent due to global warming and are expected to become even more severe and recurrent in Africa, southern Europe, the Middle East, much of the Americas, Australia, and Southeast Asia (IPCC, 2021). Their effects are exacerbated by increasing water demand, population growth, urban expansion, and environmental conservation efforts in many areas. Drought leads to crop failures and the loss of pastures designated for livestock. In a clear indication of extreme weather impacts on global food security, Iraq has been forced to halve its cultivated crop areas for the third consecutive year due to drought (FAO, 2023).

Adverse weather conditions have affected crops across vast regions in the Northern Hemisphere, from North America to the Black Sea, pushing wheat futures to multi-year highs. Although Iraq is not among the top buyers, the Middle East remains one of the largest wheat-importing regions. Iraq's neighbors, Turkey and Iran, both reliant on Iraqi river water supplies, have emerged as key buyers this season. According to **USDA (2023**), oil-rich Iraq requires approximately 4-4.5 million tons of wheat annually to meet domestic bread demand, despite overall consumption being higher. The private sector can import wheat externally. Iraq's wheat production for the current year is 3.5 million tons, compared to over 5 million tons in 2020,

according to Agriculture Ministry spokesperson Hamid Al-Nayef**, FAO (2023**).

iii. Innovations and Sustainability

One way to drive progress, especially in the agricultural sector, is to remove or redirect subsidies that encourage excessive consumption of fertilizers, water, or energy in food production. Supporting innovation and entrepreneurship can also facilitate change; new processes and technologies in natural land planning, soil analysis, irrigation, and even alternative proteins like plant-based meat contribute to making agriculture and land use more sustainable (World Bank, 2022). Similarly, changes in the construction industry, which has begun shifting towards more efficient products such as insulated wood (an alternative thermal insulation material that reduces reliance on oil-burning for heating), can help reduce carbon pollution (IEA, 2021).

Another strategy for addressing climate change risks is the use of hybridization techniques to develop plant varieties suited to climate change, considering the specific climatic conditions of each region (FAO, 2020). Finally, financing options for nature-based climate solutions must be significantly expanded. While payments for forest conservation have begun flowing under the UN's program for reducing emissions from deforestation and forest degradation, the Environmental Climate Fund has allocated $500 million for forest protection payments (Green Climate Fund, 2022).

iv. Water and Climate Change

Water and climate change are closely interconnected, as climate change affects the world's water resources in complex ways. From unpredictable rainfall patterns to the shrinking of ice sheets, rising sea levels, floods, and droughts, most climate change impacts stem from water (UN-Water, 2021). Climate change exacerbates water scarcity and related risks, such as floods and droughts, as rising temperatures disrupt precipitation patterns and the entire water cycle (IPCC, 2022).

A study published in Nature revealed that Greenland's ice sheet lost 5,091 square kilometers of its area between 1985 and 2022 (NASA, 2023 - updated from Nature reference). Currently, around 2 billion people worldwide lack access to safe drinking water (WHO/UNICEF, 2022), and nearly half of the world's population experiences severe water scarcity for at least part of the year (IPCC, 2022). These figures are expected to rise as climate change and population growth intensify the crisis (WMO, 2021).

Usable freshwater represents only 0.5 - 1% of the total water on Earth, and this supply is severely affected by climate change. Over the past 20 years, terrestrial water storage - including soil moisture, snow, and ice - has been declining at a rate of 1 cm per year, posing significant risks to water security (WMO, 2021).

According to IPCC reports, water supplies stored in glaciers and snow cover are expected to decline over the century, reducing water availability during warm and dry periods in regions that depend on meltwater from major mountain ranges, where more than one-sixth of the world's population currently resides (IPCC, 2022).

Rising sea levels are also expected to increase groundwater salinity, reducing freshwater availability for humans and ecosystems in coastal areas (IPCC, 2022). Limiting global warming to 1.5°C compared to 2°C could nearly halve the proportion of the global population projected to suffer from water scarcity, although regional variations would still exist (IPCC, 2018).

Water quality is also affected by climate change, as rising water temperatures, along with more frequent floods and droughts, are expected to worsen various forms of water pollution - from sediments to pathogens and pesticides (UNEP, 2021). Climate change, combined with population growth and increasing water scarcity, is expected to put further pressure on food supplies (IPCC, 2022). Around 70% of the available freshwater is used in agriculture, with daily food production for one person requiring between 2,000 and 5,000 liters of water, according to recent FAO reports (FAO, 2017).

Figure 15: Extreme weather events due to the Impacts of Climate Change

Climate change has significantly increased the frequency and severity of extreme weather events, including floods and droughts. According to the Intergovernmental Panel on Climate Change (IPCC, 2021), rising global temperatures enhance the atmosphere's moisture-holding capacity, leading to more intense storms and heavier rainfall. Conversely, higher temperatures also exacerbate droughts by accelerating evaporation and disrupting precipitation patterns (IPCC, 2021; World Bank, 2022).

The risks of droughts, floods, and their societal impacts are projected to escalate with each incremental rise in global warming (IPCC, 2021). Heavy rainfall events are expected to increase in frequency across most regions, elevating flood hazards, while the extent of land affected by extreme droughts is also predicted to expand (IPCC, 2021).

Water-related disasters have dominated natural catastrophe-related fatalities over the past 50 years. Data from the World Meteorological Organization (WMO, 2021) and the World Bank (2022) reveal:

- A 134% increase in flood-related disasters since 2000 compared to the previous two decades, with Asia bearing the highest human and economic losses.

- A 29% rise in the duration and frequency of droughts, with Africa experiencing the most drought-related deaths.

- Globally, these disasters now account for ~70% of all natural catastrophe fatalities (WMO, 2021; World Bank, 2022).

4. Case Studies:

4.1 Iraq

Since 2007, the effects of climate change in Iraq and the Kurdistan region, particularly drought, have posed an increasing threat to water bodies. These threats stem from external factors, such as drought and reduced water releases from the Tigris and Euphrates rivers, as well as weak water management policies by the responsible authorities.

In 2008, the FAO warned Iraq about the continued overuse of water flowing through the Tigris and Euphrates. The study indicated that the strategic water reserves in riverbeds had nearly reached zero, posing a direct threat to water security, with Iraq being one of the most affected countries.

This crisis has been exacerbated by Turkey's decision to reduce water releases to Iraq, coinciding with the near completion of the Ilisu Dam on the Tigris River. This dam is expected to cut Iraq's annual water supply from the river by 50%, significantly impacting Iraq's water availability.

Table No. (5): Data on the Tigris River and Its Riparian Countries, according to the FAO Study (2008):

Country	Water Potential	Water Consumption
Turkey	25.24 (51.90 %)	6.87 (14.10 %)
Syria	0.00 (0.00 %)	2.60 (5.30 %)
Iraq	**23.43 (48.10 %)**	**23.00 (35.07 %)**
Total	48.67 (100.00 %)	54.47

Table No. (6): Data on the Euphrates River and Its Riparian Countries, according to the FAO Study (2008)

Country	Water Potential	Water Consumption
Turkey	31.58 (88.70 %)	18.42 (51.90 %)
Syria	4.00 (11.30 %)	11.50 (32.30 %)
Iraq	0.00 (0.00 %)	23.00 (64.60 %)
Total	35.58 (100.00 %)	52.92

The same study indicates that the Iraqi individual is the highest annual water consumer compared to other riparian countries along the Tigris and Euphrates basins, as shown in the table 7:

Table No. (7): Data on the Tigris and Euphrates Rivers Among Riparian Countries, according to the FAO Study (2008)

States	Total water/year (BCM)	Population (million)	Annual per capita water (m^3)
Turkey	100	65.7	1522
Syria	23	16.3	1411
Iraq	91.2	22.7	4017

4.2 Kurdistan Region

Key points in this section draw on the 2024 publication Local Plan for Adaptation to Climate Change in the Kurdistan Region of Iraq, developed by the Environmental Protection and Improvement Institution.

4.2.1 Water Resources:

In the absence of comprehensive national water management regulations, Iraq's water withdrawal levels are nearly double the global average. Persistent drought conditions—expected to intensify—are partially driven by erratic river flow patterns. Water quality has also declined due to these droughts and reduced rainfall, leaving shallow rivers and streams increasingly susceptible to contamination from sources like untreated wastewater and industrial discharge, particularly from the petroleum sector.

The Kurdistan Region of Iraq faces mounting risks in its water sector, largely driven by the impacts of climate change. Shifts in climate patterns and rising temperatures are placing immense pressure on already limited water resources and threatening the region's water security through several interconnected challenges:

- **Growing water scarcity**: Climate-induced stress is reducing water availability for agriculture, domestic use, and industry. This is compounded by population growth and the limited capacity of existing freshwater sources—both surface and underground—to meet increasing demand. Erratic rainfall and prolonged dry spells only intensify the shortage.
- **Deteriorating water quality**: Pollution from industrial and agricultural activities, coupled with weak wastewater treatment systems, is degrading the quality of both river and groundwater sources. This not only limits access to clean drinking water but also harms aquatic ecosystems and undermines farming productivity. Warming waters and lower volumes further encourage the spread of harmful algal blooms and waterborne illnesses.

- **More frequent extreme weather**: The region is witnessing a rise in extreme events like floods and droughts. These disrupt water availability, damage critical infrastructure, and adversely affect the livelihoods that depend on stable water supply systems.
- **Agricultural stress**: With shifting rainfall patterns and shrinking water availability, agricultural output is at risk. Farmers face growing difficulties in maintaining irrigation and crop yields under changing climate conditions.
- **Inequitable water access and growing tensions**: Access to water is uneven across the region, with some communities lacking reliable infrastructure. This disparity deepens social and economic divides, and competition over scarce water resources has the potential to fuel local disputes and social unrest.
- **Trans-boundary water tensions**: Shared watercourses with neighboring countries—Turkey, Iran, and Syria—are another point of vulnerability. The construction of upstream dams and the lack of collaborative management of these resources raise concerns about long-term water availability in the region.
- **Aging infrastructure and inefficiencies**: Much of the existing water infrastructure—dams, reservoirs, and distribution networks—is outdated and poorly maintained. This contributes to water losses, inefficient allocation, and inadequate long-term planning
- **Threats to ecosystems**: Climate change also puts natural ecosystems such as wetlands and riverine habitats at risk. These ecosystems play a crucial role in supporting biodiversity and providing vital environmental services, all of which are undermined by rising temperatures and reduced water flows.

Tackling these pressing challenges demands immediate and collaborative action from the federal government, the Kurdistan Regional Government, local stakeholders, and international allies. Strengthening water governance through sustainable management approaches, prioritizing investment in climate-resilient infrastructure, and advancing water-saving technologies are essential components of a long-term solution. Equally important is the active involvement of communities in conservation efforts and decision-making

processes. By acknowledging the severity of these vulnerabilities and responding strategically, the Kurdistan Region can better protect its water resources, enhance resilience to climate impacts, and support its path toward sustainable and equitable development.

4.2.2 Agriculture and Food Security

Agriculture in the Kurdistan Region of Iraq is dominated by small-scale farming, particularly in the north, where rain-fed irrigation supports most agricultural activity. Wheat and barley are staple crops, while fruit trees serve as an important source of income. Livestock is integral to these systems, especially in rain-fed zones. However, persistent droughts have taken a heavy toll—nearly half of the northern agricultural lands were devastated between 2008 and 2009, with substantial livestock losses also reported. The already strained livestock sector, facing chronic shortages of feed, remains vulnerable to intensifying drought conditions.

Climate change is amplifying food insecurity across Iraq by undermining agricultural productivity and diminishing water supplies. Today, around 19 million people, more than half the population, experience food insecurity, with approximately 11% facing severe conditions. In the Kurdistan Region, where agriculture is particularly exposed to climate risks, a wide array of challenges demand swift and strategic action:

- **Water scarcity and unpredictable rainfall:** Shifting climate patterns are disrupting water availability and rainfall regularity, undermining irrigation systems and crop reliability. Extended droughts place additional stress on water resources, reducing yields and increasing agricultural vulnerability.
- **Soil Erosion:** Unsustainable land practices, including overgrazing and deforestation, have led to worsening soil erosion and reduced fertility. Reversing this trend will require investments in soil conservation, reforestation, and sustainable land use practices.
- **Outdated agricultural methods:** A significant number of farmers continue to use traditional techniques that limit efficiency and output. Limited access to modern tools, improved seeds, fertilizers,

and technical training further constrains progress. Accelerating the adoption of advanced practices is vital to increasing productivity.

- **Low crop diversity:** Dependence on a narrow range of crops makes the sector susceptible to pests and market shocks. Strengthening crop diversification and value chain development can help improve resilience and income stability.
- **Rising incidence of extreme weather:** The region is witnessing more frequent and severe weather events—including floods and heatwaves—that damage crops and agricultural infrastructure. This volatility presents growing risks to farmers and food systems.
- **Shifting planting seasons:** Changing climate conditions are altering the timing of planting and harvesting, making it harder for farmers to follow traditional schedules. This disrupts crop planning and lowers agricultural predictability.
- **Livestock stress and decline:** Higher temperatures and water shortages reduce animal productivity, notably milk output, and increase disease risk. These conditions endanger pastoral livelihoods.
- **Deteriorating water quality:** Pollution, driven by climate factors and human activities, is affecting both irrigation and livestock water supplies. Unsafe water sources threaten both agricultural output and animal health.
- **Biodiversity loss:** Climate impacts are undermining ecological systems that support farming, including pollinators and natural pest control mechanisms.
- **Worsening food insecurity:** The cumulative effect of these pressures diminishes access to sufficient and nutritious food, hitting marginalized communities hardest.
- **Limited financial and market access:** Farmers often lack access to credit and reliable market opportunities, restricting their ability to invest in modern solutions or expand production. Bridging these gaps is essential for sector growth.

To overcome these complex challenges, the agricultural sector in the Kurdistan Region must adopt integrated and adaptive strategies. These include promoting drought-resilient crops, enhancing water-use efficiency, modernizing irrigation infrastructure, and scaling up climate-smart agriculture. Investing in early warning systems, supporting sustainable land practices, and equipping farmers with technical knowledge are critical for long-term resilience. Strengthened collaboration among government, civil society, and the private sector can ensure that agriculture remains a pillar of food security and economic stability despite mounting climate risks.

4.3 Duhok Governorate Study (Relevant Departments)

In this part, we will focus on the capacity of the relevant governmental sectors of Duhok Governorate to address climate change risks. The analysis will highlight the roles and responsibilities of key departments such as Environment, Water Resources, Agriculture, and Planning. It will explore existing capabilities, identify institutional and technical challenges, and outline practical solutions. For each department, specific recommendations will be provided to strengthen climate resilience, improve coordination, and integrate adaptation measures into planning and implementation processes.

4.3.1 Duhok Water Directorate

The Directorate of Water – Duhok (DoW) is a governmental body operating under the Ministry of Municipalities and Tourism. It serves as the main authority responsible for providing drinking water to the population of Duhok Governorate, including Duhok city, Zawita, and Mangesh sub-districts. The department oversees the operation of water treatment facilities, distribution networks, and ensures water quality and accessibility for residents. With growing climate-related pressures such as reduced rainfall and declining groundwater levels, the DoW's role is increasingly critical. This section assesses its current capacity, identifies existing challenges, and presents practical, department-specific recommendations to enhance climate resilience in water service delivery.

Potential Role of the Water Directorate

- Preventing illegal water extensions, especially for informal green spaces within cities and residential areas.
- Encouraging non-subscribers to install water meters and float valves in water tanks.
- Proposed Solutions for Water Management Across Relevant Authorities
- Enhancing government support to provide necessary equipment and spare parts.
- Allocating a continuous budget for water resource assessments.
- Prohibiting farmers from using groundwater wells for long-term water-intensive crops like rice and grain production.
- Banning illegal deep well drilling.
- Installing groundwater extraction meters in all non-governmental wells.
- Enforcing regulations on imposing fines and fees for illegal water activities.
- Securing government support for building additional reservoirs and small dams.
- Developing coordinated action plans among all relevant entities.
- Restructuring the administrative framework of water directorates.
- Reusing municipal wastewater through specialized treatment plants.
- Implementing a water fee system to support maintenance and operational costs.
- Expanding the use of metering systems across cities and collective villages.
- Allocating specific water sources for domestic, agricultural, commercial, and industrial use based on new parliamentary regulations.
- Launching extensive awareness campaigns on water conservation, particularly targeting education and civil society sectors.

Water Infrastructure and Supply in Duhok Governorate:

1. Strategic Water Infrastructure

A. Water Treatment Plants (WTPs)

Project Name	Location	Capacity (m^3/hour)	Capacity (m^3/day)
Main Duhok Water Project	Kharab Dim	7,320	175,680
Suhaila Water Project	Suhaila	448	8,960

Combined Annual Summer Consumption: Approximately **6,000,000 m^3/year**

B. Groundwater Wells

Parameter	Value
Total Number of Wells	261
Average Depth	200 meters
Average Production Capacity	80 gallons/minute
Inactive Wells	82 (due to pollution or drying)
Active Wells	179
Total Daily Production (10 hrs)	≈ **32,220 m^3/day**

2. Water Consumers

Area/Location	Population Served
Duhok City Center	498,100
Zawita Sub-district	30,000
Mangesh Area	18,700
Suhaila Area	32,600
Sumail & Surroundings	155,350
Total Consumers	**734,750**

3. Water Network Coverage

Parameter	Value
Total Network Length	1,160 km
Total Registered Subscribers	80,000 households
Water Loss (Wastage Rate)	35%

Water losses (wastage rate): 35% due to:

- Old networks not integrated into the GIS monitoring system, with missing location data (e.g., Raza, Ayatot, and Zaniari neighborhoods).
- Continuous illegal connections, especially in newly built areas or unregistered green spaces.
- Impact of Climate Change on Water Production and Supply

Challenges facing DoW-Duhok:

- Outdated administrative structure.
- Over-reliance on deep wells instead of surface water sources.
- International disputes over the flow of the Tigris River, controlled by Turkey.
- A general **limited level of public awareness** across all social groups.
- Weak role of media and other government agencies (e.g., education sector).
- Limited financial support from relevant government institutions.
- Weak coordination by some relevant bodies.

The data in Table 8 highlights significant annual fluctuations in water supply from the Duhok Project between 2009 and 2024. While there was a notable increase from 5.5 million m^3 in 2009 to over 65 million m^3 in later years, the trend reveals variability linked to environmental and climatic conditions. These fluctuations are further reflected in Table 9, which shows the annual changes in the river's elevation. The average elevation has hovered around 313.62 meters above sea level, with peaks and drops that suggest both seasonal and long-term hydrological shifts. Together, the tables emphasize the critical need for adaptive water management strategies in response to changing water availability in the region.

Table No. (8): Annual Water Supply from the New Duhok Project in Kharab Dim for the Period 2009-2024

Year	Quantity supplied annually (m3)
2009	5,520,000
2010	30,945,312
2011	50,513,112
2012	57,812,448
2013	61,791,600
2014	64,765,608
2015	65,351,879
2016	64,879,000
2017	65,717,145
2018	64,564,765
2019	59,019,215
2020	64,037,748
2021	63,666,805
2022	65,052,615
2023	64,203,205
2024	59,801,163
Average (m^3 / year)	56,727,601
Total (m^3 /year)	907,641,620

Table No. (9) Average Elevation Above Sea Level

Year	**(m) Elevation**
2009	314.81
2010	313.36
2011	313.22
2012	312.97
2013	314.31
2014	310.63
2015	312.94
2016	310.90
2017	312.18
2018	308.66
2019	319.99
2020	319.12
2021	318.49
2022	311.31
2023	307.51
2024	317.52
Average	**313.62**

4.3.2 Directorate of Water the Outskirts:

The Directorate of Water in the Outskirts in Duhok Governorate was established in 2008, overseeing sections in four districts of Duhok Governorate: Amedi, Sheikhan, Bardarash, and Summel. Its main function is to provide drinking water for residents in these areas, in addition to 11 camps for displaced persons and refugees through its service projects and water networks, sourced either from rivers (14%) or groundwater wells (86%).

According to the recent information released by the Directorate of Water Outskirt of Duhok gov, the droughts in recent years have significantly and noticeably affected water sources, leading to the complete drying of 4% of wells and a 10% reduction in productivity from others, resulting from a decrease in groundwater levels by 10-15 meters.

Additionally, 57% of springs have dried up, causing a decline in the efficiency of strategic projects by 25%, as shown in Figure 16. The drop in the level of Mosul Dam Lake led to the suspension of the water filtration plant in Khanki and the water treatment unit in Faida for long periods, which produced about 500 m^3/h and 2500 m^3/h, respectively, to supply more than 250,000 people in the districts of Semel and Faida, as shown in Figures 16 and 17.

Figure 16: The water level in Mosul Dam has decreased due to the impact of climate change (2021 water was at car level)

Figure 17: Breaking the intakes and unscrewing the pipes in the Faida water

Figure 18: Breaking the intakes and unscrewing the pipes in the Faida water

Climate change has impacted the occurrence of floods caused by heavy, sudden rainfall and the melting of ice due to high temperatures in other seasons. This has led to an increase in turbidity levels in the Zab River from 5,000 to 30,000 NTU, consequently increasing the amount of sand, which causes erosion of pump shafts and disrupts the project. As a result, the project must be stopped during such seasons.

Figure 19: Erosion of the pump flange due to sand.

Figure 20: Showing the normal level of water in Kharab dim project in 2017 after good precipitation season.

Figure 21: Showing the severe declining of water level in Kharab dim project in year 2023 due to Climate Change Impact and drought season.

Table No. (10): Projects of Duhok Governorate Districts:

Districts	Number of Wells	Damaged Wells	Water springs	Damaged Water springs	Strategic Projects	Damaged Strategic Projects
Amedi	98	45	49	25	1	1
Summel	252	30	-	-	2	2
Sheikhan	300	20	15	11	1	1
Bardarash	211	24	2	2	1	1
Total	861	119	66	38	5	5

Challenges and Risks:

- Inability to implement annual plans due to persistent financial deficits and limited governmental and international funding. Outdated administrative structure that requires revision to improve operational efficiency.
- Heavy reliance on deep wells instead of surface water sources, stemming from the lack of financial resources needed for strategic infrastructure projects.
- Declining water availability and quality, especially in groundwater, due to reduced water inflows and over-extraction.
- Frequent failure of submersible pumps, primarily caused by calcification and lowering groundwater levels.
- Ongoing transboundary water disputes, particularly regarding Turkey's control over the Tigris River flow, are affecting the overall water supply.
- High demand for fresh water, driven by population growth and increased migration from rural to urban areas.
- Weak inter-institutional coordination, including with municipalities and other relevant government agencies.
- Low public awareness, especially in suburban and rural areas, about water conservation and the importance of sustainable practices.
- Limited engagement of media and educational institutions, such as the Ministry of Education, in raising awareness on water issues.
- Social and economic barriers in convincing residents to install water meters and pay fair prices for water usage.
- Low water tariffs that discourage conservation and lead to excessive consumption.
- Increased water loss due to aging infrastructure, particularly outdated distribution networks.

Some Proposed Plans to Overcome Climate Change Damages (Adaptation)

- Stock sufficient spare parts (submersible pumps, motors, pipes, valves, and other accessories), especially those not available in local markets, to ensure timely maintenance of projects and avoid their shutdown, and control wastage.
- Provide necessary heavy machinery (e.g., excavators, cranes, JCB, etc.) for the aforementioned purpose, as rental costs sometimes delay essential problem-solving, resulting in higher wastage and insufficient water supply.
- Connect wells via a SCADA (Supervisory Control and Data Acquisition) system to manage water supply based on demand and track water levels to prevent pump breakdowns and reduce costs.
- Rehabilitate old networks and replace them with newer, more cost-effective designs that ensure equitable water distribution, especially in expanded areas.
- Support surface water projects by conducting studies, designs, and construction to benefit from available surface water and preserve groundwater reserves.
- Support recycling projects and establish networks for treated water to be used in agriculture and other activities, reducing reliance on potable water.
- Drill alternative wells in areas where existing wells have dried up and install pipes in wells where water levels have decreased due to drought.
- Implement solar energy systems in water projects to reduce electricity consumption, minimize generator maintenance costs, and, most importantly, protect the environment.
- Ensure continuous electricity supply to projects that cannot meet the required water supply due to power outages.
- Enhance the technical capabilities of staff by providing training and operational skills to better maintain project components.

- Launch awareness campaigns across different groups to improve community behavior toward water conservation and educate about climate change impacts for a better future.
- Impose fees on water use in villages and towns to reduce overuse for non-domestic purposes, with water meters applied as in cities.

4.3.3 Irrigation Directorate:

The Directorate of Irrigation was established in Duhok Governorate in 2007 as an independent entity that branched out from the Dams Administration. It is responsible for the integrated and comprehensive management of water resources in the governorate, which includes seven main districts: Duhok Center, Zakho, Amedi, Sheikhan, Sumel, Aqrah, and Bardarash.

The directorate's operational responsibilities extend across these districts, supervising the management and operation of a wide network of vital water facilities. This includes dams of various types (earthen and structural), irrigation canal networks that irrigate agricultural lands, and drainage systems that protect them from soil salinity and flooding.

This role comes amid increasing challenges facing the Kurdistan Region and Iraq as a whole, most notably climate change (global warming), which has manifested in reduced rainfall, rising temperatures, and increased droughts. This places an additional burden on the directorate to enhance water use efficiency, adopt sustainable policies to conserve these scarce resources, and develop innovative solutions, such as water harvesting and reuse, to ensure financial and food security for citizens across all districts.

Surface water bodies are highly important for the water cycle, yet some earthen dams and water canals in the region have recently been affected by droughts and floods as a result of climate change, as illustrated in Figures 22, 23, and 24.

Figure 22: An earthen dam damaged by floods in a single season

Figure 23: An irrigation canal damaged due to the flood season

Figure 24: Soil collapse caused by flooding on a mountain farm

Impact of Climate Change on Surface Water Resources in Duhok Governorate:

1. **Continuous Decline in Water Inflow from Main and Sub Rivers:**

There has been a persistent decrease in the water flow from both the main rivers and their tributaries. This has led to reduced surface water availability for irrigation, drinking water, and other uses.

2. **Reduction of Groundwater Reserves (Declining Groundwater Levels):**

Groundwater recharge has been significantly affected, with a noticeable decline in water levels in various springs in the region. Monthly studies of local springs show a gradual decrease in water volume, further exacerbating water scarcity.

3. **Declining in Precipitation (Rainfall and Snowfall):**

The region has experienced reduced rainfall and snowfall levels, which have negatively impacted surface water supplies that normally replenish rivers, lakes, and reservoirs during rainy seasons.

4. **Decrease in the Water Levels of Shallow Wells:**

Shallow wells, which are a major source of water for many communities, have experienced a noticeable decline in water levels due to prolonged periods of drought and reduced rainfall, further intensifying water scarcity in the area.

These impacts highlight the vulnerability of Duhok's water resources to climate change, posing challenges for water supply and management in the region.

Figure 25: A spring affected by drought due to climate change in the region

Figure 26: An inlet of a water canal damaged by floods

- **Risks and Challenges:**

1. **Climate changes in the region**: These changes lead to a continuous decline in surface water inflows.
2. **Low rainfall and snowfall**: The lack of sufficient rainfall and snowfall poses a significant challenge in providing water to various areas.
3. **Impact of neighboring countries**: Neighboring countries affect the main rivers by constructing dams, which reduces the amount of water flowing from rivers with external sources.

- **Recommendations and Proposals (Adaptation):**

Continuing the construction of earthen dams in the region: The construction of earthen dams helps store water during rainfall and snowfall periods, reducing the impact of decreased water inflows.

Providing advanced hydrological devices: Using advanced hydrological devices and techniques helps to improve accuracy in water resource monitoring and analysis.

Increasing community awareness: Through organizations, authorities, the private sector, TV channels, and media, awareness can be raised among village residents about the risks of climate change and its effects on water resources.

Table No. (11) - Water Reservoirs Affected by Drought Due to Climate Change in the Region:

Water Reservoirs	District
Darkar	Zakho
Avgani	Miska
Ashawa	Amedi
Sirkli	Korkani
Zewke	Bamishmish
Jonan	Markresh
Kesi	-

4.3.4 Groundwater Directorate:

The Groundwater Directorate was established in 1971 and is administratively and technically affiliated with the Ministry of Agriculture and Water Resources. The directorate is responsible for various tasks, including the continuous maintenance of wells and the following key duties:

Identifying locations for deep wells to extract groundwater for various purposes such as drinking, industrial, and agricultural use, among others.

Overseeing the drilling operations for both public and private sectors, issuing specific reports for each well that include static and dynamic water levels, productivity, and submergence details.

The directorate has a geophysical team that identifies well locations and assesses productivity opportunities based on the requesting entity's needs. Another team monitors and inspects selected wells to track water levels on a monthly basis. The directorate conducts scientific research in collaboration with researchers, relevant authorities, organizations, and universities.

- **Groundwater and Climate Change**

Groundwater wells have been significantly impacted by climate change, especially after the drought periods of 2007-2009 and 2010-2011. Groundwater levels dropped by varying degrees across Iraq, particularly in the Kurdistan region and Duhok Governorate. According to the latest statistics from the Directorate of Water Resources in the Ministry of Agriculture and Water Resources in the Kurdistan Regional Government, groundwater levels dropped by 10-20 meters in Duhok, and 50-150 meters in Erbil and Sulaymaniyah. This is mainly due to overuse and reduced rainfall, which is further exacerbated by climate change.

Recommendations and Potential Solutions Regarding Climate Change Impacts:

1. Assist the Directorate in conducting a comprehensive survey of proposed locations for implementing artificial groundwater recharge techniques.
2. Protect groundwater from pollution by preventing waste disposal near recharge sources and reducing the use of chemical substances in agriculture, including excessive fertilizers and pesticides, without proper oversight.
3. Explore alternatives to groundwater by utilizing surface water sources while preserving groundwater as a national resource.
4. Install meters to measure the volume of groundwater extracted from private wells and establish fair pricing for its usage.

5. Implement artificial recharge techniques as an adaptation measure in response to declining groundwater levels, whether due to reduced rainfall or infiltration from riverbanks.

Some techniques for confronting climate change impacts and water harvesting:

1. Artificial Recharge of Groundwater

Artificial recharge is the process of enhancing the natural storage of groundwater and can also be defined as increasing the natural filtration of surface water and rainfall into the groundwater. This is achieved by filtering surface water through the soil via special basins or by using injection wells.

Artificial recharge helps to halt the decline in groundwater levels and even raise groundwater levels. This technique is essential in areas where groundwater levels have dropped due to climatic drought or excessive exploitation. Artificial recharge also facilitates the reuse of surface water.

The goals and benefits of artificial recharge can be summarized as follows:

1. Benefiting from floodwaters and regulating them to prevent disasters, using them instead to recharge groundwater.
2. Increasing the groundwater storage capacity.
3. Stopping the continuous decline and even raising groundwater levels.
4. Utilizing rainwater (winter) for use during dry periods (summer).
5. Purifying water from suspended materials as it enters the water-bearing layers.
6. Preventing landslides caused by excessive groundwater pumping from lower aquifer layers.

The choice of artificial recharge methods depends on the geological and hydrogeological characteristics of the recharge area. These characteristics include geological, hydraulic, and tectonic boundaries of rocks, water inflows and outflows, storage capacity of the layers, permeability and hydraulic conductivity of rocks, available recharge sources, and water

balance. When selecting a recharge area, it is essential to understand the region's natural conditions, such as geomorphology, vegetation cover, soil texture and structure, climate elements, water quality and quantity, the properties of water-bearing layers, and associated layers. Additionally, the costs, time, effort, and benefits of the operation need to be calculated.

Artificial recharge techniques include:

1. Pumping from stable surface sources to groundwater wells using special pipes designed for this purpose.

The pipe should be placed at a spring with clear water to avoid blockages, extending the pipe to the wellhead. The well should be located in a formation with high permeability to ensure the entire volume of water is absorbed, ensuring an adequate volume of water can be artificially replaced as a substitute for natural conditions.

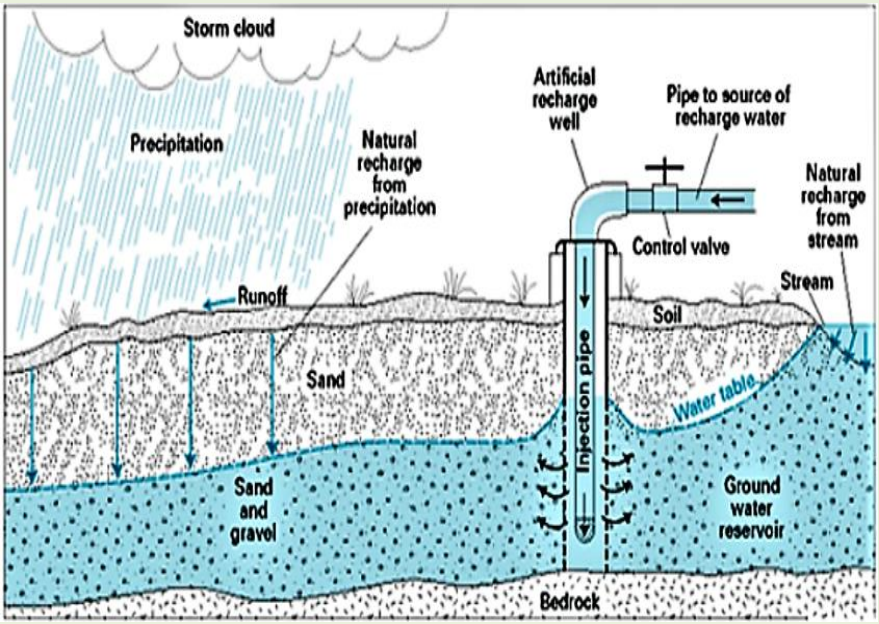

Figure 27: Recharging mechanism of underground water from natural sources.

2. Using Gabion Structures

Gabion structures involve installing gabion nets and filling them with local stones found on-site. These structures are placed in valleys near mountains, where the area is conducive to filtration. Their purpose is to block surface water during rainy days and redirect it to groundwater through a process known as infiltration. This process helps to channel the water into the groundwater levels of the region, as shown in the image below:

The use of gabion structures can be a sustainable method for improving groundwater recharge by slowing down surface runoff and allowing more water to seep into the aquifers, especially in areas vulnerable to water scarcity due to climate change.

Figure 28: Gabion structures in a mountain area.

3. Using Contour Lines

Creating contour lines with a width of 0.5–1.2 meters along the slopes of mountains and hills helps to trap rainwater and gradually convert it into groundwater through the infiltration process. This method not only helps recharge groundwater but also supports the planting of drought-resistant

trees to stabilize the soil and enhance the ecosystem. The process is depicted in the image below:

Contour lines work as a natural water management system, capturing rainwater, reducing soil erosion, and promoting sustainable land use while supporting biodiversity in vulnerable areas. This approach is particularly useful for adapting to climate changes that impact water availability.

Figure 29: Contour lines in mountain areas.

4. Small Basins and Open Channels

Creating small basins in exposed areas for storing rainwater and gradually converting it into groundwater through the infiltration process serves as an alternative to natural groundwater recharge. This method helps protect the environment by reducing soil erosion and supporting sustainable water management. It also contributes to soil conservation, which enhances agricultural productivity and ecosystem health.

By using small basins and open channels, rainwater is effectively captured and stored, helping mitigate the effects of droughts and supporting water availability during dry periods, recharging method for underground water, as well as mitigating the risk of floods and soil collapse, and erosion.

Figure 30: Small basins and open channels to store and harvest water.

Figure 31 illustrates a riverbank filtration system where treated effluent is discharged into a watercourse. The water flows through a natural bed of gravel and soil, allowing for further filtration before reaching the underlying groundwater aquifer. This process enhances water quality and supports groundwater recharge.

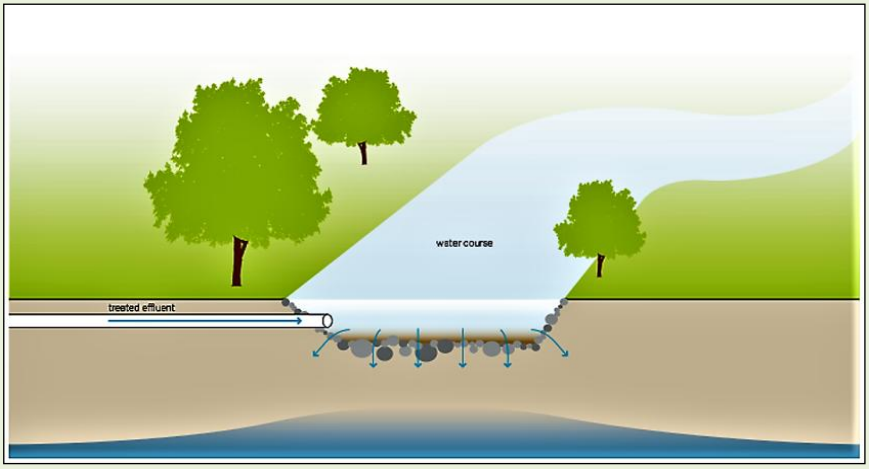

Figure 31: Riverbank filtration system showing treated effluent naturally filtered through soil and gravel into groundwater.

5. Underground Dams

Underground dams, also known as groundwater dams or, in some cases, sand dams, function to slow or prevent the flow of groundwater away from a region, storing it beneath the surface for later extraction and use over extended periods. These dams are structures designed to store groundwater in the pores of underground layers, enabling sustainable use of this valuable resource.

An underground dam typically consists of a dam body (a separating wall) built on a relatively impermeable layer of soil or fractured rock. By blocking the flow of groundwater within the reservoir, the water table rises, making it easier to extract and utilize groundwater year-round. The top of the dam is constructed at a calculated height, allowing excess groundwater to flow over the dam's peak and recharge the groundwater layers downstream.

These dams are often constructed in river valleys, where there are permeable sand and gravel aquifers that are narrow and shallow, bordered by low-permeability rock layers beneath. In such areas, it is relatively easy to build a dam that spans the entire aquifer and prevents groundwater from escaping the area being captured.

This technique helps increase water storage in regions with limited surface water and provides a reliable water source during dry periods. It is particularly useful in areas where rainfall is scarce and groundwater is an essential resource.

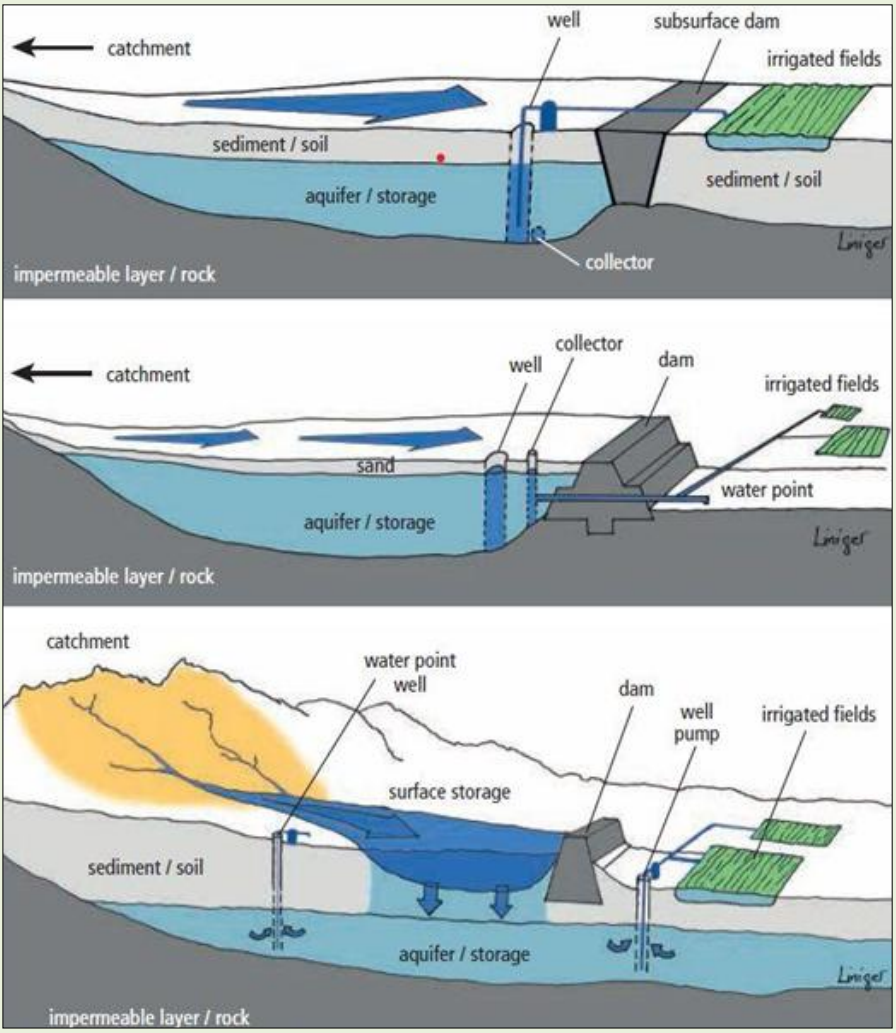

Figure 32: Illustration of underground dam systems capturing runoff in aquifers for irrigation, showing subsurface and surface storage with wells, collectors, and impermeable rock layers.

Table No. (12): Information about the number of Wells in Duhok Province and Districts:

#	District	Height (M)	Depth (M)	Water Fixed Level (M)	Water Variable level (M)	Water Production G/H	Year of Establishment
1	Duhok	984	219	65	96	87	07 September 2023
2	Duhok	1116	174	72	93	75	26 June 2018
3	Duhok	905	200	11	13	170	03 September 2023
4	Duhok	903	184	20	36	160	22 September 2021
5	Duhok	906	212	16	41	160	11 September 2021
6	Duhok	991	92	15	19	142	20 March 2018
7	Duhok	1029	185	93	110	113	20 October 2022
8	Duhok	1014	160	48	90	90	16 June 2013
9	Duhok	907	146	77	99	100	06 May 2013
10	Duhok	1045	165	68.5	80	108	12 July 2010
11	Amedi	987	145	62	65	117	01 October 2011
12	Amedi	0	148	14	45	155	22 March 2010
13	Amedi	851	264	50	120	76	10 July 2022

14	Amedi	717	160	42	60	131	04 March 2023
15	Amedi	654	190	0	0	0	04 October 2012
16	Amedi	842	273	42	117	60	11 August 2013
17	Amedi	758	180	35	132	32	13 January 2011
18	Amedi	885	185	20	0	30	22 June 2012
19	Amedi	762	227	10	55	75	30 January 2023
20	Amedi	683	180	15	112	45	01 August 2011
21	Amedi	933	213	0	0	0	14 November 2012
22	Amedi	619	194	86	86	87	26 May 2011
23	Amedi		216	11	11	25	18 August 2009
24	Duhok	838	192	39	61	121	02 October 2018
25	Amedi	-	152	63	70	112	11 October 2009
26	Amedi	1168	175	106	108	105	26 December 2023
27	Amedi	1168	170	74	88	110	11 February 2021

28	Duhok	-	170	46	56	150	24 November 2013
29	Amedi	1155	140	50	69	150	29 October 2021
30	Duhok	815	200	27	39	128	24 July 2022
31	Amedi	1152	113	49	56	80	11 November 2012
32	Amedi	1150	134	48	52	135	26 July 2012
33	Amedi	830	136	15	46	130	28 May 2023
34	Duhok	891	140	37	38	150	25 November 2012
35	Amedi	1167	120	43	40	70	01 July 2023
36	Sheikhan	706	142	73	66	122	27 August 2019
37	Sheikhan	706	192	74	52	117	21 August 2019
38	Sheikhan	701	190	44	85	95	09 November 2019
39	Amedi	806	190	23	65	112	04 September 2018
40	Sheikhan	478	221	27	34	145	30 December 2022
41	Duhok	700	85	26	29	130	03 September 2011
42	Duhok	541	280		88	300	15 November 2014

43	Amedi	801	201	150	76	100	01 October 2010
44	Sheikhan	472	200	32	60	114	26 January 2023
45	Sheikhan	728	250	85	90	96	08 July 2018
46	Amedi	433	145	8	90	96	01 April 2014

4.3.5 General Directorate of Agriculture:

Duhok Governorate is considered one of the agricultural-producing areas, as it is one of the regions with reliable rainfall and has land suitable for agriculture, whether mountainous, hilly, or flat. Most of the crops are produced in the villages and towns, totaling 1,364 villages.

Table No. (13): Agricultural land in the governorate according to the latest statistics for the year 2024.

Total Area of the Governorate	**3,357,028 dunams**
Total Arable Land	**1,575,450 dunams**
Irrigated Arable Land	**221,493 dunams**
Rain-fed Arable Land	**1,353,957 dunams**
Non-Arable Land	**1,781,578 dunams**

Climate Change and Its Impact on the Agricultural Sector in Duhok Governorate.

The governorate has been experiencing climate change in recent years, similar to other governorates in the region, Iraq, and the wider area. The General Directorate of Agriculture in Duhok Governorate has projected that

no more than 25% of the areas planted with wheat and barley will be harvested due to the low rainfall in April 2024.

This is exactly what local studies confirm that the significant variation in vegetation cover is due to topographic and climatic factors. A spatiotemporal study in Duhok Governorate revealed pronounced vegetation loss in response to shifting rainfall and elevation patterns (Mzuri et al., 2021)

Forest cover in the Kurdistan Region has undergone notable changes due to climate change and human activity. Satellite data shows a reduction in vegetation density between 2000 and 2022, with deforestation particularly evident in the Duhok Governorate. Advances in remote sensing and machine learning have significantly improved the monitoring of forest vegetation dynamics. For instance, recent deep learning models have been applied to estimate vegetation cover and assess ecosystem stressors in semi-arid regions like Kurdistan (Habeeb & Mustafa, 2024).

However, in recent decades, climate change has increasingly threatened forest ecosystems globally. Factors such as rising temperatures, changes in rainfall patterns, and the growing frequency of extreme weather events disrupt the delicate balance of these ecosystems... Moreover, climate pressure weakens tree growth, accelerates wildfires, and spreads pests and diseases at a faster pace (Eklund et al., 2017)

Main Causes of Climate Change Impact on the Agricultural Sector in Duhok Governorate:

1. Lack of a comprehensive agricultural policy at the regional level, whether short-term, medium-term, or long-term.
2. Absence of a clear vision to reduce and address the spread of such impacts and to find solutions.
3. Lack of strong agricultural infrastructure that can provide essential and sufficient services in the event of climate change.

Challenges:

1. Lack of sufficient water sources to irrigate agricultural lands.
2. Risk of flooding on agricultural lands is one of the consequences of climate change.

3. Weak coordination between farmers and government entities regarding awareness initiatives.
4. Many types of plant production are threatened due to rising temperatures caused by climate change.

Based on the aforementioned points, the relevant authorities need to develop plans and studies to mitigate the impacts of climate change on the agricultural sector, which forms one of the pillars of the national economy in Iraq and the Kurdistan Region.

Figure 33: Map of the plant production in Duhok province and districts.

Recommendations and proposals to reduce the effects and risks of climate change on agriculture in the area:

1. Environmental Awareness and Education

Integrate comprehensive environmental education into school curricula from kindergarten to university, supported by families, government entities, civil society organizations, and international partners to foster climate-smart generations.

2. Research and Evidence-Based Solutions

Conduct scientific and localized studies to identify the direct and indirect impacts of climate change on agricultural production. Develop practical, evidence-based adaptation strategies tailored to regional conditions.

3. Emergency Budget and Policy Support

Establish a dedicated emergency response fund to address climate-induced agricultural losses and ensure food security. This fund should also support alternative solutions and promote local agricultural self-sufficiency.

4. Farmer Support and Rural Stability

Provide financial and technical assistance to farmers, especially in rural and vulnerable areas, through subsidized or long-term low-interest loans for purchasing modern agricultural equipment. This support can help reduce rural-to-urban migration and strengthen community resilience.

5. Capacity Building for Agricultural Institutions

Strengthen the capacity of agricultural institutions by implementing continuous, well-structured training programs focused on climate change adaptation and mitigation in agriculture. Ensure adequate financial and moral support for the participation of skilled staff.

6. Greening and Climate-Resilient Afforestation

Fund and technically support initiatives to expand green cover by planting climate-resilient tree species and managing green spaces sustainably to mitigate desertification and improve microclimate.

7. Sustainable Energy Transition

Promote the use of clean, renewable energy sources (such as solar, wind, and micro-hydropower) in farming operations and rural infrastructure to reduce dependency on fossil fuels and minimize environmental degradation.

8. Adoption of Climate-Smart Agriculture (CSA)

Encourage the adoption of climate-resilient agricultural techniques such as drought-resistant crops, water-efficient irrigation systems, crop rotation, and soil conservation methods to enhance productivity under changing climatic conditions.

Table No. (14) shows the impact of climate change on agricultural areas and agricultural production in Duhok Governorate for the period 2021-2024.

Year	Damage Type	Affected Production	Area/ Donum	Damage Amount (Dinar)	Affected Individuals	Notes
2020 - 2021	Drought	Winter crops + fruit trees	423.268	181,144,469,994	8,284	Damage impact rate: 58%
2021 - 2022	Drought	Livestock production	-	30,049,684,000	4,808	Lack of pasture and fodder led to reduced milk production and animal deaths

2020 - 2021	Drought	Wheat crop	612,189	-	5,446	Damage impact rate: 58%
2021 - 2022	Drought	Wheat crop	282,022	-	4,096	Damage impact rate: 28%
2024	Floods	Agricultural sector	-	8,722,601,500	1,915	-
2024	Hail	Agricultural sector	4750	-	327	-

The following photos show the extent of the damage to agricultural lands caused by floods and drought in the Duhok Governorate:

4.3.6 Forests and Rangelands Directorate:

Forests and Climate Change: The Complex Relationship and Interconnected Impacts

Forests are vital ecosystems that play a crucial role in regulating the Earth's climate. They serve as major carbon sinks by absorbing carbon dioxide from the atmosphere, which helps mitigate the effects of climate change. Additionally, forests provide essential environmental services such as preserving biodiversity and regulating water and heat cycles on the Earth's surface (***FAO, 2020***).

However, in recent decades, climate change has increasingly threatened forest ecosystems globally. Factors such as rising temperatures, changes in rainfall patterns, and the growing frequency of extreme weather events disrupt the delicate balance of these ecosystems. This results in deforestation, degradation, and shifts in the distribution of plant and animal species. Moreover, climate pressure weakens tree growth, accelerates wildfires, and spreads pests and diseases at a faster pace (***Eklund et al., 2017).***

The relationship between forests and climate change is complex and reciprocal. Forests act as "carbon sinks" by absorbing carbon and reducing the concentration of greenhouse gases in the atmosphere, thus helping to mitigate global warming. However, when forests degrade or are removed due to climate or human pressures, the carbon stored within them is released, increasing the concentration of carbon in the atmosphere and accelerating climate change. This creates a vicious cycle that exacerbates both forest degradation and climate change.

Climate Change Impacts in Duhok Governorate:

In environmentally vulnerable areas such as Duhok Governorate in the Kurdistan Region of Iraq, the severity of these impacts is increased due to the semi-arid climate and growing human pressures, making the region more susceptible to climate change. These conditions have led to a noticeable decline in forest cover over recent decades (Mzuri et al., 2021).

Trends in Forest Cover in Duhok Governorate (2000-2022)

- **2000**: Forest area = 364.17 km²
- **2000 - 2010**: Forest area = 343.96 km² (Loss of 5.55%)
- **2000 - 2022**: Forest area = 240.51 km² (Loss of 33.96%)

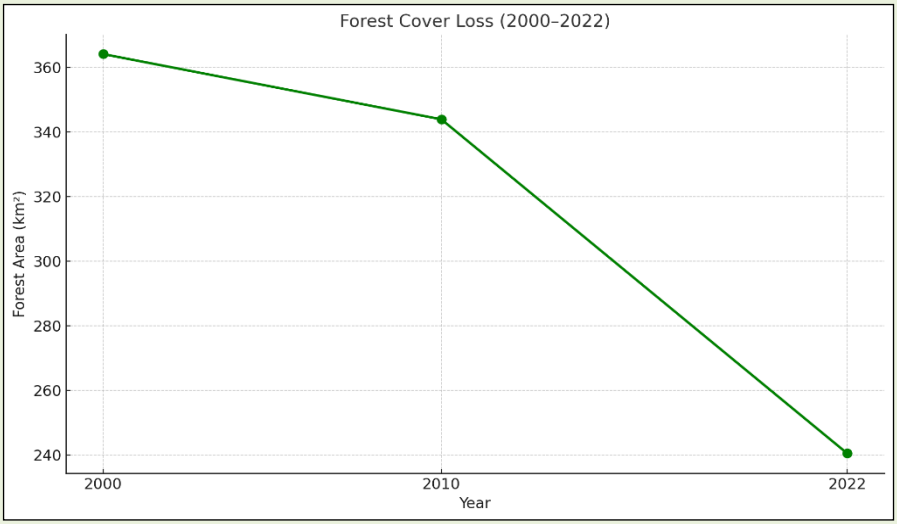

Figure 34: Forest cover loss from 2000 to 2022 in Duhok Province.

According to the Directorate of Forestry in Duhok Gov, the rate of forest cover loss has accelerated fourfold between 2010 and 2022. The data of Duhok district illustrates this trend clearly: forest area declined from 364.17 km² in 2000 to 343.96 km² in 2010, a relatively modest loss of 5.5%. However, between 2010 and 2022, the decline became much more severe, with forest cover shrinking from 343.96 km² to 240.51 km²—a dramatic loss of 30.1%. Overall, between 2000 and 2022, the district lost nearly 34% of its forest cover, reflecting a rapidly escalating environmental crisis.

At the governorate level, a survey conducted by the Food and Agriculture Organization (FAO) in 1999 estimated forest vegetation cover at about 4,381.66 km². By 2015, statistics from the Directorate of Forests revealed a shocking decline to 3,072.76 km², a reduction of more than 1,300 km². This significant decrease indicates an accelerated pace of deforestation. Even more alarming is that these figures do not include the widespread damage experienced in recent years (2023–2025) due to climate change and unsustainable human activities, suggesting that the actual forest area today is even smaller.

This alarming trajectory highlights the combined and interconnected impacts of climate change, such as rising temperatures, prolonged droughts, forest fires, and, alongside human pressures, including illegal logging, overgrazing, agricultural expansion, and urban growth. The continued loss of forest cover poses a serious threat to biodiversity, disrupts local ecosystems, and diminishes the natural capacity of forests to regulate the climate and sustain livelihoods in rural communities.

Key Factors for Forest Cover Loss:

- **Climate Change:** Rising temperatures, forest fires, and declining rainfall.
- **Urban and Agricultural Expansion:** Leading to deforestation.
- **Excessive Use of Forest Resources:** Such as tree cutting and firewood collection.

Figure 35: Forest fires are spreading in northern Iraq - the Kurdistan Region of Iraq - due to climate change in 2021.

Recommendations and Strategies to Mitigate Forest Degradation:

Sustainable Resource Management:

- Regulate tree cutting and firewood collection.
- Utilize alternative energy sources to reduce reliance on forest resources.

Afforestation and Reforestation Efforts:

- Launch large-scale afforestation programs.
- Plant drought-resistant tree species that are adapted to local climatic conditions.

Climate Change Adaptation:

- Establish local policies to reduce carbon emissions.
- Improve water resource management to support forest ecosystems.

Awareness and Education:

- Raise awareness among local communities about the importance of forests and the need for conservation.
- Encourage community participation in reforestation programs.

Research and Development:

- Promote research to better understand the impacts of climate change on forests.
- Develop continuous monitoring technologies for forest areas using remote sensing.

International Cooperation:

- Join global initiatives aimed at reducing deforestation.
- Secure international funding to support forest conservation strategies.

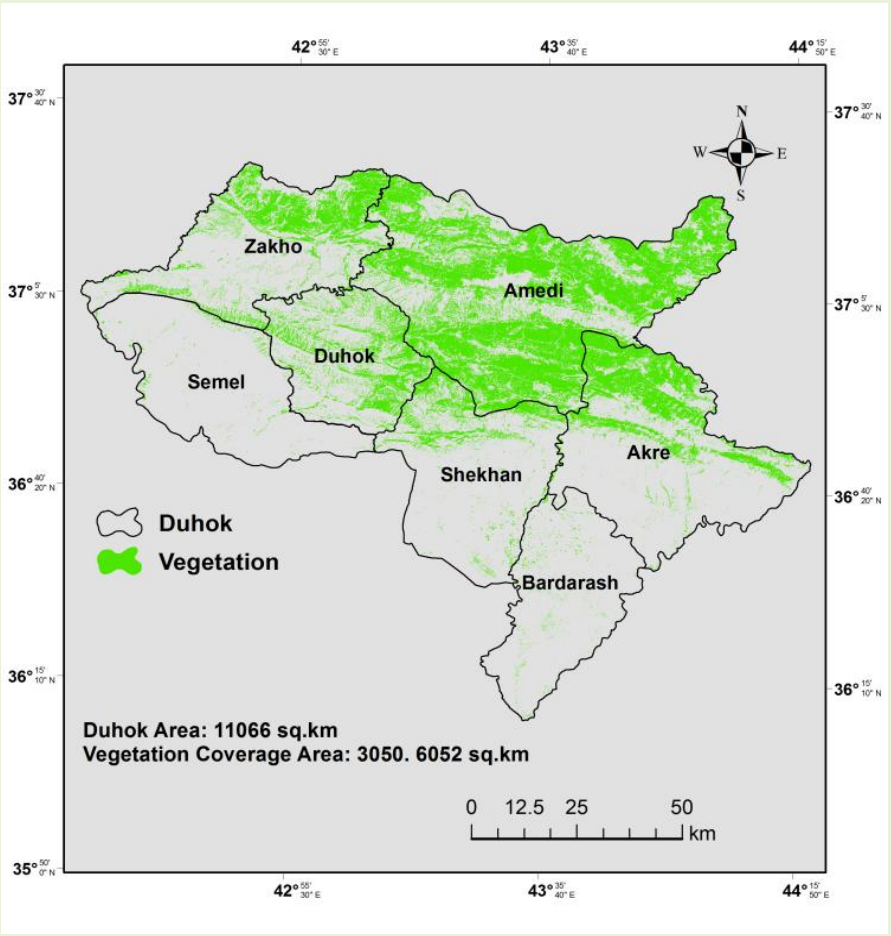

Figure 36: Forest vegetation cover of Duhok Governorate-Iraq in 2014

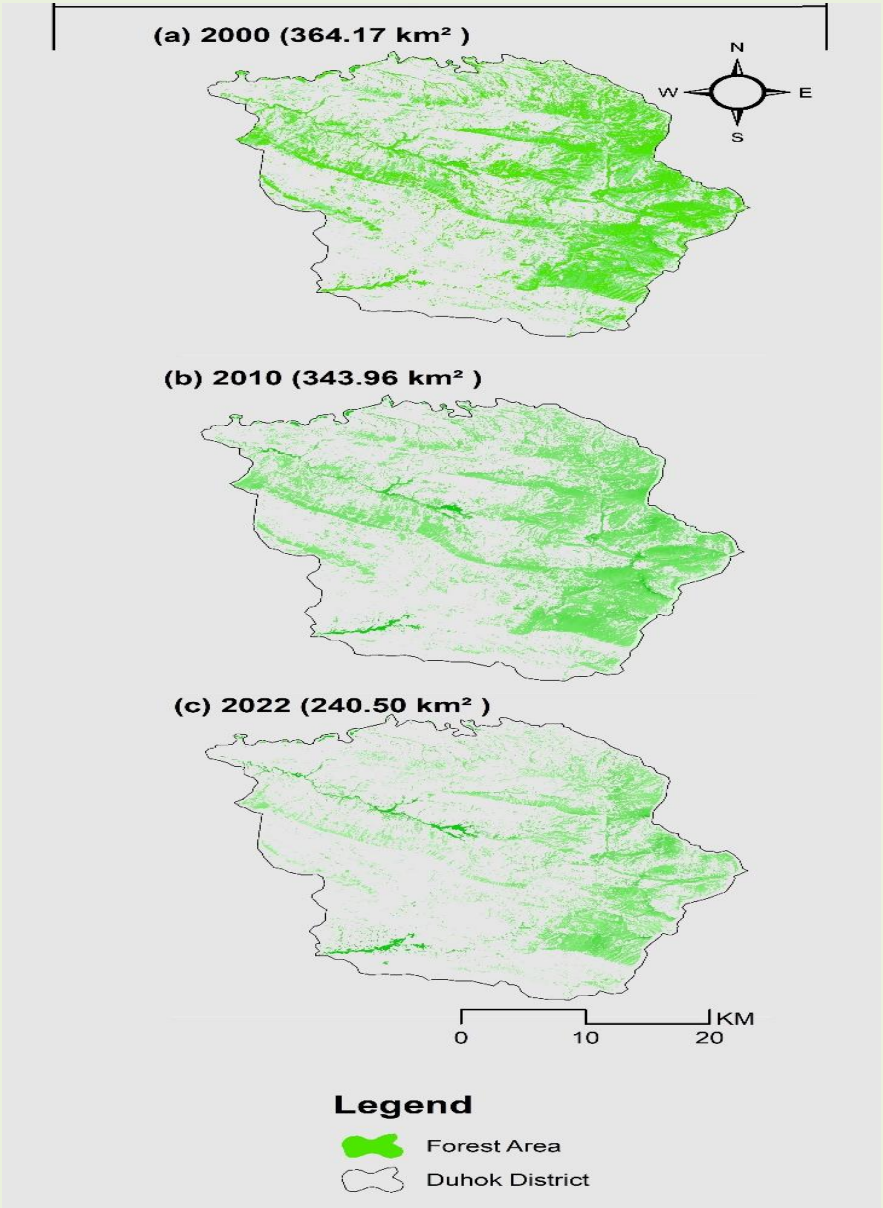

Figure 37: Impact of climate change on forestry coverage area in Duhok district in duration of 2 decades from 2000 till 2022.

4.3.7 Environment Directorate

When assessing the environmental situation in the Kurdistan Region, particularly in Duhok Governorate, it becomes evident to any observer that the environmental conditions of the area are undergoing gradual deterioration, especially the natural environment. This decline is clearly noticeable when comparing key environmental indicators from recent years with those from 25 years ago.

Environmental Degradation in the Kurdistan Region:

The Kurdistan Region is experiencing increasing environmental stress due to climate change, poor governance, and socio-political pressures. Key challenges include water scarcity, air and soil pollution, forest loss, and urban sprawl—exacerbated by weak enforcement, population growth, and legacy conflict impacts.

1. Water Scarcity and Pollution

Causes:

- Declining rainfall and snowfall due to climate change.
- Dam construction by Turkey and Iran is reducing river inflow.
- Rapid population growth, urbanization, and poor infrastructure.
- Absence of wastewater treatment, sustainable irrigation, and modern farming.
- Industrial and agricultural pollution (sewage, fertilizers, pesticides).

Impacts:

- Depletion of groundwater and drying of springs/wells.
- Contaminated water sources and salinity issues.
- Reduced availability of potable water for households and farming.

2. Air Pollution and Dust Storms

Causes:

- Poor fuel quality in vehicles, generators (~1,000 in Duhok), and industries.
- Emissions from refineries and power stations.
- Open burning of waste and frequent field/forest fires.
- Rapid vehicle increases (e.g., 290,071 in Duhok as of Nov 2024).
- Dust storms from desertification and vegetation loss.

Impacts:

- Severe air pollution exceeding WHO standards.
- Rising respiratory illnesses (asthma, bronchitis, etc.).
- Disruption to transport, agriculture, and public health systems.

3. Deforestation, Ecosystem Loss, and Desertification

Causes:

- Tree cutting for fuel, urban expansion, and tourism.
- Overgrazing, overhunting, and unsustainable land use.
- Forest fires, especially in Duhok during the tourism seasons.
- Climate-driven stress on ecosystems.

Impacts:

- Shrinking forests and biodiversity loss.
- Decline in flora and fauna; ecosystem imbalance.
- Worsening desertification and dust storms.

4. Urban Expansion and Demographic Pressure

- Internal displacement and migration to urban centers (especially Duhok).
- Horizontal expansion is damaging forests and farmlands.
- Increased demand for water, energy, and land resources.

5. Agriculture and Livelihood Impacts

- Decline in crop yields and food production due to water stress and heat.
- Farmland loss to urban expansion and soil degradation.
- Rural unemployment and displacement are driving urban migration.

6. Legacy of Conflict and Governance Gaps

- Ecosystem damage from war, chemical weapons, and sanctions.
- Unplanned reconstruction without environmental assessment.
- Weak enforcement of environmental laws and low investment in green infrastructure.
- Lack of climate adaptation/mitigation strategies and public awareness.

7. Climate Change: A Cross-Cutting Crisis

Kurdistan is particularly vulnerable due to rising temperatures (exceeding 50°C), declining rainfall, and extreme weather. These trends affect water availability, agricultural productivity, public health, and biodiversity. Climate change is magnifying existing environmental challenges, while political and economic instability hinders effective responses.

Environmental Recommendations

- Improve transboundary water negotiation and resource management.
- Invest in reforestation, modern irrigation, and pollution control.
- Strengthen environmental laws, planning, and climate adaptation.
- Raise public awareness and promote sustainable lifestyles.
- Expand regional and international cooperation for environmental sustainability.

5. Conclusion and Recommendations:

5.1 Conclusion:

Climate change poses a growing threat to the environmental, agricultural, and water systems of the Kurdistan Region, with Duhok Governorate facing a distinct set of challenges tied to rising temperatures, irregular rainfall, groundwater depletion, and ecosystem degradation. This booklet has provided a comprehensive analysis of the region's climatic trends, sector-specific impacts, institutional perspectives, and potential adaptation pathways.

The findings highlight the urgent need for integrated, multi-sectoral solutions to build resilience at both the institutional and community levels. Duhok's adaptive capacity, while relatively stronger compared to other governorates, requires continuous investment in sustainable practices, cross-sector coordination, and innovative approaches—particularly in agriculture, water resource management, and forest protection.

Efforts by the Kurdistan Regional Government, supported by partners such as the Lutheran World Federation (LWF), demonstrate the importance of participatory planning, local expertise, and climate-informed governance in shaping regional responses. The adoption of community-based and ecosystem-based adaptation strategies, improved data systems, and climate-smart technologies will be essential for protecting livelihoods and preserving environmental stability.

This booklet aims not only to serve as a reference but also as a call to action—for policymakers, practitioners, civil society, and the youth of Kurdistan—to actively engage in shaping a more resilient, sustainable future for the region.

5.2 Recommendations

To confront the escalating impacts of climate change in Duhok Governorate—particularly water scarcity, agricultural stress, ecosystem degradation, and institutional limitations—this section outlines strategic,

multi-sectoral recommendations. These are intended to guide coordinated adaptation, build climate resilience, and support sustainable development across the region. The recommendations are:

A. Addressing Water Scarcity and Drought

- Rehabilitate and expand surface water infrastructure such as reservoirs, small dams, and storage basins to improve water capture and reduce reliance on deep wells.
- Introduce and scale up water metering systems and volumetric tariffs to incentivize conservation, especially in urban and peri-urban areas.
- Enhance the efficiency of irrigation through modern techniques like drip and sprinkler systems, particularly in drought-prone areas.
- Implement integrated groundwater management, including real-time extraction monitoring, metering of private wells, and artificial recharge practices.
- Reuse treated municipal wastewater for agricultural and landscaping purposes to reduce pressure on potable water sources.
- Develop early warning systems for droughts and floods to enhance preparedness and response capabilities.

B. Strengthening Agricultural Resilience

- Promote climate-smart agriculture, including crop diversification, agroforestry, and soil and water conservation techniques.
- Distribute drought-resistant crop varieties and facilitate access to weather-based advisories and seasonal forecasting services.
- Support farmers through extension services, training on adaptive practices, and access to improved seeds, inputs, and irrigation technologies.
- Establish emergency support mechanisms—such as contingency funding and reserve stocks—to buffer against climate-induced crop losses.
- Encourage the use of digital tools for monitoring pests, crop health, and irrigation scheduling to optimize farm-level decision-making.

C. Enhancing Ecosystem and Forest Protection

- Launch large-scale afforestation and reforestation programs with native, drought-tolerant species in degraded and fire-prone areas.
- Establish and maintain protected areas and wildlife corridors to support biodiversity and regulate ecosystem services.
- Enforce regulations against illegal logging and overgrazing while promoting community-based forest stewardship models.
- Encourage alternative energy use (e.g., solar cooking, biogas) to reduce dependence on wood fuel and minimize forest degradation.
- Integrate nature-based solutions such as reforestation for slope stabilization and flood mitigation.

D. Improving Water Quality and Sanitation

- Strengthen water quality monitoring systems for surface and groundwater, with public access to pollution data.
- Upgrade and expand wastewater treatment facilities to address contamination from floods, industrial discharge, and agricultural runoff.
- Promote community awareness on water hygiene, pollution prevention, and responsible water use, especially in vulnerable and underserved areas.
- Equip strategic water infrastructure with sediment control systems to prevent damage during flood seasons.

E. Promoting Institutional Coordination and Climate Governance

- Establish a climate adaptation coordination platform at the governorate level to align policies, monitor progress, and ensure cross-sector collaboration.
- Integrate climate resilience indicators into regional development plans, budgeting frameworks, and public investment projects.
- Designate climate focal points within key sectors to oversee climate-sensitive planning and implementation.
- Mobilize international climate finance through partnerships with bilateral, multilateral, and civil society actors.
- Increase participation of youth, women, and marginalized communities in climate planning, decision-making, and green job creation.

F. Climate Data, Knowledge, and Public Awareness

- Develop a centralized climate information system that integrates meteorological, hydrological, and agricultural data to inform decision-making.
- Strengthen the technical capacity of local staff through regular training on climate risk assessment, planning tools, and sector-specific adaptation strategies.
- Launch province-wide public awareness campaigns on climate change impacts, sustainable resource use, and ecosystem protection.
- Promote environmental education in schools and universities, focusing on youth leadership in climate action and innovation.

G. Climate Finance and Investment Mobilization

- Develop a governorate-level climate financing strategy that identifies priority sectors, funding gaps, and potential international and domestic sources of finance.
- Strengthen institutional capacity to prepare bankable climate adaptation and mitigation proposals targeting sources such as the Green Climate Fund (GCF), Adaptation Fund, and bilateral donors.
- Facilitate public-private partnerships (PPPs) to co-invest in renewable energy, climate-resilient infrastructure, smart agriculture, and sustainable water management.
- Introduce incentives for climate-aligned investments, including tax benefits or streamlined permitting for businesses that adopt green technologies or water-saving systems.
- Encourage financial institutions to develop green credit lines and microfinance products for farmers, SMEs, and cooperatives engaged in sustainable practices.
- Ensure that climate finance programs are inclusive and gender-responsive, with targeted access for youth, women, and vulnerable rural populations.
- Improve transparency and accountability in climate finance allocation through robust monitoring and reporting systems, linked to measurable resilience outcomes.

6. References:

ACT Alliance & LWF. (2021). *Climate Justice Guidelines.*

Adaptation Fund. (2022). *Country project summaries on local adaptation strategies.*

Copenhagen Accord. (2009). *UNFCCC Climate Finance Commitments.*

Eklund, L., et al. (2017). "Climate-induced forest degradation." *Global Environmental Change.*

EPA – United States Environmental Protection Agency. (2023). *Ground-level ozone data.*

FAO – Food and Agriculture Organization. (2020–2023). *Climate-smart agriculture, forest degradation, and water reports.*

Green Climate Fund (GCF). (n.d.). *Financing mechanisms for adaptation and mitigation.*

Habeeb, A., & Mustafa, M. (2024). *AI-based vegetation monitoring in semi-arid zones.*

IPCC – Intergovernmental Panel on Climate Change. (2018, 2019, 2021, 2022). *Fifth and Sixth Assessment Reports (AR5 & AR6); Special Reports on Climate Change and Food Security.*

KRG General Directorate of Meteorology and Seismology. (2009–2023). *Temperature, rainfall, and drought records.*

Kurdistan Regional Government – Local Climate Change Adaptation Plan. (2024). *Sectoral strategies and planning guidelines.*

LWF – Lutheran World Federation. (2021–2024). *Iraq Strategy 2025–2031; Climate-WASH and Livelihoods Program Documents.*

Mzuri, A., et al. (2021). *Vegetation cover change and climate vulnerability in Duhok. IJRES.*

NASA – National Aeronautics and Space Administration. (2022–2023). *Ozone layer tracking, Earth climate data.*

NASA Ozone Watch. (2023). *Real-time monitoring portal.*

Nature. (2022). *Greenland Ice Sheet Melting – Scientific Communication.*

UNDP – United Nations Development Programme. (2021–2023). *Kurdistan Region Climate Data Collaboration.*

UNEP – United Nations Environment Programme. (2021–2023). *Ozone depletion and climate adaptation resources.*

UNICEF & WHO. (2022). *Joint Monitoring Programme (JMP) Reports on WASH Access.*

WMO – World Meteorological Organization. (2021, 2022). *Global temperature, drought, and atmospheric monitoring data.*

World Bank. (2022). *Iraq Climate and Development Report.*