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UNIVERSITY

20 Years

100  
THE 100TH ANNIVERSARY OF THE REPUBLIC OF TURKEY

CALL FOR PAPERS

1st International Hybrid Conference

# ROLE OF CLIMATE CHANGE ON WATER RESOURCES MANAGEMENT FOR A SUSTAINABLE FUTURE (ICCW2024)

February 29 - March 1, 2024

e-mail: [iccw2024@aydin.edu.tr](mailto:iccw2024@aydin.edu.tr)  
<https://www.iccw2024.aydin.edu.tr>

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**1st International Hybrid Conference**  
**ROLE OF CLIMATE CHANGE ON WATER RESOURCES**  
**MANAGEMENT FOR A SUSTAINABLE FUTURE**  
**(ICCW2024)**

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## **PREFACE**

Water scarcity has incrementally exacerbated in many parts of the world due to climate changes compounded by population growth, overexploitation of freshwater resources, and a lack of proper management. This upsurge has sparked worldwide interest in understanding the potential impacts of climate change on water resources. Climate change is often entwined with alterations in both water quantity and quality, aggravating the fast-growing water crisis. In envisioning a sustainable future, the capability of adapting to climate change and ensuring the sustainable management of water resources and urban planning, reflecting the urgent need for resilience and responsible stewardship in a world where water scarcity and unpredictability are increasingly prevalent are among the important aspects to consider. Investments in resilient infrastructure, such as flood defenses and improved irrigation systems, are essential to cope with changing climate conditions.

Utilizing advanced technology for data collection, analysis, and modeling can help anticipate and respond to challenges related to water resources. Governments and regulatory bodies need to develop and enforce policies that ensure equitable access to water resources and sustainable management practices. Collaborative approaches to water management, including the sharing of water resources across regions and countries, can enhance resilience in the face of changing climate patterns. Furthermore, precise definitions of regional and global action plans for climate change need to be considered.

The conference was opened by Prof. Dr. Ali SINAĞ, Vice Rector, Istanbul Aydın University. The present conference aims to be a step towards bringing together scientists, planners, practitioners, and researchers to discuss recent issues and those expected to emerge in the future before the problems become too perplexing to solve for a sustainable future on this globe.

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Anthony R. Lupo  
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Atmospheric  
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Paris, France



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Mediterranean  
Universities Union,  
Rome, Italy



Naseer GİLLANİ  
Engr.

Developent  
Finance and  
Inclusion, Pakistan

## CONFERENCE TOPICS

- Integrated Climate Change Approach
- Interactions between Irrigated Agriculture and Climate Change
- Deep Learning Methods in Water Resources Management
- Impact of Drought on Water Resources and Mitigation Action Plans for Scarcity
- Resilience and Equity for Climate Change Adaptation
- Navigating the Waters of a Changing Climate
- Renewable Energy Applications in Rural Water Distribution
- Adaptation and Mitigation Action Plans for Water Scarcity
- Water Harvesting, Soil Degradation and Securing Land related to Climate Change
- Tools and Computational Methods in Data Science for Climate, Water, and Health
- Smart Irrigation Systems in Agriculture for Sustainability
- Proposals for Policy Making to Address Issues arising from Climate Change
- Education for Awareness on Climate Change and Water Resources Management
- European Green Deal and Implementations
- Artificial Intelligence (AI) Applications in Regional Climatologic Issues
- Wastewater Uses and Management Technologies in Agriculture
- Any other topic related to the theme of the conference are welcome

## ICCW2024 - CONFERENCE PROGRAMME



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CALL FOR PAPERS

1st International Hybrid Conference

# ROLE OF CLIMATE CHANGE ON WATER RESOURCES MANAGEMENT FOR A SUSTAINABLE FUTURE (ICCW2024)

February 29 - March 1, 2024

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<https://www.iccw2024.aydin.edu.tr>

**February 29, 2024** | Meeting ID: **84536667127**  
Passcode: **4441428**

**March 1, 2024** | Meeting ID: **89497701988**  
Passcode: **4441428**



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**DAY-1: February 29, 2024**

**9.15-13.00 local / 6.15-10.00GMT**

<b>ONLINE LINK</b>		<b>FEBRUARY 29, 2024</b>
Zoom	1st International Hybrid Conference <b>ROLE OF CLIMATE CHANGE ON WATER RESOURCES MANAGEMENT FOR A SUSTAINABLE FUTURE</b>	
Zoom Type	Zoom Webinar	
Zoom ID	84536667127	
Password	4441428	
Zoom Link	<a href="https://us06web.zoom.us/j/84536667127?pwd=Hz8uaKLcaApDLd4vKcar4FpkaihU7D.1">https://us06web.zoom.us/j/84536667127?pwd=Hz8uaKLcaApDLd4vKcar4FpkaihU7D.1</a>	
Reservation	29.02.2024 09:00   29.02.2024 18:00	

**7.00-11.00 GMT /09.00-13.00 local: REGISTRATION, ICEC-SAPHIRE HALL**

<b>6.15 –6.30 GMT</b>		<b>29 February 2024</b>
<b>9.15- 9.30 Local</b>		<b>WELCOME REMARKS</b>
Conference Chair, General Director TSM, IAU Acting Rector, IAU President		
<b>Session 1: Climate Change Strategies and Policies</b>		
Chair(s): Ali SINAÇ, Rashmi BHARDWAJ		
<b>6.30 -7.30 GMT</b> <b>9.30-10.30 Local</b>	Invited Speaker: <b>Water, Water Everywhere! A Systemic Approach to Sustainability Knowledge &amp; Assessment.</b> Scott G. BLAIR, Aurélien DECAMPS, <i>Sulitest Impact, France</i>	
	Water Management in Punjab, Pakistan with community participation: A step towards sustainable water use. <b>Saira AKHTAR, Sobia MAQSOOD, E. ASHRAF, UAF, Pakistan.</b>	
	Rainwater Management Policies in İstanbul: A Comparable Analysis. <b>Zelha ALTINKAYA, Yalova University, Türkiye</b>	
<b>7:30 - 8.00 GMT</b> <b>10.30 -11.00 Local</b>		<b>BREAK / GROUP PHOTO</b>
<b>Session 2: Water Resources Analysis Tools and Techniques</b>		
Chair(s): Sajid MAHMOOD, Eman EL-SARAAG		
<b>8:00-9:30 GMT</b> <b>11:00-12:30 Local</b>	Invited Speaker: <b>A Sustainable Water and Mineral Recovery Technology: Eutectic Freeze Crystallization,</b> <i>Elif GENÇELİ GÜNER, İTÜ, Türkiye</i>	
	Assessing River Flow Patterns in the Context of Climate Change: A Machine Learning Framework <b>Vinita Sangwan, Rashmi BHARDWAJ GGSIPU, India</b>	
	Application of EM with Machine learning approach for the estimation of water quality parameters. <b>S. Garg, R. BHARDWAJ, GGSIPU, Delhi, India</b>	
	Investigation of Extreme Weather Events: Istanbul International Airports Example. <b>R. Yimit, E.Tuncay ÖZDEMİR, İTÜ, İstanbul, Türkiye</b>	
	<b>Possible Changes in Evapotranspiration Under the Influence of Climate Change in Selected Provinces of Türkiye.</b> <b>M. AZLAK, Levent ŞAYLAN, İTÜ, İstanbul, Türkiye</b>	
	Contribution by Students Club: ITU Club – METAR, Yaren KÖSE, İAÜ Club.	
<b>General Evaluation</b>		
Chair(s): Chair(s): Levent SAYLAN		
<b>9:30-10:00 GMT</b> <b>12:30-13:00 Local</b>	Discussion on joint research programs, applications and publication / a network like UNIMED, to briefly mention what UNIMED is doing in this perspective and to encourage a stronger partnership among research and education actors in the MED Region, <b>Marcello SCALISI, Director UNIMED, Rome, Italy</b>	

**DAY-2: March 01, 2024, 9.00-18.15 local / 6.00-11.00 GMT**  
**IAU T BLOCK-1, PURPLE HALL**

ONLINE LINK		MARCH 01, 2024
Zoom	1st International Hybrid Conference <b>ROLE OF CLIMATE CHANGE ON WATER RESOURCES MANAGEMENT FOR A SUSTAINABLE FUTURE</b>	
Zoom Type	Zoom Webinar	
Zoom ID	89497701988	
Password	4441428	
Zoom Link	<a href="https://us06web.zoom.us/j/89497701988?pwd=wXxeCvySg2yIAoErOAJcAB4nc8ETxh.1">https://us06web.zoom.us/j/89497701988?pwd=wXxeCvySg2yIAoErOAJcAB4nc8ETxh.1</a>	
Reservation	01.03.2024 09:00   01.03.2024 18:00	
<b>6.15 –6.30 GMT</b> <b>01 March 2024</b> <b>9.15- 9.30 Local</b> <b>WELCOME TO THE PARTICIPANT</b> <b>President, IAU; Rector IAU, ITU, Adıyaman Univ., Gn. Director TMS, Ankara</b>		
<b>Session 3: Technological Solutions for Agriculture and Water Use</b> <b>Chair(s): Metin GER, Scott G. BLAIR</b>		
<b>6.15 – 8.00 GMT</b> <b>9.15-11.00 Local</b>	Invited Speaker: <b>The atmospheric dynamics contributing to the occurrence of drought over North America and Eastern Europe, Anthony R. LUPO</b> , University of Missouri, USA	
	Invited Speaker: <b>Artificial Intelligence Wavelet Conjunction Fractal Analysis of Water Quality Bhardwaj, RASHMI, GGSIPU, Delhi, India</b>	
	Invited Speaker: <b>Environmental threats to water-world and their control strategies, Jehangir K. SIAL, FAE&amp;T, UAF, Pakistan</b>	
	Invited Speaker: <b>Scenarios of future changes in water stress under the influence of climate changes and increasing demands, Rovshen ABBASOV, Khazar University, Baku, Azerbaijan</b>	
	Sensitivity Analysis of Physical Process and Simulation in WRF-ARW Model for Medicanne in West of Türkiye. <b>S. A. SIRDAS and Muhammet Mert ÇIRAK , İTÜ; Türkiye.</b>	
	Global ramifications of inadequate solid waste management and its influence on climate change, <b>Jasir Mushtaq &amp; Zeyneb KILIC, Adıyaman University, Türkiye</b>	
	Sustainable Water Management: Rainwater Harvesting, <b>Vildan BAYRAM, İstanbul Aydın University, ABMYO, İstanbul, Türkiye</b>	
	The Effect of Climate Change on Flood Water Levels, <b>Burhan YILDIZ, Onur ATALIK, Aytun EKEROĞLU, Beyza Nur YUVALLI, Muğla Sıtkı Koçman University, Türkiye</b>	
<b>8:00 - 8.30 GMT</b> <b>BREAK</b> <b>11.00 -11.30 Local</b>		
<b>Session 1.2 (Cont.): Climate Change Strategies and Policies</b> <b>Chair(s): Eşref ADALI, Rovshen ABBASOV</b>		
<b>8.30 – 9.30 GMT</b> <b>11.30-12.30 Local</b>	Invited Speaker: <b>High-resolution future SSP 8.5 scenario results over Türkiye: The impact of climate change on water budgets of snow-dominated basins, İsmail YÜCEL, METU, Ankara, Türkiye</b>	
	The Potential of Olive Production in The Keçiözümlü District. <b>A. TOKGÖZLÜ, T. A. TIK, SDÜ, Isparta, Türkiye</b>	
	Safran, the golden plant grewed in the dry season, <b>A. TOKGÖZLÜ and K. TEMURÇİN, SDÜ, Isparta, Türkiye</b>	
	Impact of Varying Climatic Conditions on Irrigation Water Demand and Food Availability <b>Kajal Chaudhary, Rashmi BHARDWAJ, USBAS, GGSIPU, Delhi, India</b>	
	Assessment of Drought Risk and Adaptation Strategies to Climate Change in Tunceli: SPI and RDI Analysis, <b>Meral KORKMAZ,<sup>1</sup> Munzur University, Tunceli, Türkiye.</b>	
	Investigation of the climate change and meteorological drought in coastline of Eastern Black Sea Region, <b>Barış AYDIN, Osman ÜÇÜNCÜ, TSM, Trabzon, Turkey.</b>	

9:30- 10.30 GMT		LUNCH/ GROUP PHOTO	
12.30-13.30 Local			
Session 3.2 (cont.): Technological Solutions for Agriculture and Water Use			
Chair(s): Kasım KOÇAK, , Sevinç A. SİRDAŞ			
10.30-12.00 GMT 13.30-15.00 Local	Invited Speaker: Climate change predictions over Türkiye and effects on water resources: Example of Euphrates Tigris river basin, E. SALKIM, Yurdanur S. ÜNAL, İTÜ, İstanbul, T		
	Invited Speaker: Climate Change and Winter Drought, Naseer GILANI, DFI Pakistan		
	Purification of Industrial Water By Plants For Irrigation Purposes, Abida KAUSAR and Ayesha ATHER, Government College Women University Faisalabad, PAKISTAN		
	Use of Straw Water Holder in Agriculture, Funda DÖKMEN, Kocaeli University, TÜRKİYE.		
	Influence of climate change conditions on phytomass production of perennial grass in and ecosystems of Tunisia, Lobna Mnif FAKHFAKH and Mohamed CHAIEB, Tunisia		
	Monitoring and Management of Groundwater in Pakistan for Sustainability of Agriculture and Rural Livelihood, Saira AKHTAR, Ghulam Zakir Hassan SIAL, IRI, Pakistan		
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# Water, Water Everywhere!

## A Systemic Approach to Sustainability Knowledge & Assessment

### *A Systemic Approach to Assessing Student Sustainability Knowledge of Water*

*Vis-à-vis the Role of Climate Change on Water Resource Management*

Scott G. Blair, PhD, Content Development Editor, Sulitest Impact, [scott@sulitest.org](mailto:scott@sulitest.org)

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## Introduction

This study provides provisional insights into the many principles, properties, and roles of water as they locate within the cognitive landscape of sustainability knowledge as defined and structured by Sulitest TASK™—*The Assessment of Sustainability Knowledge*. Designed by Sulitest in 2023 as an external assessment instrument for higher education institutions (HEI) committed to addressing the [2030 Agenda for Sustainable Development](#) through both transformative curricular change (Mezirow, 1997; Moore, 2005) and pedagogical innovation (Blair, 2024), TASK™ is an online, standardized, certificate-bearing, 112-multiple-choice psychometric test of sustainability knowledge providing reliable and comparable data across 28 subject areas and within 4 types of knowledge.

The knowledge assessed by TASK™ is structured by the *Sulitest Knowledge Matrix* which is based primarily upon the 17 Sustainable Development Goals (SDGs), the research by [The Stockholm Resilience Centre](#) on the nine planetary boundaries ([Steffen, W. et al, 2015](#)), the research agenda on *Doughnut Economics* ([Raworth, 2017](#)), and the UN analysis of the *Science for Achieving Sustainable Development* ([Messerli et al., 2019 United Nations](#).) TASK™ explores the multiple interactions between the domains of Earth science, the SDGs, and the levers of action and opportunity available to humans that make sustainability possible.

As such, the model of sustainability knowledge is operationalized via a foundational matrix organized into three frameworks:

1. **Earth Systems** — This framework includes two domains: core planetary boundaries and regulating planetary boundaries, both of which indicate the safe operating space for humanity. Together, these domains constitute the “environmental ceiling” of the Earth Systems framework.
2. **Human Welfare** — This framework includes three domains: safety and basic needs for all, social welfare for people, and elements that contribute to human flourishing. Together, these domains constitute the “social foundation” of the Human Welfare framework.
3. **Levers of Opportunity** — This framework includes four domains: governance, economy and finance, science and technology, and individual and collective action. Together, these domains indicate the “levers of opportunity” or action that make sustainability possible.

A more granular view of the content of the 28 subjects included in the three frameworks is provided in a bank of 28 *Navigational Charts* designed by the Sulitest research and content staff. The content of each TASK™ NavChart includes: a grounded definition of the sustainability subject at hand, a list of 10-12 key ideas that relate to the subject, and bullet-point examples and descriptions that detail the

content of each key idea. As an example, the NavCharts for matrix subject 1.2.1 on *Freshwater Use*, and 2.1.3 on *Access to Water and Sanitation*, are provided below in Annex 1.

Within this context, the purpose of this study is thus two-fold. First, to identify where the concept of water in its many manifestations “scatters” across the landscape of sustainability knowledge. Second, to quantify the level of knowledge about water held by students in higher education today. The data for the second part of this research is based upon a sample of 11,500 students attending over 50 HEI who took part in a TASK™ assessment in the one-year period between March 1, 2023, and February 29, 2024. One year later in February 2025, the data set stands at approximately 37,000.

## **Part 1. The Place of Water Within Sustainability Knowledge**

While the primary purpose of the NavCharts is to inform a process of reviewing and revising course learning objectives and corresponding curricular content in line with the construct of sustainability knowledge, for the purpose of this study, we use the bank of 28 NavCharts to identify the place of water within the cognitive landscape of sustainability knowledge. To achieve this, we subject the NavCharts to a word search for the following terms: *water, hydro, flood, wetland, rain, sanitation*. Across the three frameworks, this word search found 228 uses of these terms—113 in Earth Systems, 102 in Human Welfare, and 13 for Levers of Opportunity. It is without surprise that most terms congregate around only two subjects: *Freshwater Use* and *Access to Water and Sanitation*, with 75 and 81 appearances respectively. The only other subjects that reveal a relative concentration of such terms are *Biogeochemical Flows*. (15) and *Infrastructure, Planning, and Natural Resource Management* (9). All other subjects tallied 5 or fewer terms. Seven subjects tallied only 1 and four subjects tallied 0 terms. See Figure 1 below.

## Water within the Sulitest TASK™ Matrix of Sustainability Knowledge

Word search in TASK™ Navigational Charts: *water, hydro, wetland, flood, rain, sanitation*

Framework	Domain	Subject	Frequency
1. Earth Systems The Environmental Ceiling	1.1 Core Planetary Boundaries	1.1.1 Climate Change	5
		1.1.2 Biosphere Integrity	5
	1.2 Regulating Planetary Boundaries	1.2.1 Freshwater Use	75
		1.2.2 Land-System Change	3
		1.2.3 Ocean Acidification	3
		1.2.4 Novel Entities	4
		1.2.5 Biogeochemical Flows	15
		1.2.6 Atmospheric Aerosols Loading	2
		1.2.7 Stratospheric Ozone Depletion	1
		Subtotal	113
2. Human Welfare The Social Foundation	2.1 Safety and Basic Needs	2.1.1 Nutrition	2
		2.1.2 Health	2
		2.1.3 Access to Water and Sanitation	81
		2.1.4 Housing and Human Settlements	4
		2.1.5 Access to Energy	4
	2.2 Social Welfare	2.2.1 Basic Income	1
		2.2.2 Social Equity	3
		2.2.3 Gender Equality	1
	2.3 Human Flourishing	2.3.1 Education and Culture	1
		2.3.2 Peace, Justice, and Political Voice	2
2.3.3 Access to Networks and Social Interaction		1	
		Subtotal	102
3. Levers of Opportunity That Make Sustainability Possible	3.1 Governance	3.1.1 Laws, Policies, and Institutions	0
		3.1.2 Infrastructure, Planning, and Natural Resource Management	9
	3.2 Economy and Finance	3.2.1 Macroeconomic Considerations and Finance	1
		3.2.2 Microeconomic Considerations, Business, and Industry	0
	3.3 Science and Technology	3.3.1 Sustainability Science	0
		3.3.2 Technology and Innovation	2
	3.4 Individual and Collective Action	3.4.1 Transformative Change	1
		3.4.2 Cognitive Capacity for Sustainability	0
		Subtotal	13
		Total	228

Figure 1. Water-related Topics in TASK Matrix

For the sake of simplicity in this article, when identifying the many key ideas to which the six water-related terms most frequently relate within sustainability knowledge, we use the word “water” to represent them all. Similarly in such a short article, we can only present but a selected sample of representative examples, as indicated below.

### Knowledge of Water within the Planetary Boundaries of Earth Systems

Considering the nine subjects of the Earth Systems framework, and for the subject of **Climate Change**, *water* relates to the greenhouse effect, climate change impacts, and climate change mitigation: (e.g., water vapor, scarcity, flooding, wetland restoration, etc.). For **Biosphere Integrity**, *water* relates to ecosystems, direct drivers of biodiversity decline, ecosystem services, and sustainable marine and coastal governance: (e.g., freshwater ecosystems, water-borne pollution, freshwater quality and quantity, international and coastal waters, etc.). For **Land-System Change**, *water* relates to land uses and land ecosystems, ecosystem services, and agricultural expansion and intensification: (e.g., wetlands, water provision, water pollution, etc.). For **Ocean Acidification**, *water* relates to principles of ocean acidification, anthropogenic causes, and water ecosystem and acidification beyond the oceans: seawater composition, rainfall/runoffs, brackish water etc.). For **Novel Entities**, *water* relates to household and commercial chemicals (PFAS), release of NEs into the environment, and use and impact in farming and agriculture: water-resistant fabric, acid rain, hydrological contamination, etc.). For **Biogeochemical Flows**, *water* relates to the water cycle, nitrogen cycle, phosphorus cycle, eutrophication, impacts of biogeochemical disruption, water restoration and management strategies: (e.g., acid rain wastewater discharge, contamination, drinking water, water quality, water treatment, wetlands, etc.). For **Atmospheric Aerosols Loading**, *water* relates to impacts on ecosystem, and

climate and weather effects: (water acidification, acid rain, etc.). For **Stratospheric Ozone Depletion**, *water* relates to ozone-depleting substances (e.g., wastewater). For **Freshwater Use**, *water* relates to key ideas almost too numerous to list: natural water cycles, types of blue water, green water, misuse of freshwater, water pollution, threats to water resources, freshwater ecosystems, water scarcity and overabundance, water governance and policy, and sustainable freshwater use and management: (e.g., groundwater, water rights, access to water, saltwater intrusion, waterborne disease, water wars, virtual water, etc.).

When searching for *water* within the planetary boundaries' framework as structured in the TASK™ Earth Systems matrix—as we have just done—a few recurrent themes emerge. These include the importance of water to life and food chains, the consequences of both water scarcity and water abundance, the role of water in weather patterns, the importance of water to the health of multiple and discrete ecosystems, the challenge of minimizing and managing wastewater and water pollution, the critical role water plays in regulating planetary boundaries, and the important but relatively little-known role of water within Earth's biogeochemical flows.

#### Knowledge of Water within the Social Foundations of Human Welfare

Considering the eleven subjects of the Human Welfare framework articulated by the TASK™ matrix, and for the subject of **Nutrition**, *water* relates to the environmental impact of food production, and food loss and waste: (e.g., water pollution, water waste, etc.). For **Health** *water* relates to health determinants: (access to clean water and sanitation). For **Housing and Human Settlements** *water* relates to waste generation and management: (sanitation, hygiene, etc.). For **Access to Energy**, *water* relates to renewable energy, fossil fuel impacts, and energy transition: (e.g., hydropower acid rain, hydroelectricity, etc.). For **Basin Income and Decent Work**, *water* relates to the structure of poverty: (e.g., access to water). For **Social Equity**, *water* relates to definitions of inequality, and rights to land, property and natural resources: (e.g., access to water and sanitation water privatization, water mining, etc.) For **Gender Equality**, *water* relates to leveraging women in the community: (e.g., privatization of water, water provisioning, etc.) For **Education and Culture**, *water* relates to education for sustainable development: (e.g., systems-thinking vis-à-vis water cycles, etc.) For **Peace, Justice, and Political Voice**, *water* relates to economic, social and cultural rights, and the impact of corruption on such rights: (e.g., access to water, water and waste management, etc.). For **Access to Networks and Human Interaction**, *water* relates to sustainable communities: (e.g., access to recreational water facilities). For **Access to Water and sanitation**, *water* relates to key ideas almost too numerous to list: global freshwater cycles, access to water, drinking water, sanitation and hygiene, water use efficiency, freshwater use and misuse, water recycling, wastewater management, water resources management, and water and sustainable development: (e.g., water stress, transboundary water, water exports, water quality, water harvesting, water leakage, water rights, water desalination, water farming, wastewater treatment, water and gender, etc.)

When searching for *water* within the social foundation framework of the UN Sustainable Development Goals as structured in the TASK™ Human Welfare matrix—as we have just done—another set of recurrent themes emerges. These include the importance of water to human life, health, basic hygiene, and human dignity. Social justice themes include equitable access, access to water at the nexus of social justice, and the dangers that water scarcity portend vis-à-vis social violence and international conflict.

#### Knowledge of Water within Levers of Action and Opportunity

Considering the eight subjects of the Levers of Opportunity framework, and for the subject of **Infrastructure, Planning, and Natural Resource Management**, *water* relates to infrastructure management, “green” transition planning and management, critical raw materials extraction, and water resource management: (e.g., water distribution systems, wetlands management, water pollution, water use in mining, groundwater contamination, water footprints, etc.) For **Microeconomic Considerations, Business, and Industry**, *water* relates to sustainable supply chain management: (e.g., water footprints). For **Technology and Innovation**, *water* relates to renewable energy, and emerging environmental technologies: (e.g., hydropower, water technology, etc.). For **Transformative Change**, *water* relates to climate activism: (e.g., acid rain, ecosystem protection, etc.)

When searching for *water* within the framework of the *Global Sustainable Development Report 2019: The Future is Now – Science for Achieving Sustainable Development* as structured in the TASK™ Levers of Opportunity matrix—as we have just done—a final set of recurrent themes emerges. These include the challenge of managing water resources equitably and sustainably in the context of increasing demand by industry, agriculture, and human demography, as well as the dangers of water scarcity to both domestic, cross-boundary, and international peace.

#### Part 1 Initial Findings: Water Within the Construct of Sustainability Knowledge

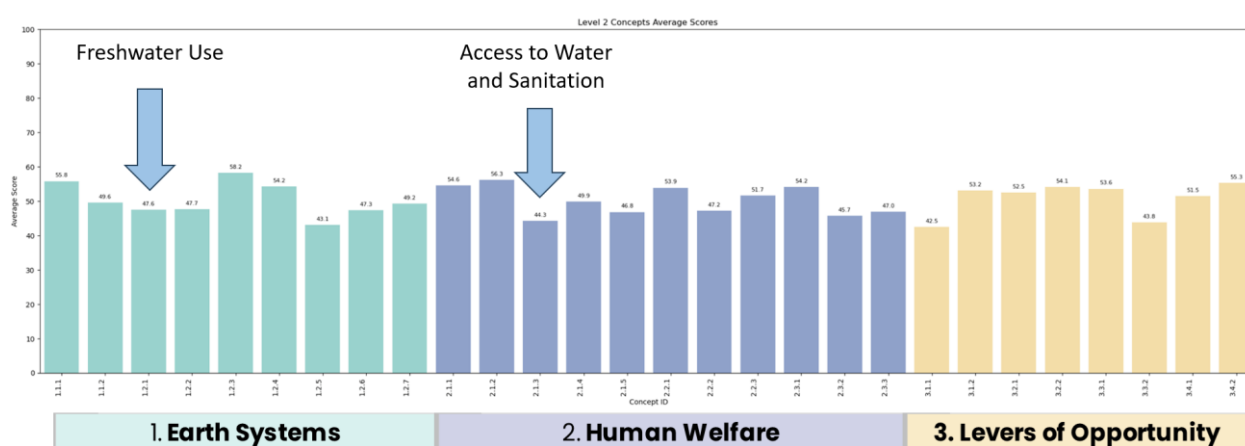
1. Water is an integrated, organic, and systemic component of sustainability, and thus of sustainability knowledge.
2. Water and its many related dynamics and influences are heavily concentrated in the planetary boundary of *Freshwater Use* within Earth systems.
3. Water and its many related dynamics and influences are also heavily concentrated in *Access to Water and Sanitation* within Human Welfare (See SDG-6 on Clean Water & Sanitation).
4. Water is substantially present in the less well-known planetary boundary of *Biogeochemical Flows*.
5. Water management is critical to tomorrow’s challenges and solutions concerning *Infrastructure, Planning, & Natural Resource Management*.
6. Water (and particularly the lack of water) constitutes a significant risk of becoming a source of tension and potential conflict at multiple levels of analysis: individual, local, regional, national, and international.

While water has traditionally been conceived as a specialized domain of knowledge within the environmental, physical, and meteorological sciences, the TASK™ matrix and corresponding TASK™ Navigational Charts defining the content and boundaries of sustainability knowledge reveal water to be an essential and substantive part of knowledge that cuts across the physical, social, human, and cultural sciences. As such, knowledge of the systemic and integrated role water plays in Earth systems, in the social foundations of human welfare, and in action-based solutions to the Earth crisis—is an essential part of sustainability knowledge. In short, there is no pathway to a sustainable future if humans lack systemic, integrated, and transdisciplinary knowledge of water and the role it plays, primarily in supporting life, but also in sustaining organized, advanced societies.

## Part II. Assessing & Evaluating Knowledge of Water Among Students in Higher Ed

For each knowledge subject, individual TASK™ scores are calculated according to three distinct criteria: the number of questions answered, the number of questions answered correctly, and the parameters associated with each question (i.e., its difficulty level, its ability to discriminate, and its place within the TASK™ matrix). The third criterion means that correct answers to questions with a greater degree of difficulty result in additional points for that question. As such, the final aggregate score reflects more than just the number of correctly answered questions out of 96—the model geometrically transforms these variable into a score between 0 and 100. As mentioned above, the data for the second part of this research is based upon a sample of 11,500 students attending over 50 HEIs who took part in a TASK™ assessment in the one-year period between March 1, 2023, and February 29, 2024. It is these scores that serve as a proxy for evaluating student levels of sustainability knowledge within the 28 TASK™ subjects.

### Average Score per Subject



Based on current sample of 11500+ TASK takers in about 50 universities

Figure 2. Average Score Per Subject

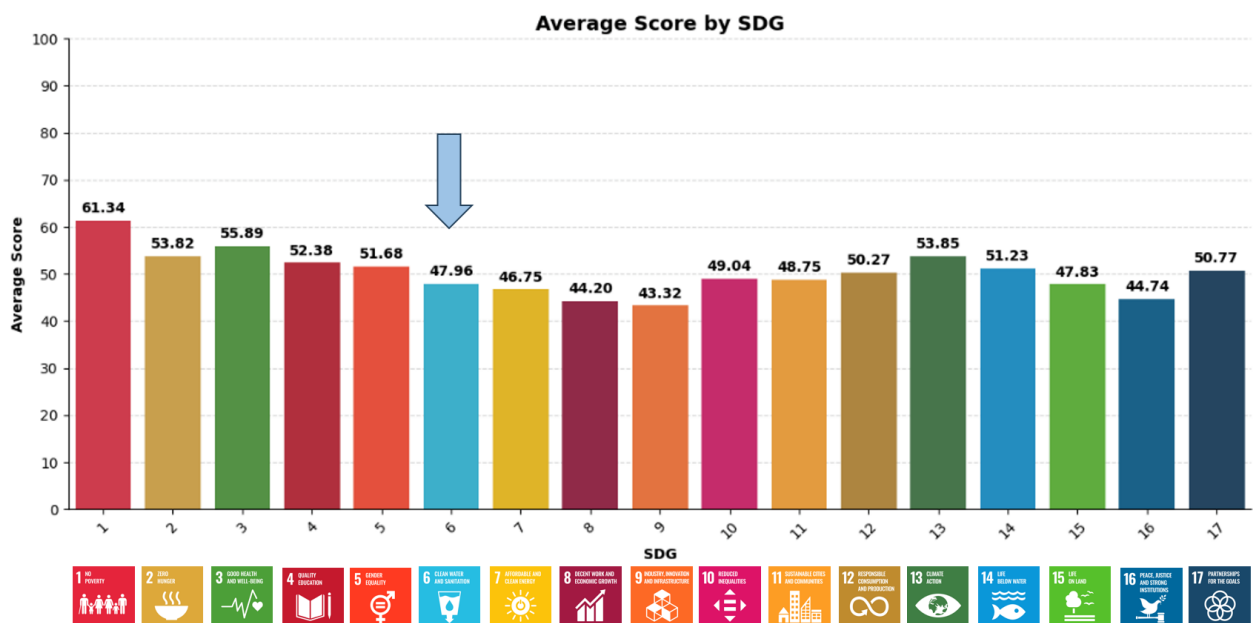
As indicated in Figure 2 above, for the two main TASK™ subjects focused directly on water—*Freshwater Use*, and *Access to Water and Sanitation*—aggregate average scores are below and well below the average score of each of the two frameworks, respectively 47.6 (vs. 50.3) and 44.3 (vs. 50.1). For the Earth Systems framework, only the subject of *Biogeochemical Flows* is significantly lower. For the Human Welfare framework, *Access to Water and Sanitation* is the lowest score. It is clear that knowledge around water-related topics is, for example, significantly lower than that on *Climate Change* or social inequalities around *Nutrition, Health, Basic Income, Gender Equality, or Education and Culture*. Tentative conclusions might posit these relatively lower knowledge scores reflect general characteristics of the test cohort—for the former framework, a largely urban population having little direct experience of the use and management of freshwater that mainly takes place in rural and non-urban spaces; and for the latter, a largely affluent population living in high-income countries and cities, with little or no experience of the common struggles in low-income countries for *Access to Water and Sanitation*. Nevertheless, these low scores are in sharp contrast to the main conclusion of Part 1 of this study—i.e., the ubiquitous presence of water in the world around us and its constant reality to us as an essential daily need. This gap has important educational implications.

## Average Score per Type of Knowledge

	x.1.1 Definitions and Key Concepts <i>Descriptive Knowledge</i> What are we talking about? How does this work?	x.1.2 Current State and Trends <i>Contextualized Knowledge</i> Where are we now? How are things changing?	x.2.1 Major Causes <i>Causal Knowledge</i> Why is this happening? Who is doing what and why?	x.2.2 Systemic Impacts <i>Integrated Knowledge</i> What are the related effects? How is this affecting the larger system?
1.2.1 Freshwater Use	40,04	39,81	59,47	44,19
2.1.3 Access to Water and Sanitation	42,72	33,4	41,1	52,72

Figure 3. Average Score per Type of Knowledge

When looking at scores for these same two TASK™ knowledge subjects across the four distinct types of knowledge of *descriptive*, *contextualized*, *causal*, and *integrated* (see Figure 3 above), we see that 6 of the 8 values are below or well below the aggregate average TASK™ score of 50.4, with *Current State and Trends* for both frameworks significantly below the global average. Foundational knowledge and understanding of basic concepts are less developed for these two frameworks. So, while students' knowledge of the aspects of water in these two frameworks is strongest when presented in the context of interlinkages, i.e., "cause and consequence," they have acquired considerably less knowledge in identifying basic definitions and key concepts, and in gauging current orders of magnitude vis-à-vis trends, particularly as applied to *Access to Water and Sanitation*.



Based on current sample of 11500+ TASK takers in about 50 universities

Figure 4. Average Score by SDG

It is also instructive to view data on student sustainability knowledge as structured by the [UN Sustainable Development Goals](#) (SDG). As each TASK™ question is tagged to one or more of these goals, it is possible to disaggregate the data for each of the 17 SDGs (See Figure 4 above), and thus provide insights into student knowledge around SDG-6 *Clean Water and Sanitation* and by extension, its 8 specific targets. Consistent with trends found in the TASK™ matrix, the aggregate average score for SDG-6 is among the lower values for all SDGs. Of course, such descriptive statistics are but early

indicators of student knowledge around water-related themes, but they suggest a need to enhance knowledge on water-related subjects within the larger teaching and learning ambitions of the UN 2030 sustainability agenda

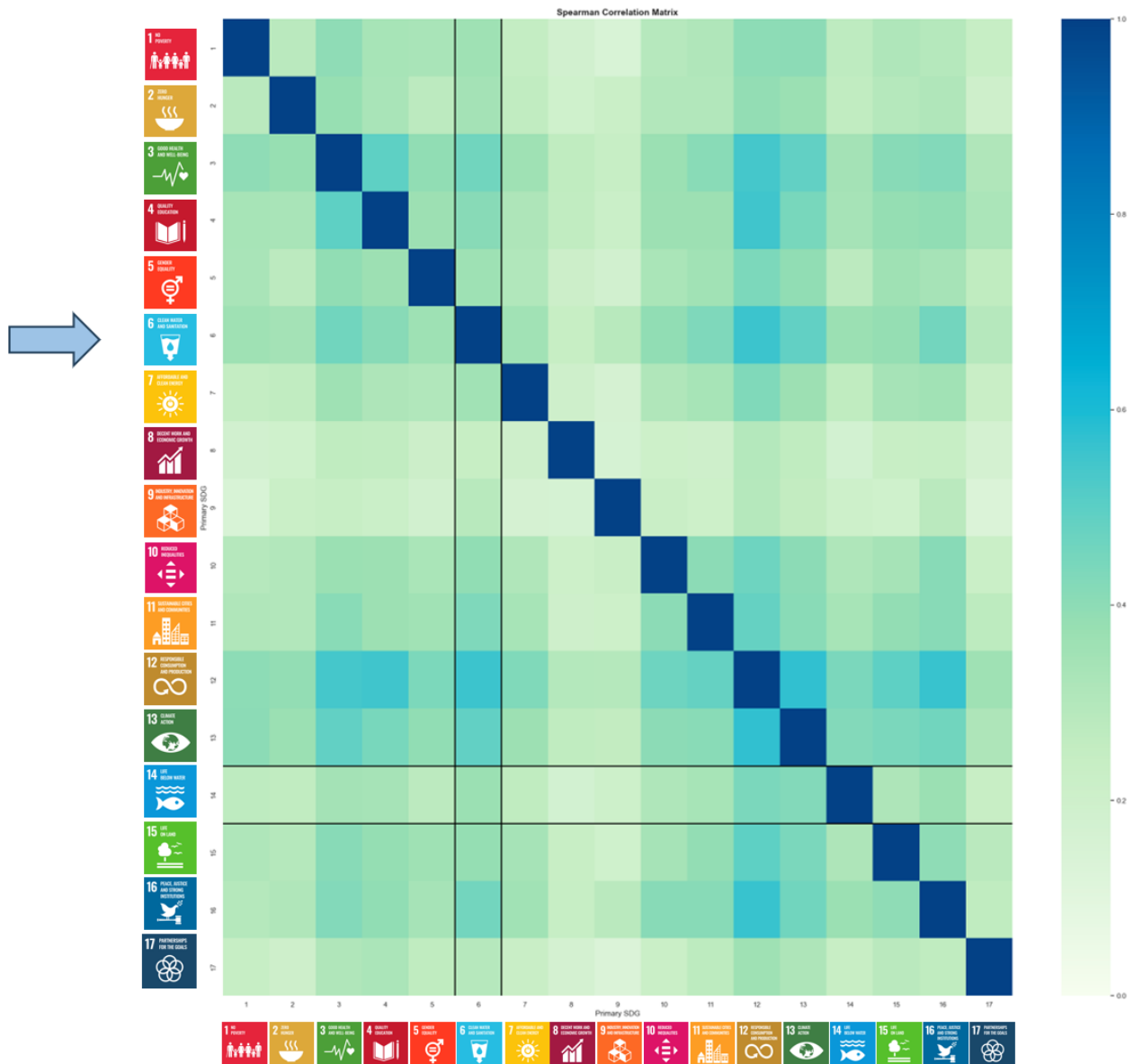


Figure 5. Spearman Correlation Matrix

Finally, the TASK™ assessment instrument also provides data for mapping correlations both within TASK subjects and within SDGs, thus providing a means of demonstrating the system and integrated nature of sustainability (See Figure 5, above). In this manner, we see that SDG-6 (and to a lesser extent, SDG-14 on *Life Under Water*) is most highly correlated with SDG-12 on *Responsible Consumption and Production* meaning that as knowledge consolidates around habits and patterns of individual and collective consumption and production, so too does it consolidate around knowledge of water-related themes, as applied both to human and non-human populations. Similarly for SDG-6, there are clear yet less strong correlations with SDG-13 on *Climate Change*, SDG-3 on *Good Health and Well-Being*.

## Conclusion

The epic poem of Samuel Taylor Coleridge, *The Rime of the Ancient Mariner* (1798), serves as a useful parable helping account for the quantity, structure, and context of student knowledge around water-related themes, as applied to the role of climate change on water resources management for a sustainable future, and as revealed through data generated through the recently released assessment instrument called *TASK™—The Assessment of Sustainability Knowledge*.

*“Water, water, every where,  
And all the boards did shrink;  
Water, water, every where,  
Nor any drop to drink.”*

Samuel Taylor Coleridge, lines 119-122

While water plays a key role in regulating Earth’s planetary boundaries, constitutes a basic social foundation of human welfare, is a daily and essential necessity for all life on Earth (both human and non-human), and (for most people in high-income countries) is so abundant, accessible, and affordable as to be “taken for granted”—general knowledge about its basic principles, properties, and roles is noticeably lacking. This has important implications for the agenda of education for sustainability.

This is because, as we learn more about the cognitive landscape of sustainability knowledge across international higher education via *TASK™ The Assessment of Sustainability Knowledge*, we find that while the presence of water is everywhere, there’s surprisingly little thirst for knowledge about it. To build a sustainable future, educators will want to address this important knowledge gap vis-à-vis water resources management.

## 1.2.1 — Freshwater Use

TASK Framework: Earth Systems → Domain: Regulating Planetary Boundaries → Subject: 1.2.1 – Freshwater Use		Click <a href="#">here</a> for User Guidelines
<b>Definition:</b> “Humans are now the dominant driving force altering global scale river flow (L). Global manipulations of the freshwater cycle affect biodiversity, food, and health security and ecological functioning, such as provision of habitats for fish recruitment, carbon sequestration, and climate regulation, undermining the resilience of terrestrial and aquatic ecosystems.” (Rockström, J. W. Steffen, 2009, p.46–47)		
<b>Planetary Boundary Control Variable:</b> Global: Maximum amount of consumptive blue water use ( $\text{km}^3 \cdot \text{yr}^{-1}$ ). Basin: Blue water withdrawal as % of mean monthly river flow. For Green water: Monthly root-zone soil moisture deviates from Holocene variability (Wang-Erfandsson et al., 2022)		
<b>Key Ideas</b> <ol style="list-style-type: none"> <li>1. Natural cycle and processes</li> <li>2. Types of blue water</li> <li>3. Green water distinctive features</li> <li>4. Human use and misuse of (blue) freshwater</li> <li>5. Water pollution</li> <li>6. Threats to freshwater use</li> <li>7. Freshwater ecosystems and biodiversity</li> <li>8. Impacts of water scarcity and overabundance</li> <li>9. Water governance and policy</li> <li>10. Sustainable freshwater use and management</li> </ol>		
<b>1. Natural cycle and processes</b> <ul style="list-style-type: none"> <li>• Global water cycle</li> <li>• Hydrological cycle and the role of freshwater</li> <li>• Carbon and nutrient cycles in freshwater systems</li> <li>• Evapotranspiration and precipitation</li> <li>• Sea-to-land moisture transport: influence on rainfall, implications for agricultural regions</li> <li>• Water scarcity: Causes (drought, overuse), impacts (shortages, restrictions, rationing)</li> <li>• Water abundance: Causes (heavy rainfall, rapid snowmelt), impacts (flooding, soil erosion)</li> <li>• Proportion of freshwater to salt water</li> <li>• Proportion of accessible freshwater to freshwater stock</li> </ul>	<b>2. Types of blue water</b> <ul style="list-style-type: none"> <li>• Blue water</li> <li>• Global scale vs Basin scale; regional hydrological cycles</li> <li>• Surface water: Lakes, rivers, reservoirs, their ecological and economic importance</li> <li>• Groundwater: Aquifers, wells, importance for agriculture and drinking water supply</li> <li>• Interaction between surface/groundwater: recharge and discharge zone, impacts on water availability</li> <li>• Global freshwater distribution</li> <li>• Freshwater resources and supply</li> </ul>	<b>3. Green water distinctive features</b> <ul style="list-style-type: none"> <li>• The role of green water in Agro-ecosystems: Crop growth, maintenance of soil moisture</li> <li>• Anthropogenic causes of disruption of               <ul style="list-style-type: none"> <li>◦ Precipitation: land-use change, GHG and aerosol emissions...</li> <li>◦ Evaporation: agriculture and pasture expansions, CO<sub>2</sub> emissions...</li> <li>◦ Soil moisture: agricultural intensification/expansion, urbanization, precipitation, and evaporation alterations</li> </ul> </li> <li>• Differentiated impact of activities (e.g., deforestation) on blue and green water</li> </ul>
<b>5. Water pollution</b> <ul style="list-style-type: none"> <li>• Water pollution: types, sources, and quantities</li> <li>• Eutrophication: causes, consequences, and scale</li> <li>• Nitrogen pollution (fertilizers)</li> <li>• Phosphorus pollution (phosphate detergents)</li> <li>• Pesticide and herbicide contamination: effects on aquatic life, bioaccumulation</li> <li>• Microplastic pollution</li> <li>• Heavy metal pollution</li> <li>• Pharmaceutical residues</li> <li>• Impacts on human health: chronic/waterborne diseases</li> </ul>	<b>6. Threats to freshwater resources</b> <ul style="list-style-type: none"> <li>• Over-extraction and unsustainable usage: aquifer depletion, groundwater, lake, reservoir degradation</li> <li>• Impacts of climate change: changes in precipitation patterns, increased evaporation, sea-level rise causing saltwater intrusion, desertification...</li> <li>• Habitat destruction: Dam construction, river diversions, wetland drainage, urbanization</li> <li>• Land conversion: Loss of biodiversity, increased carbon emissions, loss of natural flood defenses</li> <li>• Water storage: mega-basins</li> </ul>	<b>4. Human use and misuse of freshwater</b> <ul style="list-style-type: none"> <li>• Concept of virtual water, water footprint</li> <li>• Agricultural use: Irrigation and livestock</li> <li>• Industrial use: Manufacturing, waste disposal</li> <li>• Domestic use: Drinking, sanitation, and recreation</li> <li>• Aquaculture: fish and shellfish</li> <li>• Energy: Hydropower, cooling water for power plants</li> <li>• Political and legal aspects: Water rights, transboundary conflicts, water legislation</li> <li>• Economic water scarcity: Lack of infrastructure to access water, primarily in developing nations</li> </ul>
<b>9. Water governance and policy</b> <ul style="list-style-type: none"> <li>• Policy instruments: water pricing, water rights</li> <li>• Role of local communities, NGOs, and international organizations in freshwater management</li> <li>• Community-based water management: Local stewardship, traditional knowledge, capacity building</li> <li>• Transboundary water management: international treaties and cooperation, cooperative models</li> <li>• Water privatization: pros and cons, impacts</li> </ul>	<b>7. Freshwater ecosystems and biodiversity</b> <ul style="list-style-type: none"> <li>• Freshwater ecosystems: wetlands, lakes, rivers, and their varieties and characteristics</li> <li>• Importance of freshwater biodiversity: Indicator species, ecosystem services, genetic resources</li> <li>• Eutrophication impacts: Algal blooms, red tides, dead zones... (see 12.5)</li> <li>• Threats to coastal ecosystems</li> <li>• Freshwater food webs: Trophic levels, keystone species, impact of species loss</li> <li>• Deforestation impacts: Increased runoff, reduced infiltration, siltation of water bodies</li> </ul>	<b>8. Impacts of water scarcity and overabundance</b> <ul style="list-style-type: none"> <li>• Health impacts: Waterborne diseases, malnutrition due to crop failure</li> <li>• Social impacts: poverty, environmental refugees...</li> <li>• Water conflict: water war (Tigris and Euphrates Rivers, Egypt and Ethiopia, Colorado...)</li> <li>• Water and education: Impact of water-related chores on school attendance, especially for girls</li> <li>• Flood risk management: infrastructure, land use planning, early warning systems</li> <li>• Drought risk management: Water conservation, drought-resistant crops, climate forecasting</li> </ul>
<b>10. Sustainable freshwater use and management</b> <ul style="list-style-type: none"> <li>• Technologies for water conservation: efficient irrigation methods (drip, sprinkler), wastewater reuse systems, rainwater harvesting, soil conservation</li> <li>• Integrated water resources management (IWRM)</li> <li>• Desalination: Methods, potential, environmental impact</li> <li>• Nature-based solutions: Wetland conservation, reforestation, green infrastructure</li> <li>• Resilience building in freshwater management</li> </ul>		

## 2.1.3 — Access to Water and Sanitation

TASK Framework: Human Welfare → Domain: Safety and Basic Needs → Subject: 2.1.3 – Access to Water and Sanitation		Click <a href="#">here</a> for User Guidelines
<b>Definition:</b> The right to <b>water</b> entails everyone to have access to sufficient, safe, acceptable, physically accessible, and affordable <b>water</b> for personal and domestic use. The right to sanitation entails everyone to have physical and affordable access to sanitation, in all spheres of life, that is safe, hygienic, secure, and socially and culturally acceptable and that provides privacy and ensures dignity. Physical presence is not the same as access. ( <a href="#">UN Water</a> )		
<b>Social Foundation Illustrative Indicator:</b> The social foundation for access to <b>water</b> and sanitation is determined by two control variables: 1) the percent of population without access to improved drinking <b>water</b> , and 2) percent of population without access to improved sanitation. (Raworth, 2017)		
<b>Key Ideas</b> <ol style="list-style-type: none"> <li>1. Global <b>water</b> cycles and <b>freshwater</b></li> <li>2. Access to <b>water</b></li> <li>3. Drinking <b>water</b></li> <li>4. Sanitation and hygiene</li> <li>5. <b>Water</b> use efficiency</li> </ol>	<ol style="list-style-type: none"> <li>6. <b>Freshwater</b> use and misuse</li> <li>7. <b>Water</b> recycling</li> <li>8. Waste <b>water</b> management</li> <li>9. <b>Water</b> resource management</li> <li>10. <b>Water</b> and sustainable development</li> </ol>	<b>Social Foundation Status:</b> Stocks of <b>freshwater</b> remain in the safe zone at the global level, but numerous <b>water</b> basin areas are operating beyond the zone of uncertainty and high risk. (Steffen, 2015) However, billions of people live without safely managed <b>water</b> and sanitation. (Raworth, 2017)
<b>Key International Regulatory Initiatives</b> <ul style="list-style-type: none"> <li>• Convention on the Protection and Use of Transboundary <b>Water</b> courses &amp; International Lakes (1996)</li> <li>• General Comment No. 15 (2002) The right to <b>water</b> (arts. 11 and 12 of the ICESCR)</li> <li>• Human Rights Council Decision 2/104 – Human Rights and Access to <b>Water</b></li> <li>• Intergovernmental Panel on Climate Change (IPCC) 1988</li> <li>• UN Framework Convention on Climate Change – UNFCCC (1994)</li> <li>• IPCC Sixth Assessment Report (AR6) 2021–2023</li> </ul>		
<b>1. Global water cycle and freshwater</b> <ul style="list-style-type: none"> <li>• Hydrological cycle, systems, and processes</li> <li>• <b>Freshwater</b> resources and supply</li> <li>• Surface <b>water</b> / ground<b>water</b></li> <li>• Scarcity, drought, shortages, restrictions, rationing</li> <li>• Abundance: floods, flash floods, soil erosion, landslides</li> <li>• <b>Freshwater</b> stress (<b>water</b> stress, <b>water</b> crisis)</li> <li>• Proportion of <b>freshwater</b> to salt <b>water</b></li> <li>• Proportion of accessible <b>freshwater</b> to <b>freshwater</b> stock</li> </ul>	<b>2. Access to water</b> <ul style="list-style-type: none"> <li>• <b>Water</b> as a basic need, human right, and common good</li> <li>• Principles of access: available, accessible, equitable, affordable, safe, gender equality, adequate, universal</li> <li>• Unequal access to safe drinking <b>water</b></li> <li>• Disparities between rich and poor</li> <li>• <b>Water</b> distribution</li> <li>• Transboundary <b>water</b> (access, regulation, conflict, etc.)</li> <li>• <b>Water</b> exports</li> </ul>	<b>4. Sanitation and hygiene</b> <ul style="list-style-type: none"> <li>• Basic sanitation</li> <li>• Safely managed sanitation services</li> <li>• Sanitation facilities management</li> <li>• Improved sanitation facilities</li> <li>• Principles of sanitation and hygiene: available, accessible, equitable, affordable, safe, gender equality, adequate, universal</li> <li>• Open defecation</li> <li>• Handwashing facilities and hand hygiene</li> <li>• Unequal access to sanitation facilities</li> </ul>
<b>5. Water use efficiency</b> <ul style="list-style-type: none"> <li>• <b>Water</b> exports (virtual <b>water</b>)</li> <li>• <b>Water</b> harvesting</li> <li>• <b>Water</b> leakage</li> <li>• Agricultural <b>water</b> productivity</li> <li>• <b>Water</b> sprinkling and evaporation</li> <li>• <b>Water</b> storage</li> <li>• Irrigation and micro-irrigation</li> </ul>	<b>6. Freshwater use and misuse</b> <ul style="list-style-type: none"> <li>• Conflict between human use and ecosystem health</li> <li>• Irrigation</li> <li>• Excessive extraction for agricultural use (Overdrafting)</li> <li>• <b>Water</b> use by sector</li> <li>• Degradation and/or depletion of aquifers, ground<b>water</b>, lakes, rivers, wetlands, reservoirs</li> <li>• <b>Water</b> rights (patents, regulations, treaties, boundary <b>water</b>, etc.)</li> </ul>	<b>8. Wastewater management</b> <ul style="list-style-type: none"> <li>• Safely treated waste <b>water</b></li> <li>• Wastewater treatment</li> <li>• Untreated waste <b>water</b></li> <li>• Waste <b>water</b> generation</li> <li>• Wastewater collection</li> <li>• Household waste <b>water</b></li> <li>• Waste <b>water</b> monitoring</li> <li>• Centralized plants</li> <li>• Septic tanks</li> </ul>
<b>9. Water resource management</b> <ul style="list-style-type: none"> <li>• <b>Water</b> management programs (multiple types)</li> <li>• Sustainable <b>water</b> resource management</li> <li>• Integrated <b>Water</b> Resource Management (IWRM)</li> <li>• Transboundary <b>water</b> cooperation (river / lakes)</li> <li>• <b>Water</b> assistance programs (for developing countries)</li> <li>• Community engagement and participation in <b>water</b> management</li> <li>• Role in global, systemic interrelationships</li> </ul>	<b>7. Water recycling</b> <ul style="list-style-type: none"> <li>• <b>Water</b> reuse technologies</li> <li>• Desalination</li> <li>• Safe <b>water</b> reuse</li> <li>• <b>Water</b> programs               <ul style="list-style-type: none"> <li>◦ <b>Water</b> harvesting</li> <li>◦ <b>Water</b> desalination</li> <li>◦ <b>Water</b> farming</li> </ul> </li> </ul>	
<b>10. Water and sustainable development</b> <ul style="list-style-type: none"> <li>• Key role <b>water</b> plays in achieving other SDGs</li> <li>• <b>Water</b> and gender</li> <li>• <b>Water</b> and inequality</li> <li>• <b>Water</b> and health</li> <li>• <b>Water</b> and cities</li> <li>• <b>Water</b> and energy</li> <li>• <b>Water</b> and food security</li> <li>• <b>Water</b> and the economy and jobs</li> </ul>		

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# **WATER MANAGEMENT IN PUNJAB, PAKISTAN WITH COMMUNITY PARTICIPATION : A STEP TOWARDS SUSTAINABLE WATER USE**

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## ***Abstract***

*Pakistan's Indus Basin has the largest irrigation system in the world, yet it is not enough to meet the needs of an increasingly dependent agricultural economy. Insufficient supply of canal water combined with ongoing pressure is forcing irrigators to draw more groundwater. Uncontrolled extraction is causing groundwater quality to decline and has significantly dropped water tables. The only option to support a growing population and economy is to raise cropping intensity and use high-yielding crop types, yet this is putting more strain on groundwater resources. This study's main objectives are to improve farmers' livelihoods and conserve water. In two case study sites, a co-inquiry method was employed to obtain a comprehensive grasp of the local context. In order to comprehend how groundwater consumption and water conservation practices vary along the distributary's length, each case study concentrated on a single canal distributary in the Indus Basin. Water-efficient irrigation techniques are not widely used despite incentives to do so due to maintenance costs and a lack of competent labor. Although farmers are aware of the need to preserve water, they continue to employ flood irrigation as their primary technique due to the low cost of supplies and government-subsidized energy. The preference of rural young people to abandon farms in order to find work elsewhere raises additional concerns about the future. Another factor is gender; for example, women prefer to irrigate with groundwater because it is easier to obtain for herding and cultivating vegetables. They are also in charge of water use in homes. When it comes to promoting water conservation, women can be very active. It is possible to adopt best-practice technology and cropping techniques, but they must be economical, easily accessible, and well-liked by the community. This means that in order to instill a sense of ownership and accountability as a delegate, community-centered initiatives are required, and a self-centered approach is prohibited.*

**Keywords:** Indus Basin Irrigation, Water, Groundwater, Women, Youth, Pakistan, Agriculture

# RAINWATER MANAGEMENT POLICIES IN İSTANBUL : A COMPARABLE ANALYSIS

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## **Abstract**

*Policies on water management have gained more importance due to the effects of climate change felt deeply in most parts of the World in the last decades. The extraordinary weather conditions make water supply unsteady. The policies for rainwater harvesting, reuse, and management of water have been under discussion in many countries like the EU. The policies arrange protection of inland surface waters, transitional, coastal and groundwater. Policies aim to avoid and diminish pollution, support sustainable water use, protect the environment and reduce the effects of floods and droughts. Specifically, policies applied in Germany are considered as a good practice of water management. This paper aims to analyze the policies applied for utilization of rainwater in Istanbul, Türkiye. The analysis will be based on a comparable analysis with Germany. Istanbul, located in the Mediterranean region, is one of the most crowded cities in the World with a population of 16 million people, officially, and 24 million people who are visiting business, touristic purposes in a day. The rising demand for drinking water and management of wastewater are critical concerns in Istanbul, especially, when it is considered that Istanbul is subject to extraordinary weather conditions due to climate change. A comparable analysis methodology will be used.*

**Keywords:** climate change, rainwater, İstanbul

# A SUSTAINABLE WATER AND MINERAL RECOVERY TECHNOLOGY: EUTECTIC FREEZE CRYSTALLIZATION

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*This paper is related with sustainable water and mineral recovery technology, which is detective free crystallization. It is a new technology. There is also linked to climate, to Arctic ice and Antarctic ice to climate. This paper covers a kind of a new technology for water and mineral recovery. We all want to live in a clean world with beautiful environment. And although water covers 70 percentage of Earth's surface, only three percentages is fresh water and only one percentage can be used as drinking water. Rivers, reservoirs, lakes and seas are drowning with chemicals, waste, plastic and other pollutants. These pollutants are not only toxic to humans and to the environment, but they also destroy our clean water sources and create low of raw materials and water by introducing what these these toxic streams to the water by by adding those chemicals. Several actions are taken and precautions are done. They are not so sensitive and effective nowadays. For instance, those waste streams are stored in tailing ponds like in Impala Platinum refinery in South Africa. Ponds are filled, they open a new pond or they are treated using a separation industry. And it's calculated that as big as RLC every year can be saved and as big as 10 to the power 14 megajoule energy can be saved every year if we have a better separation technology. Ofcourse there are some conventional methods that we apply. For concentrated solutions, they stream and they are mainly precipitation, evaporation, crystallization, ion exchange, membrane filtration, biological treatment and chemical oxidation methods. But they are mostly energy intensive and partially feasible. This paper is related with eutectic frisk crystallization, which is kind of a new technique for water treatment. It explains the separation principle using the phase diagram for a binary system. We can see the concentration, Y axis is the temperature, water, pure water freezes at zero degrees Celsius. We place some impurities in terms of minerals into this water, and then the blue line goes down. That's the freezing line of the ice and water, ice and water equilibrium line. And it goes down and down. This green line is the salt equilibrium line where we have the salt crystallization. And the conjunction point of this ice and salt equilibrium lines are called the eutectic point. It's a very special point. We fill it up with our crystallizer with this base stream that we take from the industry and we cool down the stream till we reach to the to this ice line. We start to produce ice crystals and with further cooling we produce more ice crystals as we travel on this line and go down. When we reach to the conjunction point of this blue line and green line, so-called eutectic point, we start to have salt crystals as well. And when we remove steering, ice crystals float, and salt crystals settle down, and we take two products from the crystallizer simultaneously. And ice crystals from top, like the icebergs afloat on the sea, and salt crystals settle like when you put sugar in your tea, it settles down. Well, the futures of the technology are listed: We can save up to 90 percentage of energy, and theoretically we have 100 percentage yield. And we can apply it to several streams from process waste mining streams and to temperature sensitive products as we work at low temperature. And the system is environmental friendly. Since we work at low temperature, we don't have to deal with corrosive media. And we can preserve the product quality so that we can apply it to food and pharmaceutical industries. We can get rid of the wastewater treatment side effects like no poisonous fumes are coming out or we don't have to add extra chemicals to get rid of one chemical. This technology started to be developed in 1995 in the Delft Technical University in the Netherlands in a small-scale setup. And after proving that the system might work, then a seven-batch crystallizer and then the continuous crystallizers were developed.*

*This method was also applied in industrial scales all around the world. That's for the recovery of magnesium sulfate hydrate from washing liquid excluded sulfurization system. According to the protocol that we developed, we take, we took the brine and then we did chemical analysis for the brine. This is the wastewater that we get and we just checked what are the main impurities inside together with the minor impurities. A logical number, it's -4.2 degrees Celsius with 18 mean percentage of magnesium sulfate composition. With the presence of impurities, this point might shift to different values so that it was tested for different scales of crystallizers for operating parameters, product recoveries, purities, and particle characteristics. Then we defined the batch and continuous operation conditions for different parameters and changing those parameters, variating and calculating the supersaturations. In the end, we managed to find out the product sizes and capacities.*

*In this study, some economical evaluation and feasibility tests were done. Then we considered the existing technologies that are used in the industry for recovery of magnesium sulfate. As a conclusion, it was found out that eutectic freeze-crystallization has lower payback time with 2.4 years, which is quite an attractive method. It was taken that blow downstream and neutralize it with sulfuric acid afterwards, put base into it in the column purification in Rotterdam. It was proved for two weeks that we would be able to save 90 percentage of energy, sorry, 90 gigawatts per hour energy per year can be saved compared to triple stage evaporated crystallization. It was recovered 25 to 30 tons per hour of water that's in fact just was discharged to the sea and also, sodium carbonate, bicarbonate of 1.5 tons per hour. The products were quite pure for the ice, for the water, the impurities were less than 10 PPM. The results were compared with the conventional method, we don't have to place extra chemical of sulfuric acid and we can recover bicarbonate and carbonate which used to be disposed to the sea and no carbon dioxide emission was coming out. So, something has to be done to this wastewater so that we again checked the eutectic point and we did our experiments in the cold room that we have with the facility that we have and we can recover ice and salt through the space stream.*

*The last example for the application case that we recently work on is nickel sulfate, cobalt sulfate and water system from battery industry. That's also very attractive because recycling raw materials is crucial for conserving energy and reducing demand of new resources, greenhouse gas emissions and waste. We apply detective free crystallization method to several industries from washing liquid, gas, firm, desulfurization, agro industrial waste, biotechnological industry, electronic and battery industry, food industry, process and waste streams. As a conclusion, for sustainable feature, water and raw materials management are significant and this is crucial not only for economic reasons but for the environmental threats as it affects the climate change. So, you take the freeze crystallization of water and a force economically, environmentally and socially an attractive alternative for commercial separation techniques. And the system can work also approaching to 0 liquid discharge principle and which is in line with cradle to cradle green concept. Together with the Antarctic ice and inside the Antarctic ice I found the natural occurrence of those crystals and then we named them as a meridianate, the first one which belongs to magnesium sulfate 11 hydrate and the name comes from Mars the and we we named it together with NASA in effect and the and from the Meridian Paleto in Mars. And the second one is magnesium metanosulfonate, a natural occurrence in Antarctic ice that is Ernst Berkite, its name comes from and that is dedicated to a very well-known geologist, mineralogist. That's his name is given to that new mineral. We are still working on Antarctic ice and so we hope to find new minerals also.*

**Keywords:** Wast water treatment, liquid discharge, and environment

# ASSESSING RIVER FLOW PATTERNS IN THE CONTEXT OF CLIMATE CHANGE: A MACHINE LEARNING FRAMEWORK

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## Abstract

*This study investigates changes in river flow patterns attributed to climate change. Given the anticipated rise in extreme weather events, accurate streamflow predictions are increasingly vital. Three machine learning (ML) models – artificial neural network (ANN), recurrent neural network (RNN) and adaptive fuzzy neural inference system (ANFIS) were assessed for streamflow prediction. Four key performance indicators, mean square error (MSE), root mean square error (RMSE), and coefficient of determination ( $R^2$ ), guide the evaluation. These models employ daily precipitation, maximum and minimum temperatures as inputs, and discharge as the output. These results underscore the potential of ANN models for robust futuristic streamflow estimation, offering valuable insights for water resource management and planning.*

**Keywords:** Machine Learning (ML) models, Artificial Neural Network (ANN), Recurrent Neural Network (RNN), Adaptive Fuzzy Neural Inference System (ANFIS), Coefficient of Determination ( $R^2$ )

## Introduction:

Human-induced actions causing global warming significantly impact both the distribution of rainfall and air temperatures, consequently leading to substantial changes in streamflow patterns. Forecasting streamflow accurately is vital for efficient hydrology and the management of water resources<sup>[1]</sup>. Forecasting river flow is really important for controlling reservoir outflows during floods and droughts. This helps manage our water resources better<sup>[2]</sup>. Accurate predictions of river flow are needed for good planning and management. This includes plan and design hydroelectric projects, operate water resource projects in real-time, manage resources well, and take steps to lessen the impact of climate events on the environment<sup>[3][4]</sup>.

To make correct predictions about streamflow, researchers have created different types of models that study water. These models can be grouped into three categories: ones based on observations(empirical), ones that use simplified ideas(conceptual), and ones that rely on the laws of physics(physically based) <sup>[5][6]</sup>. In earlier times, different statistical techniques were used to predict water flow patterns over time<sup>[7]</sup>. Different statistical models like Simple Regression Model (SRM), Multiple Regression Models (MRL) and Autoregressive Moving Average (ARMA) to forecast streamflow<sup>[8]</sup>. These models rely on traditional statistics to study past data and come up with ways to forecast streamflow. However, they might not always be precise because they can't grasp the complex changes that happen when rain turns into runoff<sup>[9]</sup>.

Artificial Neural Network (ANN) is a type of semi-parametric regression tool often applied to forecast streamflow and use of neural network technology has brought about many good results in studying water and simulating water resources<sup>[10]</sup>. Several research works have shown that using data-driven methods is effective for imitating hydrological processes. These processes include forecasting rainfall turning into runoff, predicting sudden floods and estimating water levels during surges<sup>[11]</sup>. The use of ANN models has become more widespread because they can represent both simple and complex systems without needing the assumptions typical of most traditional statistical methods<sup>[12]</sup>. So, ANN was employed to predict streamflow in Indus river at Tarbela. Feed-Forward Neural Network (FFNN) and Recurrent Neural Network (RNN) were also utilized by researchers to forecast monthly streamflow <sup>[13]</sup>. Chang et al. applied RNN to forecast streamflow in the Da-Chia River of Taiwan<sup>[14]</sup>. Carcano et al. checked how well RNN could accurately recreate daily streamflow patterns by using data on rainfall and temperature<sup>[15]</sup>. Neuro-fuzzy systems represent a novel research area that has surfaced in recent times. These

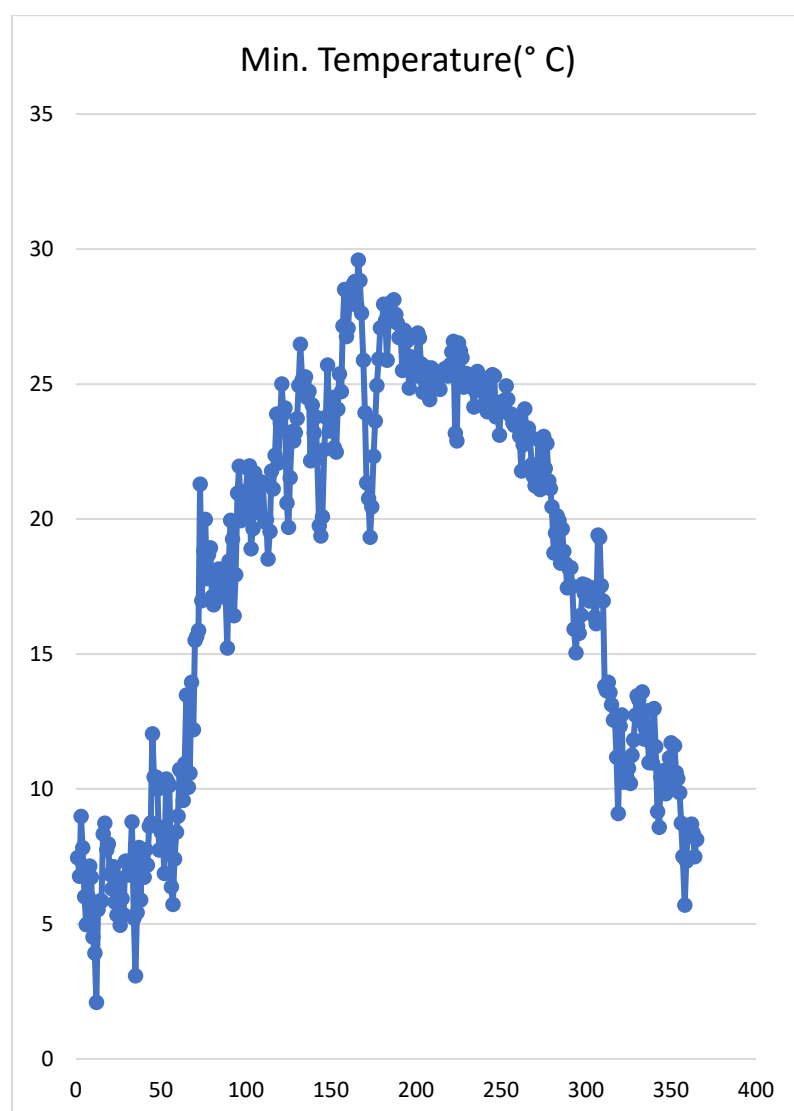
systems integrate neural networks and fuzzy logic, providing advantages from both approaches within a unified framework<sup>[16]</sup>.

RNNs, known for their strong ability to learn from time series data, have been utilized in forecasting streamflow using deep learning algorithms. RNNs have the ability to recall past inputs and make decisions using information from both past and present inputs. The adoption of more intricate RNN designs and other deep learning methods like long short-term memory (LSTM) and gated recurrent unit (GRU) has demonstrated superior performance compared to traditional RNNs in certain cases<sup>[17][18][19][20][21]</sup>.

The primary goal of this study is to forecast the streamflow of Indus river at Tarbela by employing machine learning techniques such as ANN, RNN, and ANFIS models, followed by a comparison of their outcomes.

### Methodology:

Meteorological data including daily precipitation, minimum temperature and maximum temperature were gathered from Power Data Access Viewer v2.0.0 from 1 January, 2022 to 31 December, 2023. Likewise, hydrological data, like daily streamflow, was collected from the Water and Power Development Authority (WAPDA) from 1 January, 2022 to 31 December, 2023.



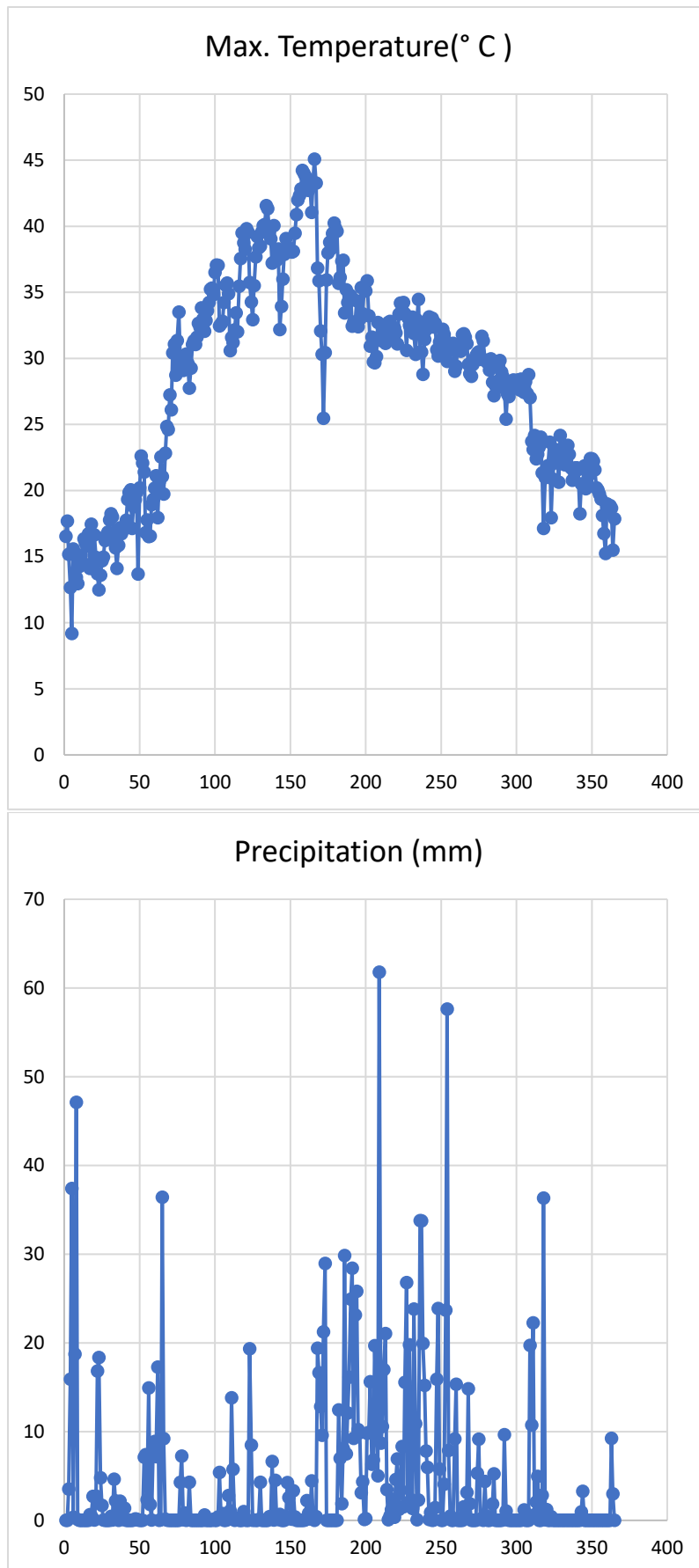
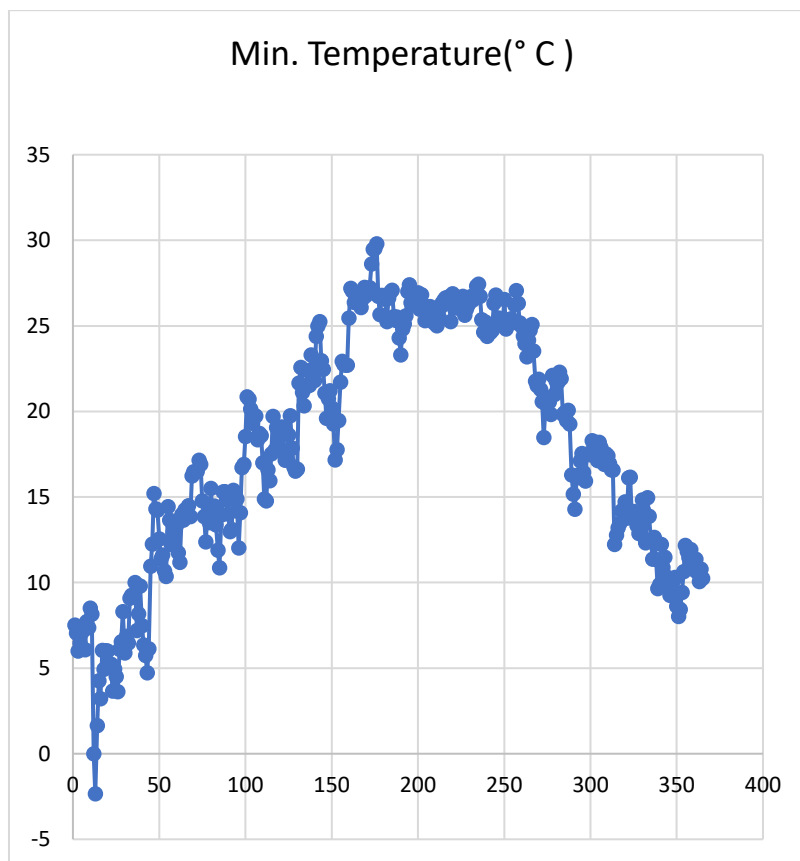
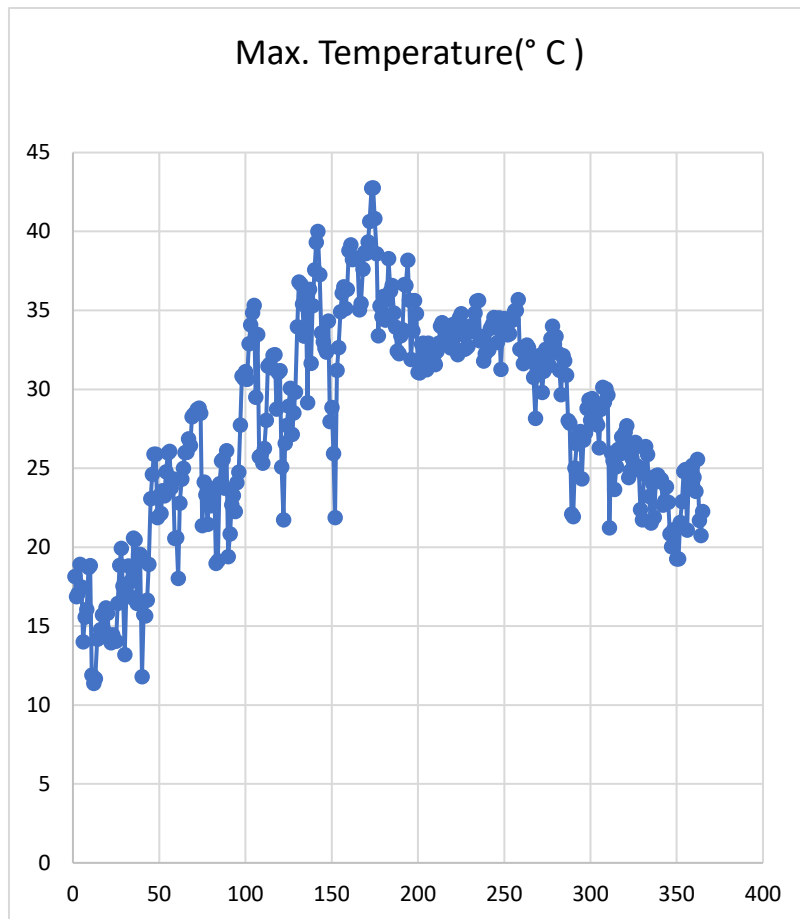


Fig 1. Demonstrating Daily Observed Data for Min. Temperature (° C), Max. Temperature (° C) and Precipitation (mm) for year 2022



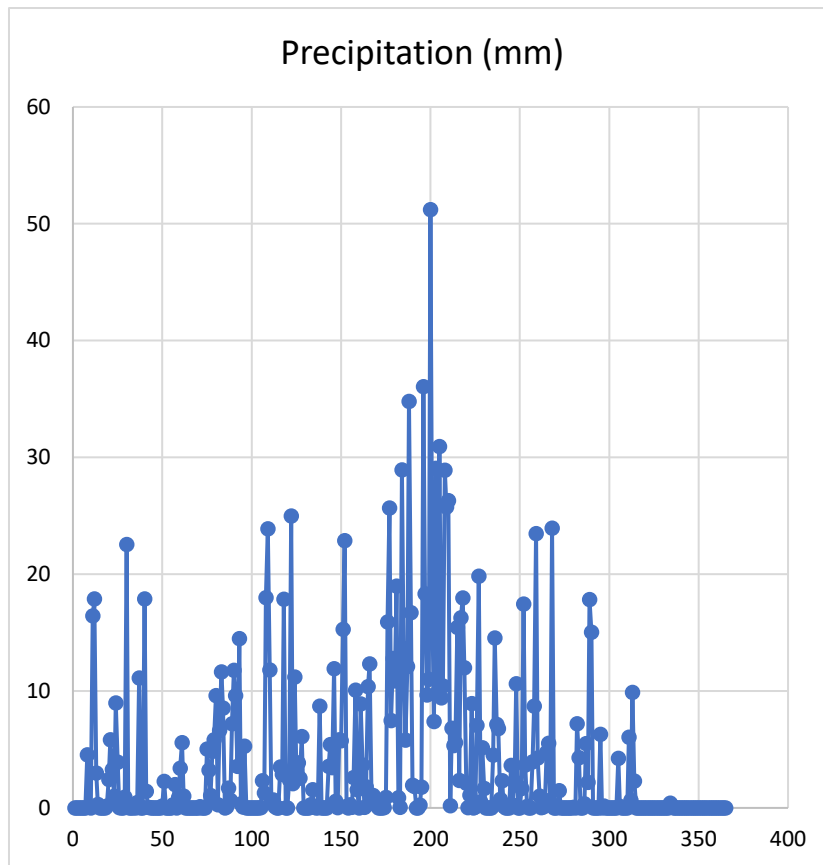
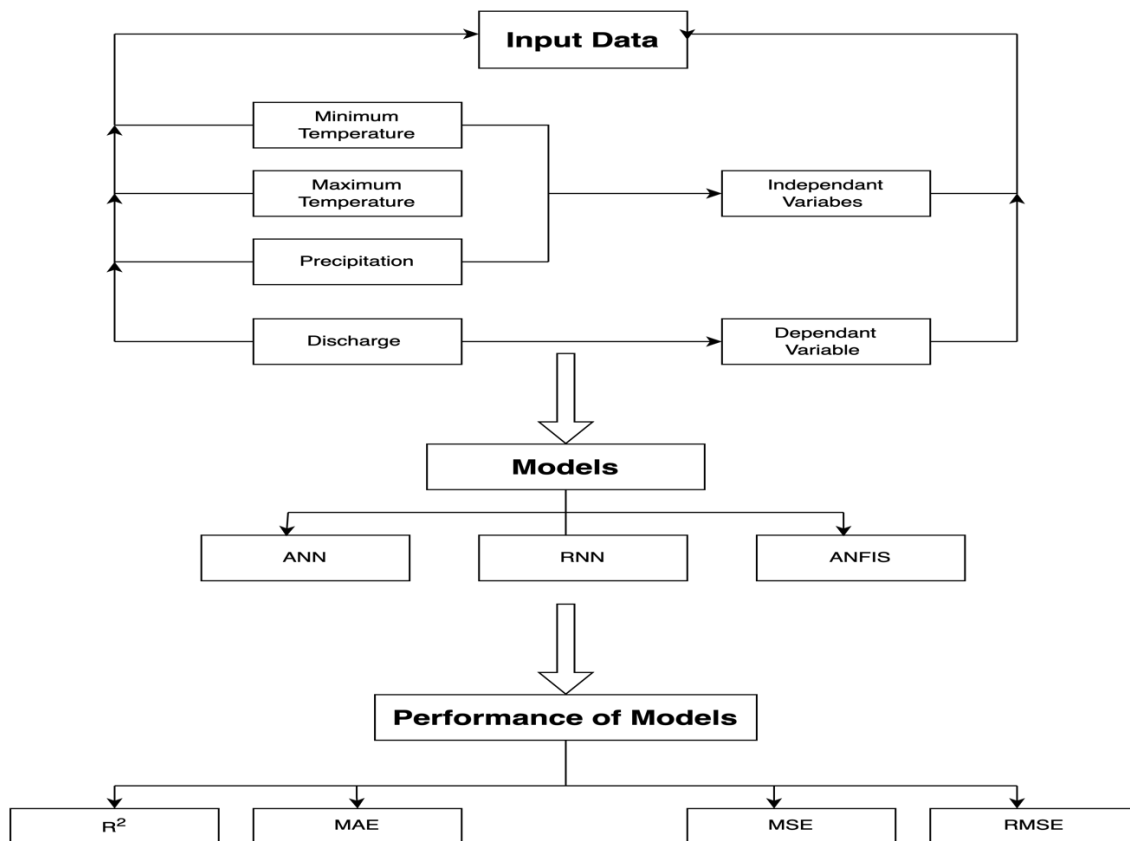


Fig 2. Demonstrating Daily Observed Data for Max. Temperature ( $^{\circ}C$ ), Min. Temperature ( $^{\circ}C$ ) and Precipitation (mm) for year 2023

The study's method is depicted in following flowchart. Research methodology includes minimum temperature, maximum temperature and precipitation from 1 January, 2022 to 31 December, 2023 as an independent variable with stream inflow from 1 January, 2022 to 31 December, 2023 serving as dependent variable. ANFIS, ANN, RNN were used to predict inflow of Indus river at Tarbela. 80% of the data were used for training while 20% for testing. The indicators used for evaluating performance of ANFIS, ANN and RNN are  $R^2$ , MAE, MSE and RMSE.



Flowchart depicting the methodology used in the present study

#### Artificial Neural Network:

ANN is defined as an information-processing model that is inspired by the way biological nervous systems, such as brain, process information. This model tries to replicate the most basic functions of brain. ANN is composed of a large number of highly interconnected processing units (neurons) working in unison to solve specific problems. Each neuron is connected with the other by a connection link and each connection link is associated with weights which contain information about the input signal. This information is used by neuron network to solve a particular problem. ANN's collective behavior is characterized by their ability to learn, recall and generalize training patterns or data similar to that of a human brain. They have the capability to model networks of original neurons as found in the brain. Thus, ANN processing elements are called neurons or artificial neurons. Each neuron has an internal state of its own. This internal state is called activation level of neuron which is transmitted to other neurons.  $R^2$ , MSE, RMSE and MAE these metrics were evaluated for ANN. Daily inflow predictions were most accurate with the chosen ANN architecture.

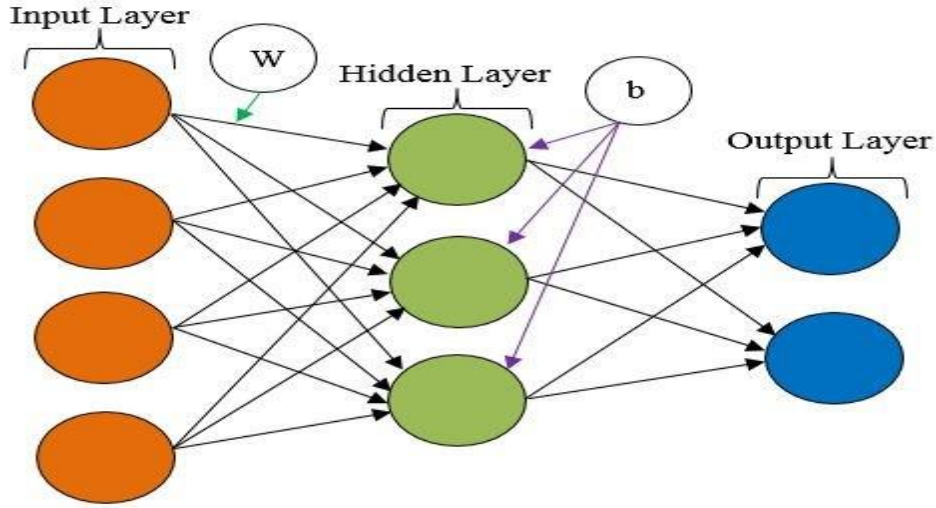


Fig. 3 ANN Structure

#### Recurrent Neural Network:

RNNs are a special class of neural networks that operate on sequence data and allow previous outputs to be used as inputs while having hidden states. Recurrent neural networks leverage backpropagation through time (BPTT) algorithm to determine the gradients, which is slightly different from traditional backpropagation as it is specific to sequence data. The principles of BPTT are the same as traditional backpropagation, where the model trains itself by calculating errors from its output layer to its input layer. These calculations allow us to adjust and fit the parameters of the model appropriately. BPTT differs from the traditional approach in that BPTT sums errors at each time step whereas feedforward networks do not need to sum errors as they do not share parameters across each layer.

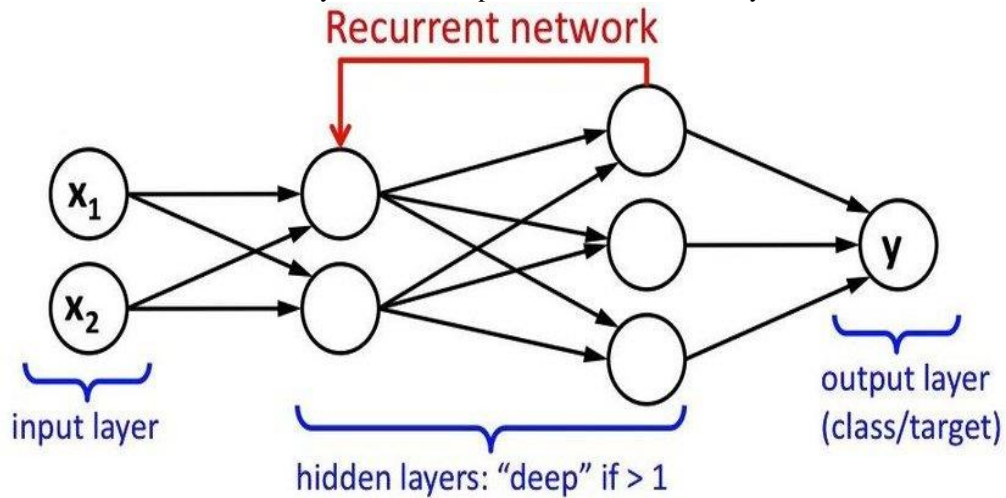


Fig. 4 RNN Structure

#### Adaptive Neuro-Fuzzy Inference System:

ANFIS is based on Sugeno Fuzzy Model, where a rule  $R_k$  can be represented as:

$R_k$ : IF  $\mu_{A_i}(x)$  AND  $\mu_{B_i}(y)$  THEN  $f = p_kx + q_ky + r_k$ ,

Where  $k$  is the number of rules,  $A_i$  and  $B_i$  are  $n$  fuzzy membership functions denoted by  $\mu$  in the antecedent part of the rule  $R_k$  and  $p_k, q_k, r_k$  are the linear parameters of consequent part of the  $k^{\text{th}}$  rule.

ANFIS is Neuro-Fuzzy system that uses 5-layer network with supervised learning. It is based on Hybridization scheme of Neural Network and Fuzzy Inference System. ANFIS comprises of two types of nodes: fixed and adaptable. Every node “ $i$ ” in layer 1 is an adaptive node with a node membership function:

$$O_i^1 = \mu_{A_i}(x), i = 1, 2, \dots$$

$$O_i^2 = \mu_{B_i}(y), i = 1, 2, \dots$$

Fuzzy membership functions of any shape i.e., gaussian, triangular, trapezoidal etc. Layer 2 calculates the firing strength of a rule via product operation

$$O_i^2 = w_i = \mu_{A_i}(x) \times \mu_{B_i}(y), i = 1, 2, \dots$$

Layer 3 calculates the normalized firing strength of a rule from previous layer

$$O_i^3 = \bar{w}_i = \frac{w_i}{\sum w_i}, i = 1, 2, \dots$$

In Layer 4, each node represents consequent part of fuzzy rule. The linear coefficients of rule consequent are trainable.

$$O_i^4 = \bar{w}_i \cdot f_i = \bar{w}_i \cdot (p_k x + q_k y + r_k), i = 1, 2, \dots$$

where  $p_k, q_k, r_k$  are the linear parameters.

In Layer 5, nodes perform defuzzification of consequent part of rules by summing outputs of all the rules.

$$O_i^5 = \sum_{i=1}^n \bar{w}_i \cdot f_i = \sum_{i=1}^n \bar{w}_i \cdot (p_k x + q_k y + r_k)$$

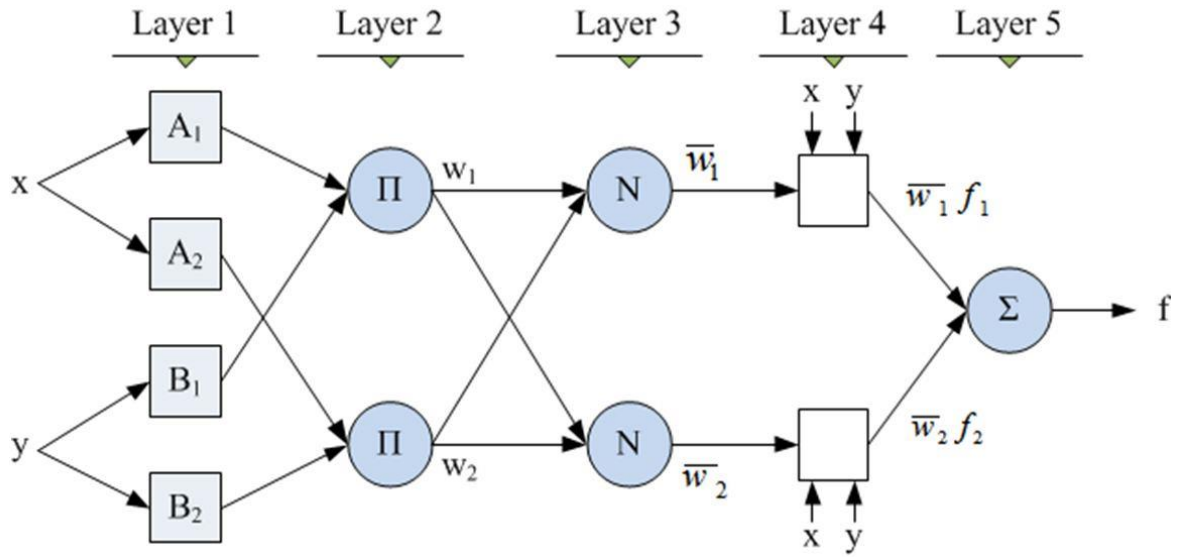


Fig. 5 ANFIS Structure

**Performance of Models:** The performance of ANN, RNN and ANFIS models are evaluated with the help of MSE, RMSE and  $R^2$  metrics.

- **Mean Squared Error:** Average of the squared difference between observed and forecasted values over the data set.

$$MSE = \frac{\sum_{i=1}^N (y_i - \hat{y})^2}{N}$$

- **Root Mean Squared Error:** Square root of MSE is defined as RMSE.

$$RMSE = \sqrt{MSE} = \sqrt{\frac{\sum_{i=1}^N (y_i - \hat{y})^2}{N}}$$

- **Goodness of fit or Coefficient of Determination:** measures the improvement of regression line over a simple mean line.

$$R^2 = 1 - \frac{\sum_{i=1}^N (y_i - \hat{y})^2}{\sum_{i=1}^N (y_i - \bar{y})^2}$$

$$\text{Or } R^2 = 1 - \frac{SS_r}{SS_m}$$

where  $SS_r$  is sum of squared error of regression line and  $SS_m$  is sum of squared error of mean line. Value of  $R^2$  lies in between 0 and 1, higher value of  $R^2$  indicates the model is better.

## Results and Discussions:

This study looks at using three factors for input - daily precipitation, minimum temperature and maximum temperature and one factor for output - daily discharge based on 2 years of historical data from 1 January, 2022 to 31 December, 2023. The data was split into two parts: 80% for training and 20% for testing. The aim of training was to find the best model using measures like  $R^2$  and RMSE. The models were built in

two stages: training and testing. We evaluated how well the models worked using MAE, MSE, RMSE and  $R^2$  metrics. Tables 1–3 show the results for all three models created.

#### ANFIS:

**Table 1. Results of ANFIS:**

Input	Output	MSE		RMSE		$R^2$	
Minimum Temperature, Maximum Temperature and Precipitation	Streamflow	Training	Testing	Training	Testing	Training	Testing
		52019.8022	69308.9341	228.0785	263.2659	0.7013	0.7548

ANFIS model was constructed with three input factors (daily precipitation, minimum temperature and maximum temperature) and one output factor (daily discharge) and model's performance was assessed using RMSE and  $R^2$  values during both training and testing phases. In the training phase, the RMSE for the ANFIS model was 228.0785, while during testing, it was 263.2659. Additionally, the  $R^2$  value during training was 0.7013, and during testing, it was 0.7548. The ANFIS model findings are outlined in Table 1

#### RNN:

To evaluate the RNN model's performance, three transfer functions were applied: Tan-sig, Log-sig and Purelin. These functions produce output between 0 and 1 as the net input of neurons varies from negative to positive infinity. Among these functions, Tan-sig yielded superior results in terms of  $R^2$  values during both training and testing phases. Specifically, 3-1-1 architecture utilizing Tan-sig function demonstrated highest  $R^2$  values of 0.7838 and 0.8439 for training and testing phases, respectively. In contrast, for Log-sig and Purelin, the  $R^2$  values were 0.8153 and 0.7317, respectively, during the testing phase.

#### ANN:

To assess the effectiveness of ANN model, three distinct architectures were experimented: 3-1-1, 3-2-1 and 3-3-1. Among these setups, the 3-3-1 architecture delivered the highest  $R^2$  values, recording 0.9522 during the training phase and 0.9699 during the testing phase.

#### Conclusion:

The outcomes of this study reveal that the ANN model with a 3-3-1 architecture exhibits superior performance in streamflow prediction for Indus river at Tarbela, surpassing both the RNN and ANFIS models. The elevated  $R^2$  values attained during both training and testing phases imply that ANN model effectively captures the intricate connections among hydro-meteorological variables and streamflow. These results underscore the potential of employing ANN models in hydrological forecasting to facilitate efficient water resource management and planning. Accurate streamflow predictions can play a crucial role in mitigating the impacts of extreme events like floods and droughts, optimizing hydropower generation, streamlining water system operations and supporting agricultural irrigation. Ultimately, the findings of this research contribute to enhancing sustainability in the water environment under changing climatic conditions and offer valuable insights for water professionals and policymakers engaged in future water-related planning endeavors.

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# APPLICATION OF EM WITH MACHINE LEARNING APPROACH FOR THE ESTIMATION OF WATER QUALITY PARAMETERS

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## Abstract

The significance of using mathematical models to find connections between water quality metrics is justified by the considerable cost and time involved in doing so. This research proposes an updated version of an Entropy method (EM) with a machine-learning approach for parameter estimation related to water quality. The Entropy approach with machine learning is used to determine the objective weights of the criterion. In this study, dissolved oxygen, pH, nitrate, and fecal Coliform in the water of the Yamuna River is studied for various sites. For the government to take prompt, proactive action regarding the parameters and to impose strict legal penalties on those who are accountable for this significant chaos, this study primarily reveals the parametric estimations of water quality parameters to determine the weightage of the parameters using the updated version of EM along with the machine learning techniques.

**Keywords:** Mathematical Modeling, Entropy method, Water Quality Parameters

## 1. Introduction

Analyzing the quantity and quality of water is essential to making the most of available resources. Water quality criteria play a crucial role in the withdrawal and use of these resources by providing customers with information about the health and hygienic aspects of the water being utilized [1]. Because of its importance for public health, there were several reports generated by the researchers on water quality estimation. The government also imposed several restrictions on the industries as well as on the people on dumping waste and harmful chemicals into the water as it deteriorates and makes the water unfit. Different parameters are present in water through which water quality can be determined [2]. Dissolved oxygen, pH, BOD, Nitrate, and fecal coliform are the main parameters of water through which we can assess the quality of water. Dissolved oxygen measures the amount of oxygen available to the aquatic organisms. Oxygen enters the water body through the atmosphere or from the ground water discharge. As the organic matter decays, water bacteria consume oxygen and the excessive organic material causes eutrophic conditions which make the water body deficient of oxygen and leads to the dying condition for water body [3]. The pH of water determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals. Excessive high and low pH can be detrimental for the use of water [4]. BOD is a measure of the quantity used by the microorganisms in the oxidation of organic matter. It is difficult for aquatic

animals to survive in high BOD which eventually deteriorates the water quality [5]. Nitrates are plant nutrients but used in excess amounts cause significant water quality problems. It also accelerates eutrophication when combined with phosphorus [6]. The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of humans or other animals. At the time this occurred, the source water may have been contaminated by pathogens or disease-producing bacteria or viruses which can also exist in fecal material [7].

These parameters affect the quality of water immensely so there is a need to keep a check on these parameters and control these parameters. Past literature mainly focuses on the overall water quality index but not on which parameters are involved in deteriorating the quality of water [8]. We can determine the main factors that are involved in the problem as well as the best course of action for lowering them with the aid of multi-criteria decision analysis [9]. Additionally, it assists in identifying compounds and their constituents, such as anions or cations, which can be analyzed to determine the presence of significant ions in water bodies, as well as in measuring the risk to human health [10]. We can assess the water quality index and determine the water quality in a different district using a variety of MCDA methodologies [11]. We can also prioritize our aims and goals and evaluate how the cropping system affects the water quality in a certain area [12]. An essential factor in the MCDA is weight. While in Subjective Weights, a decision-maker is required before weights are calculated, in Objective Weights, we already have the data and can use it to determine the weights of the criteria/attributes that contribute more to the objective. With this, we may integrate the opinions of several decision-makers to obtain the best possible data.

In this study, we try to find out the connections between mathematical modeling and the quality of water. For this, we propose an updated version of EM along with the machine learning approach to get a clear view of the problem and to reveal the contribution of parameters in deteriorating the quality of water. Section 1 gives the introduction part. In section 2, a description of the pollutants is given. In section 3, the methodology part is discussed in detail. Section 4 comprised the application of the proposed methodology along with the results of the case study followed by the conclusion in Section 5.

## **2. Description of the Pollutants**

### **1. Dissolved Oxygen**

Dissolved Oxygen measures the amount of oxygen available to the aquatic organisms. Oxygen enters through the atmosphere or from the ground water discharge. As the organic matter decays, water bacteria

consumes oxygen and the excessive organic material causes eutrophic conditions which makes the water body deficient of oxygen and lead to the dying condition for the water body.

## **2. pH**

The pH of water determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals. Excessive high and low pH can be detrimental to the use of water.

## **3. BOD**

B.O.D. is a measure of quantity of oxygen used by the microorganisms in the oxidation of organic matter. If the B.O.D is high, it is difficult for the larger aquatic animals to survive thus leading to bad water quality and vice versa.

## **4. Nitrate**

Nitrates are essential plant nutrients, but in excess amounts, they can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication.

## **5. Faecal Coliform**

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of humans or other animals. At the time this occurred, the source water may have been contaminated by pathogens or disease-producing bacteria or viruses which can also exist in fecal material.

## **3. Methodology**

In this research, we are trying to establish the mathematical relationship between the water quality metrics. For this, we are using the updated version of the EM with the machine learning approach. The modified version of the EM method is different from the original EM method in terms of the different and optimal normalization techniques used in the newer one. Entropy method is one in which we are trying to find out the contribution of the factors that affect our objective. In this method, we are dealing with the objective weights and create the decision matrix according to the availability of the data so that the chances of getting a biased result because of the conflict of the decision-makers views are less. Entropy has a strong connection with the machine learning approach as like the entropy and gini's coefficient in machine learning, updated version of EM also gives the variation and disturbances among the factors. Basically, EM method gives us the measurement of volatility and the disorderliness of the criteria/attributes. It provides us with the average information that we get from the criteria.

The steps involved in implementing the updated EM method are as follows: -

**Step 1:** - Collect the data based on the main objective along with different criterias/factors and alternatives. The factors should be closely related to the goal.

**Step 2:** The general representation of matrix of the problem with the alternatives and criterias is given in [Table 1](#). Here  $S_n$  represents the  $n$ th alternative.  $Y_{ij}$  represents the level of the criteria of type  $j$  corresponding to the  $i$ th alternative.

**Table 1: Matrix Representations**

Alternatives/Criteria	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$
S1	$Y_{11}$	$Y_{12}$	$Y_{13}$	$Y_{14}$	$Y_{15}$
S2	$Y_{21}$	$Y_{22}$	$Y_{23}$	$Y_{24}$	$Y_{25}$
S3	$:$	$:$	$:$	$:$	$:$
.....	$:$	$:$	$:$	$:$	$:$
$S_n$	$Y_{n1}$	$Y_{n2}$	$Y_{n3}$	$Y_{n4}$	$Y_{n5}$

**Step 3:** Data are not normalised here so we first normalised the data using the weighted sum logarithmic normalisation method. So, the normalisation of the decision matrix can be done by Equation (1):

$$N_{ij} = \ln \frac{Y_{ij}}{\sum_{j=1}^m Y_{ij}}, \quad (1)$$

where  $Y_{ij}$  represents the criteria level of the  $i$ th alternative of type  $j$ .

**Step 4:** Entropy of the criteria is now given by Equation (2):

Entropy of the  $j$ th type criteria is given by:

$$E.C.j = -a \sum_{j=1}^m N_{ij} \ln N_{ij} \quad (2)$$

Where  $a = 1/\ln(m)$

Where  $N_{ij}$  represents the normalized value of the decision matrix.

$m$  represents the number of the alternatives

**Step 5:** Calculation of weights of the criteria using the updated EM method discussed above. Weights are given by equation (3): -

$$W_j = I - E.C.j / \sum_{j=1}^m (I - E.C.j) \quad (3)$$

**Step 6:** After obtaining the weights of each and every criterion, we can find out the individual weightage/contribution of each criteria and also can find out the criteria which is the dominant one among all the criterias.

**Step 7:** Compare the result that we get from the updated EM method with the machine learning approach.

#### 4. Application of Proposed Methodology

To verify and validate the proposed methodology, we are taking the data of Yamuna River as a study area. The Yamuna is the longest tributary and the second-largest river in terms of the discharge of water. It is accompanied by various states like Haryana, Uttarakhand, Uttar Pradesh, Delhi and also indulged with many rivers. The quality of water at the upper Yamuna, that is, from Yamunotri to Okhla till Wazirabad barrage is of significant-good quality, and below this, between Wazirabad and Okhla, the quality of water is severely poor due to the discharge of chemicals from industries. It is a very small area of the river nearly 2% between this but the same small area contributes 80% of the total polluted river therefore there is a need to identify the factors or particulates that mainly cause water pollution. For this, we are using the updated EM method and comparing our results with the machine learning approaches. The data of the pollutants including Dissolved Oxygen, Biological Oxygen Demand (BDO), pH, Nitrate and Faecal Coliform are taken from the CPCB website.

After implementing the steps given in the Methodology section, we get the following results as shown in Table 2. Table 2 shows the normalization table after applying the weighted average logarithmic approach: -

**Table 2. Normalization Matrix**

Station Code	LOCATION	STATE	DO	pH	BOD	Nitrate	Faecal Coliform
1490	YAMUNA AT U/S DAK PATHER,	UTTARAKHAND	0.0553	0.0412	0.00471	0	3.2923E-06
1553	YAMUNA RIVER, U/S PAONTASAHIB	HIMACHAL PRADESH	0.0488	0.0393	0.003425	0.018404908	4.8013E-07
1554	YAMUNA RIVER, U/S PAONTA SAHIB	HIMACHAL PRADESH	0.0475	0.0398	0.00471	0.023006135	5.6244E-07
4439	RIVER YAMUNA U/S RANBAXY	HIMACHAL PRADESH	0.046	0.0409	0.002143	0.010736196	5.2128E-07
4440	RIVER YAMUNA U/S RANBAXY	HIMACHAL PRADESH	0.0453	0.0407	0.002355	0.013803681	7.4077E-07
1117	YAMUNA AT HATHNIKUND, YAMUNANAGAR	HARYANA	0.0401	0.0434	0.009848	0.02607362	0.00011249
1496	YAMUNA AT KALANAU, YAMUNA NAGAR	HARYANA	0.0425	0.0429	0.010276	0.02607362	0.00056655
10004	RIVER YAMUNA AT KHOJIPUR PANIPAT	HARYANA	0.0491	0.0429	0.032755	0.01993865	0.00193148
1119	YAMUNA AT SONPAT	HARYANA	0.054	0.0442	0.047099	0.023006135	0.0012888
1120	YAMUNA AT PALLA, DELHI	DELHI	0.0621	0.0448	0.022479	0.032208589	5.6518E-05
1121	YAMUNA AT NIZAMUDDIN, DELHI	DELHI	0.0149	0.0393	0.090599	0.023006135	0.13292676
1375	YAMUNA AT OKHLA BRIDGE (INLET OF AGRA CANAL), DELHI	DELHI	0.0193	0.0395	0.074288	0.018404908	0.15183007
1812	YAMUNA AT OKHLA AFTER MEETING OF SHAHDARADRAIN, DELHI	DELHI	0.0205	0.0407	0.152858	0.016871166	0.67519566
1497	YAMUNA AT MAZAWALI, U.P	UTTAR PRADESH	0.0183	0.0407	0.109398	0.032208589	0.02342748
2493	RIVER YAMUNA AT SHAHPUR	UTTAR PRADESH	0.0286	0.0382	0.055663	0	0.00235948
2495	YAMUNA AT KESIGHAT, RINDAVAN	UTTAR PRADESH	0.0339	0.0412	0.041533	0	0.00201664
1123	YAMUNA AT MATHURA U/S, U.P.	UTTAR PRADESH	0.0345	0.042	0.048812	0.076687117	0.00049522
1124	YAMUNA AT MATHURA U/S, U.P.	UTTAR PRADESH	0.032	0.0412	0.047313	0.061349693	0.0033993
1125	YAMUNA AT AGRA U/S, U.P.	UTTAR PRADESH	0.0264	0.0415	0.041747	0.144171779	0.00024586
1126	YAMUNA AT U/S OF AGRA, U.P.	UTTAR PRADESH	0.0407	0.0412	0.055663	0.056748466	0.00108646
1498	YAMUNA AT BATESWAR, U.P	UTTAR PRADESH	0.0618	0.0437	0.05502	0.116564417	0.00108374
1127	YAMUNA AT ETAWAH, U.P.	UTTAR PRADESH	0.0646	0.0437	0.047527	0.159509202	0.00032926
1499	YAMUNA AT JUHIKA B/C WITH CHAMBAL, ETAWAH, U.P	UTTAR PRADESH	0.0565	0.0437	0.030186	0.058282209	0.001509
1069	YAMUNA AT ALLAHABAD U/S (BALUA GHAT), U.P	UTTAR PRADESH	0.0575	0.0434	0.009634	0.042944785	0.00013169

After the normalized value, we calculate the entropy of each of these five criteria. The entropy and weights of the criteria are given in Table 3.

**Table 3. Entropy and weight matrix**

Station Code	LOCATION	STATE	DO	pH	BOD	Nitrate	Faecal Coliform
1553	YAMUNA RIVER	HIMACHAL PRADESH	-0.1473	-0.1271	-0.01944	-0.073530146	-6.98548E-06
1554	YAMUNA RIVER	HIMACHAL PRADESH	-0.1448	-0.1284	-0.02524	-0.086779011	-8.094E-06
4499	RIVER YAMUN	HIMACHAL PRADESH	-0.1416	-0.1308	-0.01316	-0.048679357	-7.54137E-06
4440	RIVER YAMUN	HIMACHAL PRADESH	-0.1403	-0.1302	-0.01425	-0.059118681	-1.04564E-05
1117	YAMUNA AT H	HARYANA	-0.1289	-0.1362	-0.0455	-0.09508609	-0.001022808
1496	YAMUNA AT K	HARYANA	-0.1343	-0.135	-0.04704	-0.09508609	-0.004235501
10004	RIVER YAMUN	HARYANA	-0.1479	-0.135	-0.11198	-0.078061714	-0.012070749
1119	YAMUNA AT S	HARYANA	-0.1577	-0.138	-0.14391	-0.086779011	-0.008581391
1120	YAMUNA AT P	DELHI	-0.1726	-0.1391	-0.08531	-0.11065332	-0.000552799
1121	YAMUNA AT N	DELHI	-0.0627	-0.1271	-0.2175	-0.086779011	-0.268240481
1375	YAMUNA AT O	DELHI	-0.0761	-0.1277	-0.19313	-0.073530146	-0.286198669
1812	YAMUNA AT O	DELHI	-0.0797	-0.1302	-0.2871	-0.068870617	-0.265184393
1497	YAMUNA AT N	UTTAR PRADESH	-0.0733	-0.1302	-0.24207	-0.11065332	-0.087943152
1123	YAMUNA AT M	UTTAR PRADESH	-0.1161	-0.1332	-0.1474	-0.196934168	-0.003768858
1124	YAMUNA AT M	UTTAR PRADESH	-0.1101	-0.1314	-0.14435	-0.171237123	-0.019322269
1125	YAMUNA AT A	UTTAR PRADESH	-0.0959	-0.132	-0.13259	-0.279224661	-0.00204403
1126	YAMUNA AT D	UTTAR PRADESH	-0.1303	-0.1314	-0.16078	-0.162818537	-0.007414907
1498	YAMUNA AT B	UTTAR PRADESH	-0.172	-0.1368	-0.15956	-0.25053321	-0.007399082
1127	YAMUNA AT E	UTTAR PRADESH	-0.177	-0.1368	-0.14479	-0.292803652	-0.002640209
1499	YAMUNA AT J	UTTAR PRADESH	-0.1624	-0.1368	-0.10566	-0.165664754	-0.009802928
1069	YAMUNA AT A	UTTAR PRADESH	-0.1641	-0.1362	-0.04473	-0.135183315	-0.001176675
	sum		-2.735	-2.7897	-2.48552	-2.728005935	-0.987631979
	Entropy		0.8983	0.9163	0.816389	0.896037389	0.324396354
	1- Entropy		0.1017	0.0837	0.183611	0.103962611	0.675603646
	Weights		0.0885	0.0729	0.159863	0.090516386	0.588223014

From Table 3, we can say that faecal coliform contributes more in deteriorating water quality with a percentage of 58.82% followed by BOD which is 15.99% and Nitrate, 9.05%. pH and DO contribute less than other pollutants, that is, 8.85% and 7.29%, respectively. So, from the results, we can say that we should be more focused on the quantity of Faecal Coliform in the river Yamuna.

## 5. Conclusions

Currently increasing level of harmful pollutants in the water and tremendously increasing urbanization and industrialization in today's era will pose a major threat to the environment as well as on the human health too. And as there is an immediate need to identify the factors and through the application of updated EM with machine learning approach, we can estimate the weights or contribution of the pollutants which are causing water pollution so that the pollutant which contribute the more can easily be recognized and proper steps can be taken to curb the level of this pollutant as when the environment is healthy only then we will become healthier.

## Data Availability

Data analyzed during the study are confidential and available from the corresponding author on reasonable request.

## Declaration of Interest

None

## Acknowledgment

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#### Short Biography

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# INVESTIGATION OF EXTREME WEATHER EVENTS: ISTANBUL INTERNATIONAL AIRPORTS EXAMPLE

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## ABSTRACT

Weather is important for our daily life and the aviation industry. Extreme weather conditions may occur. It is vital to detect these situations and take precautions. Extreme weather conditions are thought to increase with climate change. This increase and its results do not occur the same everywhere. In some regions, extreme rainfall occurs and in others, extreme drought occurs. In this study, in which we analyzed the 15-year extreme weather events of Atatürk International Airport (International Civil Aviation Organization (ICAO) code: LTBA) and Sabiha Gökçen International Airport (ICAO code : LTFJ), using the (+) severe weather events of the Meteorological Terminal Aviation Routine Weather Report (METAR) forecast, the trend of these events from past to present was examined. Even though the two airports are in the same city, different trends were observed. Istanbul International Airport (ICAO code: LTFM) the years 2019-2022 was also included in these analyses. It was determined that the number of extreme event days seen in these three airports was 122. During the years examined, an increasing trend in extreme events was observed at LTFM and LTFJ airports, and a decreasing trend was observed in LTBA. News about the days when extreme events occurred are classified in the table. Events for which there is no warning or disaster news reflected in the press are classified in green, events for which a warning is received from the competent authorities are classified in yellow and orange, and extreme events that are a disaster or a consequence are classified in claret and red according to the disaster size. The instability indices of these events were also given and compared.

**Keywords:** Extreme weather conditions, climate change, risk analysis.

# POSSIBLE CHANGES IN EVAPOTRANSPIRATION UNDER THE INFLUENCE OF CLIMATE CHANGE IN SELECTED PROVINCES OF TÜRKİYE

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## **Abstract**

*Evaporation and transpiration (evapotranspiration) are important components of the water cycle. It is a variable of critical importance for irrigation in the agricultural sector, where most of the water is used. However, evapotranspiration is generally calculated using equations. Precise estimation of near and distant future values of evapotranspiration is particularly important for sustainable water resources planning and management. In this study, the possible impact of climate change on evapotranspiration in various provinces in both the Thrace and the Central Anatolia Region of Türkiye was revealed according to different climate change scenarios. For the analysis, methods frequently used by researchers in the world to calculate evapotranspiration were used and the results were compared. The study was conducted using widely used climate change models. As a result of the research, it was determined that there will be a steady increase in the amount of evapotranspiration in the coming years according to climate change scenarios in the places where the research was conducted.*

**Keywords:** Climate change, evapotranspiration, water resources

## GENERAL EVALUATION

### *Marcello SCALISI*

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*Gorkem KAYA, the representative of the Industrial Engineering and Engineering Faculty Community Student Club explained on their activities. The club's vision focuses on properly guiding engineering students through their career processes. The club has created a calendar for the second term and are planning many activities. These activities include conferences, training programs, technical trips, and social responsibility projects. Student Club is particularly planning to organize the Industry 4.0 Summit; this summit will be an event themed on sustainability. At the summit, they will host speakers from major companies such as Ford, Renault, Mercedes. Delegates of this conference have been invited you all to participate in these events.*

*Fatma Yaren KÖSE, explained the mission and vision of Club METAR, Istanbul Technical University (ITU). Club METAR was founded in 1991 at ITU. Together with her team, they have a stand at the conference. They are very active to organise some periodic and scientific activities after their action plan.*

*Vision Ahi, the president of the Sustainability and Environment Club and also the Vice President of the Board was shortly summarised the club history. They founded the environment and sustainability club in 2019. They have implemented many projects. They are working on European Union projects and have conducted development projects in Africa. They prepared some documentaries on environmental education in Africa and presented these documentaries to the European Union. They have organized many events together with other clubs at IAU.*

*Director of UNIMED, Marcello SCALISI deliver a talk on internship facilities of university students and their collaboration to develop for their training and research abilities.*

# THE ATMOSPHERIC DYNAMICS CONTRIBUTING TO THE OCCURRENCE OF DROUGHT OVER NORTH AMERICA AND EASTERN EUROPE

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## **Abstract**

The Central USA (CUSA) and Eastern Europe are two very productive agricultural regions which are susceptible to drought. Understanding the conditions leading to drought may result in being to anticipate drought earlier.

**Keywords:** Drought, La Nina.

## **Introduction**

Drought is a serious economic and societal problem for many areas where people live and societies are built. It affects more people than almost any other natural hazard. Studies cited by the Intergovernmental Panel on Climate.

Change has shown these may increase in a Drought is a long-term issue. It may take months to develop and months to diminish. It can occur gradually and societies may not be aware of the damage until it's too late.

There are several different types of drought including in order of severity; meteorological, agricultural, and hydrological drought. In the USA, drought conditions are monitored at the University of Nebraska – Lincoln (National Drought Mitigation Center). In Europe, drought is monitored by the European Drought Observatory (EDO) and warmer climate along with a more vigorous water cycle.

## **Motivation /Goals**

In order to make extended range forecasts, the large-scale conditions associated with drought over a large fraction of the Northern Hemisphere should be examined, including the relationship with teleconnections and large-scale climate variations

## **Data/Used**

**The NH 500 hPa height (m), precipitation rate (mm day<sup>-1</sup>) (P), and potential evaporation (W m<sup>-2</sup>) (E)** data were retrieved from the National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric

Research (NCAR) re-analyses, available through the NOAA Earth System Research Laboratory (ESRL) website. These data are available from 6 h to monthly and on a 2.5° latitude by 2.5° longitude grid. The observed atmospheric blocking information was obtained from the blocking archive housed in the University of Missouri Weather Analysis and Visualization (WAV) laboratory by the Global Climate Change Group (GCC), The study period was 1970 - 2020 .

## Study Regions/Criteria

CUSA and Eastern Europe (including the region of Türkiye along the Black Sea): We used seasonal precipitation. Minus evaporation was modified by the areal coverage to identify Extreme and moderate dry years and compared to wet years.

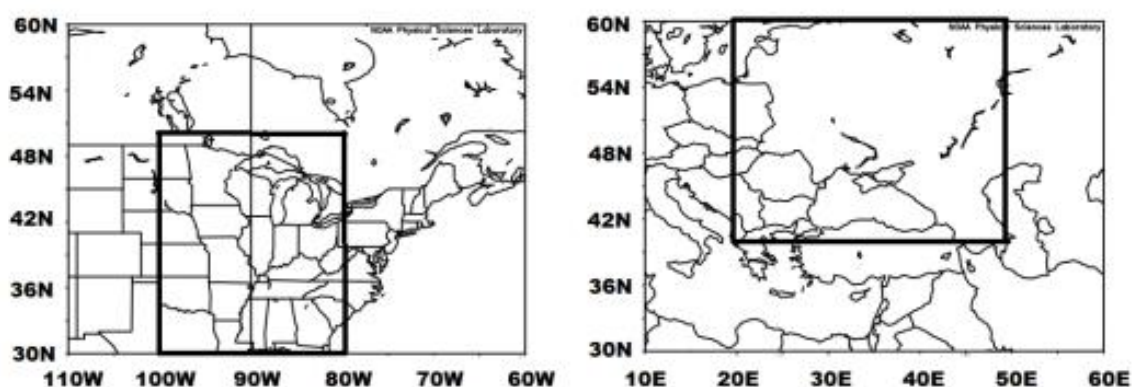
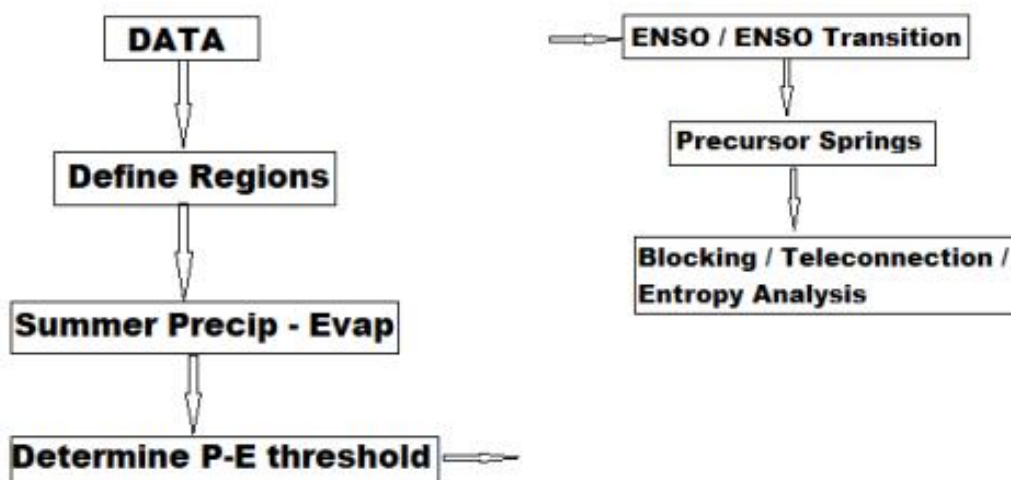


Figure 1. The study regions used here, NA (left) and EE/WR (right).



## Results

In CUSA, there were 10 extreme drought years, and 12 moderate drought years. Extreme drought was usually accompanied by a dry spring (9 of 10), while for moderate it was closer to 50% (7 of 12), [1,2]. In Eastern Europe only four of eight extreme summer droughts were preceded dry springs, and seven of eight moderate droughts.

Blocking and Teleconnections (blue  $\rightarrow$   $p = 0.1$ , green  $\rightarrow$   $p = 0.05$ , and red  $\rightarrow$   $p = 0.01$ ). Left bars are block occurrence, middle are block intensity, and right blocking days.

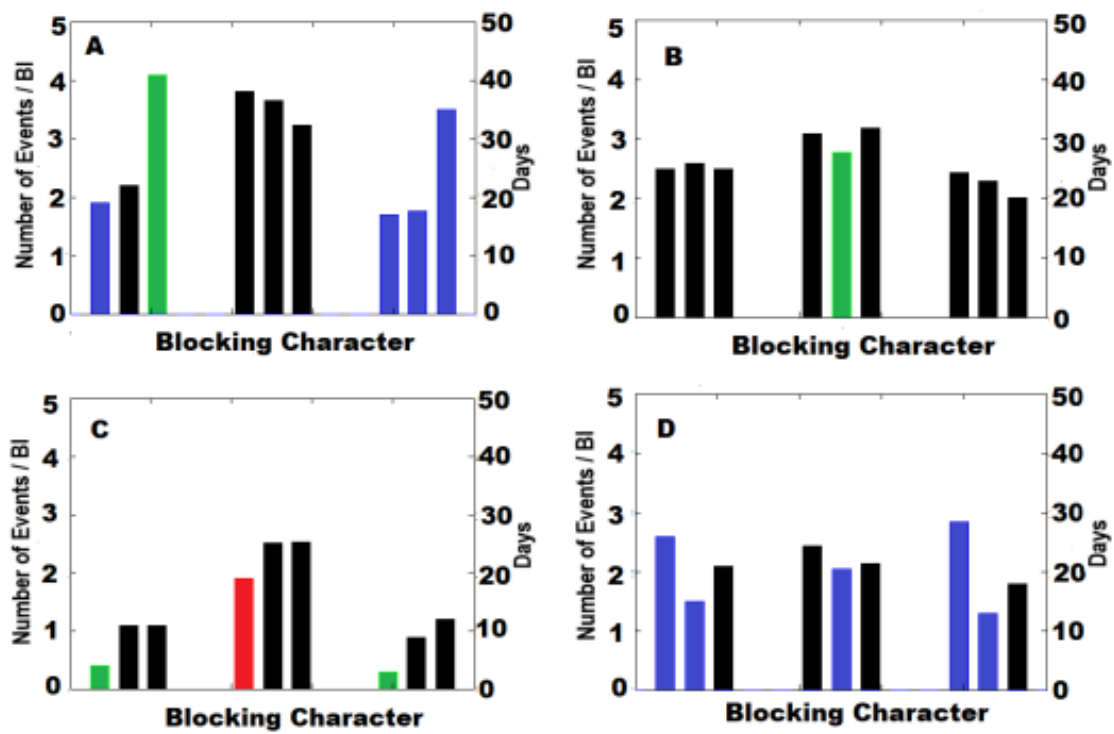


Figure2. Number of events and blocking character.

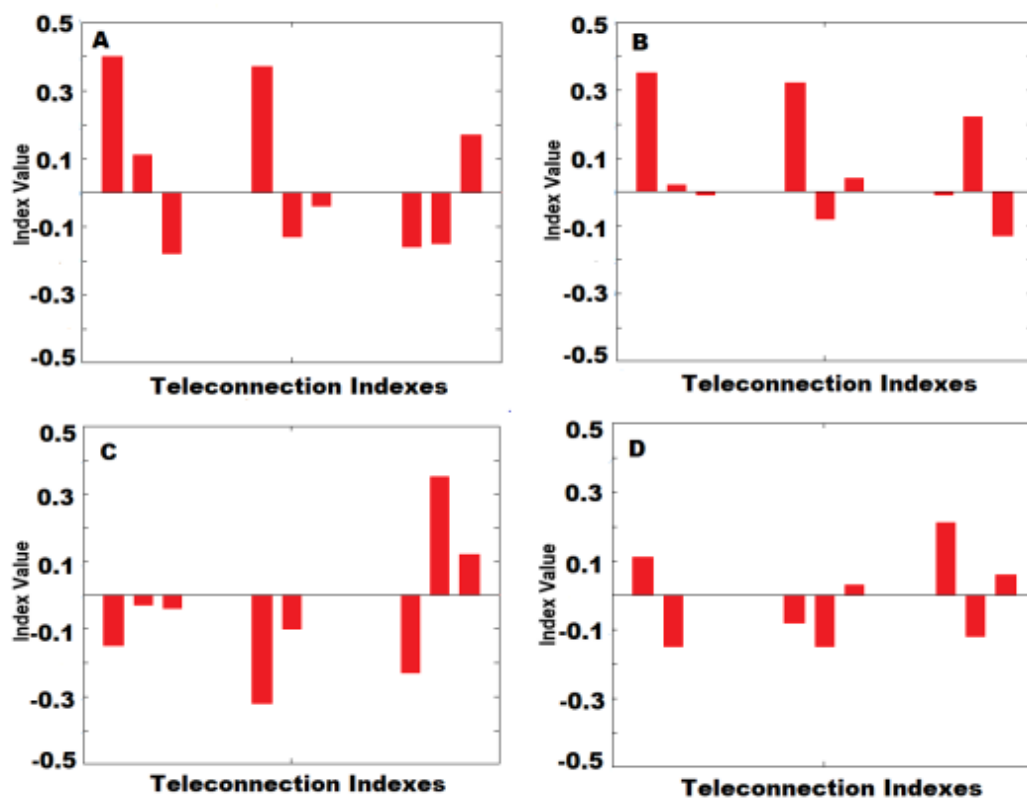


Figure 3. Index value and teleconnection indexes

Large-scale 500 hPa, summer season height anomaly composites CUSA. Top = Severe drought Middle = moderate drought Bottom = wet years

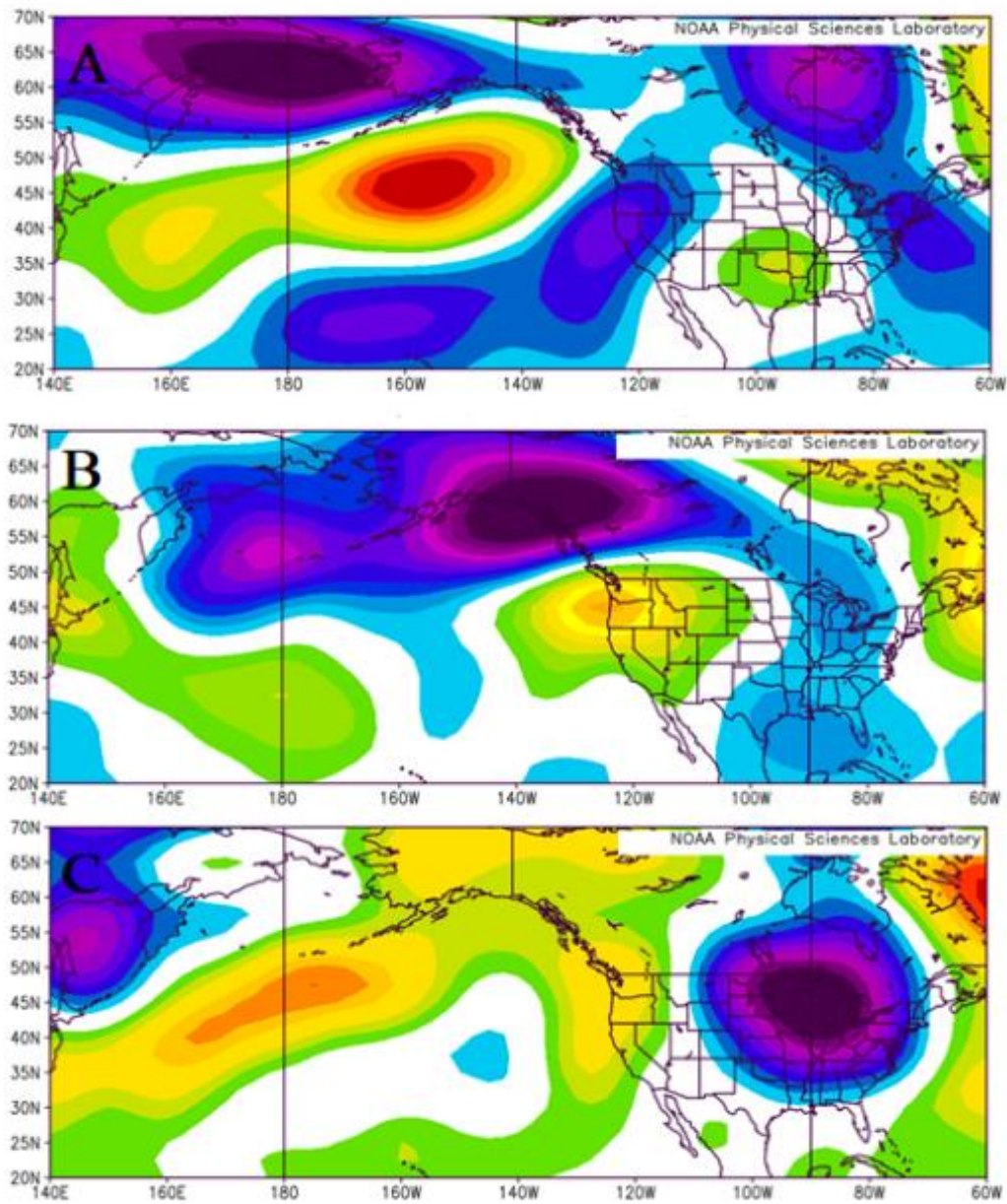


Figure 4. Large-scale 500 hPa summer season height anomaly composites Eastern Europe Top = Severe drought  
Middle = moderate drought

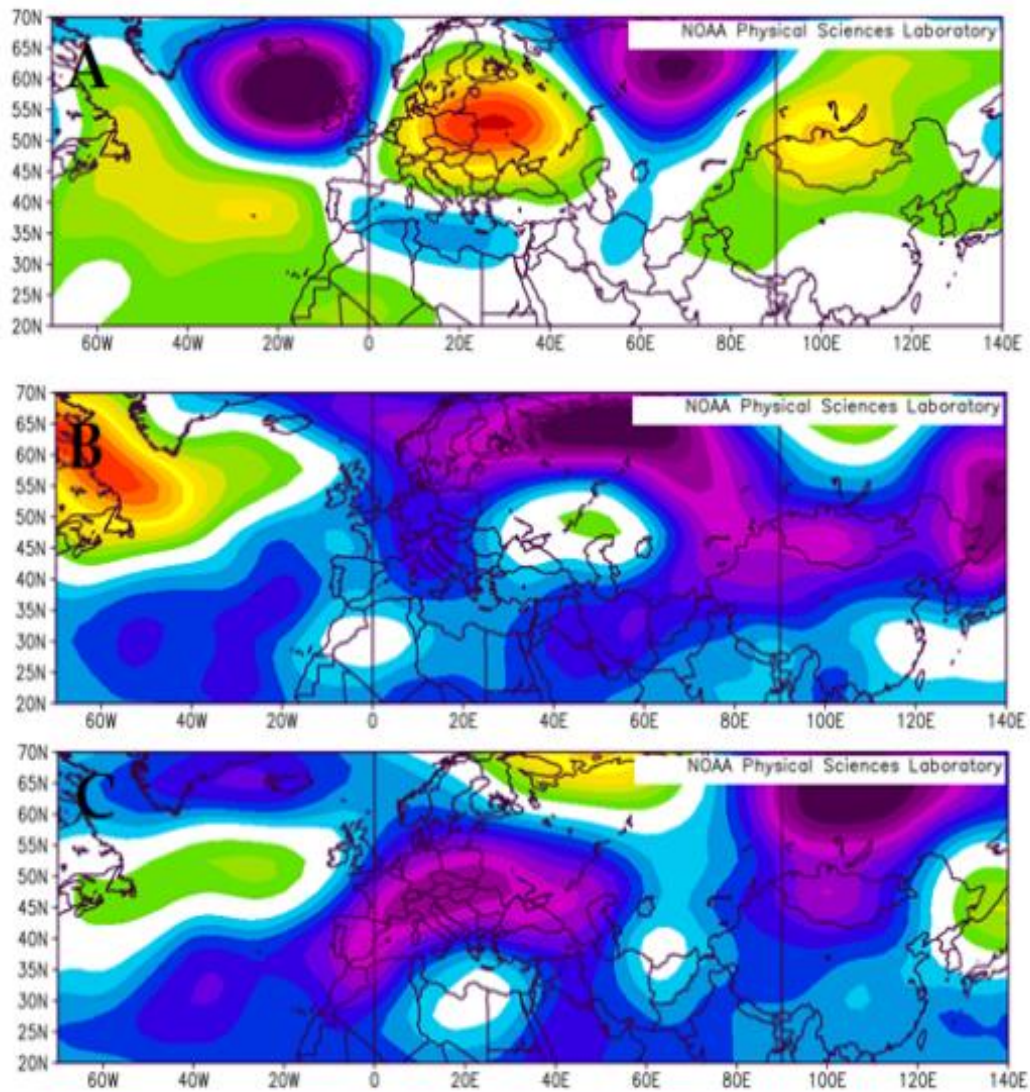


Figure 5. Wet years

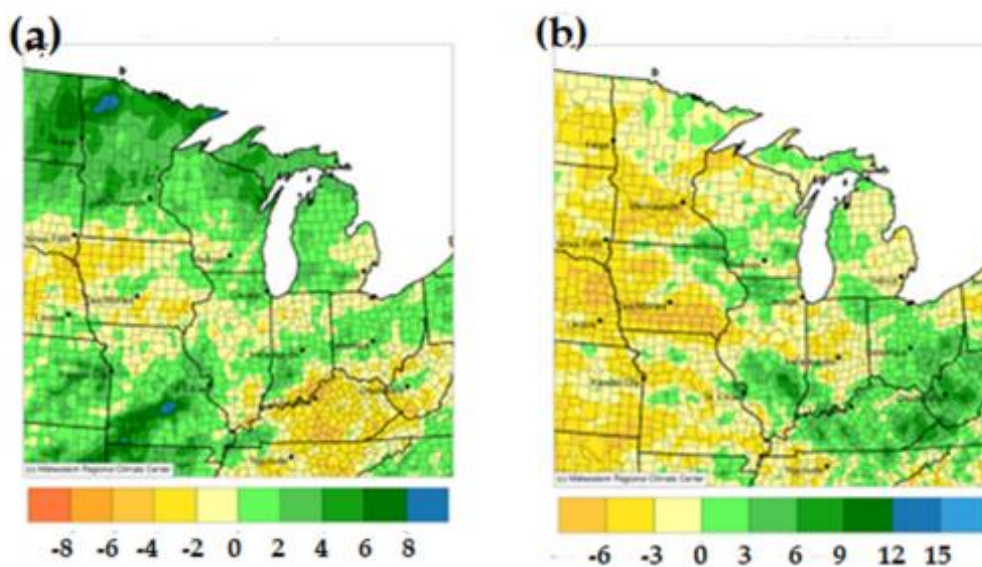


Figure 6. Case Study – Drought in CUSA 2012 versus 2022



Figure 7. Daily teleconnection indexes in summer, 2012 and 2022

Use of Northern Hemisphere Integrated Entropy 2012 versus 2022, (Eq. 1).

$$\text{IE} = \sum_{i>0} \lambda_i \approx \int_A \zeta^2 dA \quad (1)$$

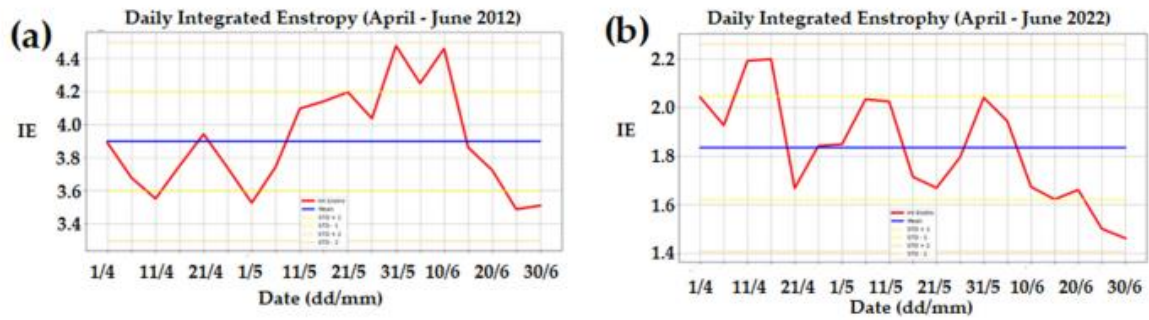


Figure 8. Daily integrated entropy, in 2012 and 2022.

## Summary and Conclusion

Long term – drought over both study regions was more prevalent in the 1970s and 2010s (and now into the 2020s) and less so in the 1990s and 2000s.

A weak association with El Nino and Southern Oscillation was noted in both regions. In CUSA extreme droughts were more often with La Nina years, moderate droughts with El Nino. The opposite was found for Eastern Europe.

For CUSA – summer drought is associated with fewer and weaker blocking events over the Eastern Pacific, for Eastern Europe there is more and stronger blocking associated during severe drought years as well as a strongly negative Eurasian Pattern (meridional). Wet years are opposite.

Many indicators pointed toward drought occurring within the CUSA in 2022 even though the spring was a bit wetter than normal. This drought has persisted for two years.

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# ARTIFICIAL INTELLIGENCE WAVELET CONJUNCTION FRACTAL ANALYSIS OF WATER QUALITY

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## ***Abstract***

Water is life and is the most precious resource on Earth. Earth is covered with 70% of water, 2.5% is freshwater and 1% is easily accessible freshwater; thus only 0.007% of Earth's water is accessible. The survival of life on Earth is directly proportional to presence to water among other important resources. Water remains to be a natural resource with no replacement. In today's era where science and technology are growing every hour and innovating new technologies and devices to make life easier and comfortable, but no artificial intelligence could either replicate or replace the need for water on Earth. The present study deals with the qualitative exploration of water quality components like potential-of-Hydrogen (pH), chemical-oxygen-demand (COD); biochemical-oxygen-demand (BOD); dissolved-oxygen (DO) of Yamuna River in India at different sample sites. Various sample sites designated for highly reported pollutants using artificial intelligence through Least Square Support Vector Regression (LSSVR) and hybrid of Wavelet and LSSVR. It is observed that hybrid of Wavelet and Least Square Support Vector Regression (W-LSSVR) predicted good quality accurately among the two prototypes simulated on the basis of the simulation errors i.e. root mean square error (RMSE); mean absolute error (MAE); coefficient of determination ( $R^2$ ) and execution time for both prototypes. RMSE values decrease overall on training and validating via W-LSSVR as compared to LSSVR. It is observed that MAE values show a lesser decrease as it is in RMSE; on an average MAE has lesser variability and  $R^2$  has a greater variability as per simulations. The simulation is carried out to analyze the level of various pollutants in the Yamuna River at different sites for the consideration of quality of water. The observed pattern from the study may help for future prediction of the quality of water parameters, so that it prohibits the further decay of water quality which may prove to be lethal to the environment. These forecasts may be helpful for the formulation of policies, planning and execution for protection of environment and quality of water.

**Keywords:** Fractal, Least Square Support Vector Regression, Wavelet Decomposition, Water quality, Wavelet-LSSVR (WLSSVR), coefficient of determination.

# ENVIRONMENTAL THREATS TO WATER WORLD AND THEIR CONTROL STRATEGIES

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## **Abstract**

*Irrigated agriculture directly linked with human survival on this globe. Man – made activities are continuously polluting our source of life. The amount of ongoing water flow; It causes serious concerns in terms of health, river life, agriculture and industry. Water permit agreement in general and a result of industrial products. Analyzes made with ground observations revealed that the nitrate level in feeds with industrial waste materials is higher, they have superior drainage and have lower nitrate content. In general, almost all factors have significant effects on the leaching of fertilizer (NO<sub>3</sub>-N) into the main lines. Current research shows that nitrogenous fertilizer containing NO<sub>3</sub>-N leaches up to 150 cm. The results show that Fe, Cu and Mn in agricultural water reached the dissolved level along the non-initial part of the sludge carrier. Thus, a serious concentration of Fe, Cu and Mn was detected in this region. The situation is slightly different in Pb. As a result of Fe, some water samples along the lined section of the sludge carrier appear to be problematic.*

**Keywords:** Agriculture, Environment, Contamination, Water quality

# WATER AVAILABILITY SCENARIOS FOR AZERBAIJAN

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## **Abstract**

*70 percent of Azerbaijan's water resources come from neighboring upstream countries (Turkey, Armenia, Georgia and Iran) through transboundary rivers. Water supply in Azerbaijan closely depends on natural and human made factors in the upstream countries. The analyzed scenarios show that in order to fully meet the water needs of the country and reduce water shortages, effective water management must be established in the country, as well as transboundary water cooperation with upstream countries. The analysis of the first scenario shows that if no action is taken, Azerbaijan will become a country experiencing severe water stress, which in turn will have a negative impact on all water-related livelihoods.*

**Keywords:** Water resources, water stress

## **Introduction**

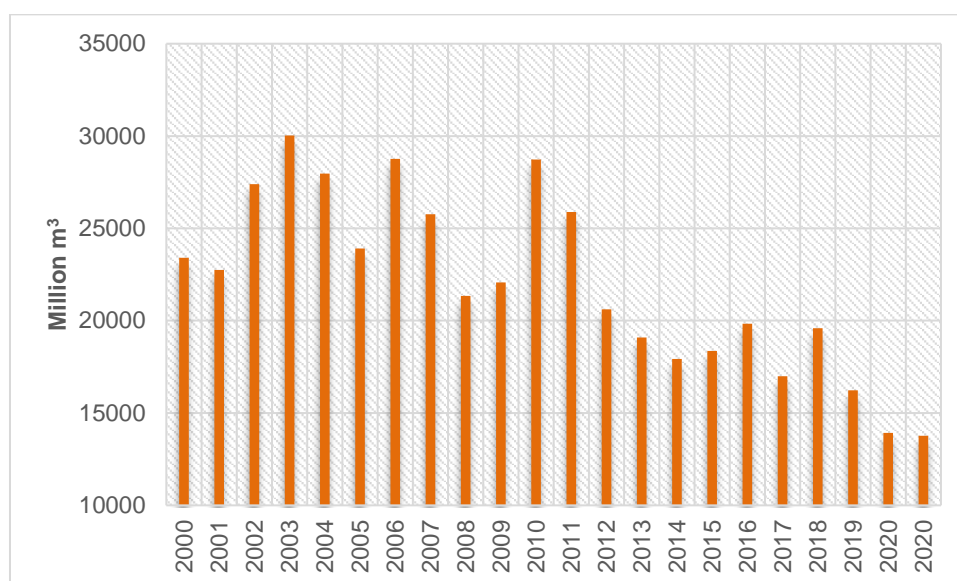
Currently, the water sector in Azerbaijan has met with several problems arising from the effects of climate changes and structural deficiencies. These problems include both institutional and management concerns, since until 1992, the economy of Azerbaijan had been based on a centralized planning economy, where market mechanisms were very weak or completely absent (Ahmadov, 2020; Aliyev et al, 2014). In recent decades, under the influence of broad range of factors, significant difficulties have arisen in Azerbaijan's water supply (Scandizzo and Abbasov, 2012; Abbasov, 2011).

The country is under the threat of all the possible expected global changes affecting the water sector (Verdiyev, 2016). Water shortages, floods, droughts and expected effects of the climate change are the major environmental concerns of the region (Baba et al, 2011; Hasanova and Imanov, 2010).

Azerbaijan is a downstream country and about 70 percent of Azerbaijan's water resources come from neighboring upstream countries (Turkey, Armenia, Georgia and Iran) through transboundary rivers (Abbasov and Smakhtin, 2013; Abbasov et al, 2022). Water supply in Azerbaijan closely depends on natural and human made factors in the upstream countries (Abbasov and Smakhtin, 2009). At present, water shortages in the country's main agricultural regions are increasingly having a negative impact. There are many reasons for the gradual decline in water supply in Azerbaijan, both natural and man-made (Kirilenko and Dronin, 2011). On the one hand, the growth of population and agricultural production, on the other hand, the negative effects of climate change on water resources have significantly reduced water supply. Simultaneously, most of the country's water resources are formed outside the country, and this factor creates additional negative side effects that cannot be resolved within the country.

The figure 1 shows the changes in Azerbaijan's water resources over the last 20 years (STAT AZ, 2021). However, currently more than 10 billion m<sup>3</sup> of reserves are taken from upstream countries (Garayev et al, 2020; Abbasov and Flores, 2023). The declining trend observed over the course of many years of water resources is mainly due to climate change and the increase in transboundary water abstractions.

**Figure 1 Renewable Water Resources of Azerbaijan (STAT AZ 2021)**



The arid climate of Azerbaijan, the non-uniform distribution of limited water resources in the region, increasing water demand due to population growth and the rapid development of agriculture in recent decades are increasing the pressure on the water resources in the country. Currently, the main factors causing water shortages in the country are the allocation of water from drinking water sources to irrigation, and water losses in the irrigation and drinking water networks. In addition, declining water resources as a result of climate change and transboundary water withdrawals also limit the access to water. According to the 4<sup>th</sup> National Communication on Climatic Change of Azerbaijan future scenarios predict further reduction of water resources at transboundary and local level (FNC AZ, 2021). This will make the water supply even more difficult in the country if no water saving or other adaptation measures are applied.

Studying the future of water resources and analyzing how the factors that negatively affect them will change in the long run is a priority for each country (Frederick and Major, 1997). This is even more important for water scarce countries such as Azerbaijan, which are very vulnerable to climate change (e.g. Mall et al, 2006). Acquiring such knowledge can help prevent future adverse events and, at the very least, reduce their impact, as well as identify the foundations of a country's long-term water strategies (Kabat and Van Schaik, 2003; Huntjens et al 2012; Ludwig et al, 2012). In this regard, the establishment of long-term water scenarios, taking into account climate change as well as other negative effects, can be very beneficial (Gallopin and Rijsberman, 2000; Cosgrove, 2013).

Along with the assessment of the current state of the country's water resources, the study of their future changes is also the subject of broad range of studies currently (e.g. Reed et al, 2013; Rahaman et al, 2013; O'Hara, 2000). For example, there is a large body of literature examining the future effects of climate change on water resources, many of which consider the future effects of climate change on water resources to be an important component in a country's water planning. These studies have both scientific (e.g. Eriyagama et al, 2010; Bharati et al, 2014; Amin et al, 2017) and technical content (FNC AZ, 2021; IPCC, 2019) and water scenarios are among the priorities of international organizations and national governments.

### **Aim of the study**

The development of scenarios in the field of water use has the potential to demonstrate the effectiveness of the measures that need to be undertaken (Alcamo et al, 1997). In this regard, the development of scenarios is very important to inform policy-making and the adoption of the right actions. Scenarios also help demonstrate that if

policy-makers won't take any steps to improve the situation then the country may face more serious problems in the future (Hejazi et al, 2013).

As a downstream country, more than 70 percent of Azerbaijan's water resources are formed outside the country, and this factor, along with climate change, is a major threat to the country's future water security (Zhong et al, 2016; Verdiyev, 2016; Jafarov, 2004). The existence of these factors indicates that even if Azerbaijan makes its own efforts to effectively manage water resources in the future, its positive impact may be negligible (Garayev et al, 2020). Simultaneously, the inability to fully resolve the "poor water legacy" of the Soviet era and the large-scale losses in the irrigation and water supply networks should also be considered as factors that negatively affect future water supply.

The main purpose of this study, initiated by FAO Azerbaijan, is to identify state of the future water use and water management in Azerbaijan through scenario development and to suggest adaptation measures considering future climate change trends and water demand. In formulating future water scenarios for Azerbaijan, the main starting point was the need to analyze all the factors that could negatively affect the country's water supply in the future and how the factors will affect the country's access to water in the long run.

## **Methodology**

The study intends to develop the scenarios of future state of water supply in the context of various activities. The current study considers two time periods, 2020-2040 and 2041-2070, and three main scenarios are devised for each period. These scenarios will help assess the degree of water supply efficiency depending on actions taken at national and transboundary levels in the future towards increasing water use efficiency. A comparison of these scenarios would allow the authorities to assess what activities will be important to address water security issues in the future and to incorporate these activities in its development programs and state water policy.

While developing the scenarios the following factors will be taken into account that affect future water access:

- Forecasted future water withdrawals in upstream countries
- Future effects of climate change on water resources
- Future water losses in the agricultural and drinking water sectors
- Environmental flow demands in renewable water sources
- Increased demand for drinking, industrial and irrigation water in the future

Detailed explanations for these "effects" and information to be used in assessing these effects are provided below.

The following formula can be used to determine the availability of water in Azerbaijan in the future and the amount of water available for use in water sources:

Equation 1:  $ARWR = TRWR - EN - TRWW - CCR - INWD - TWL$

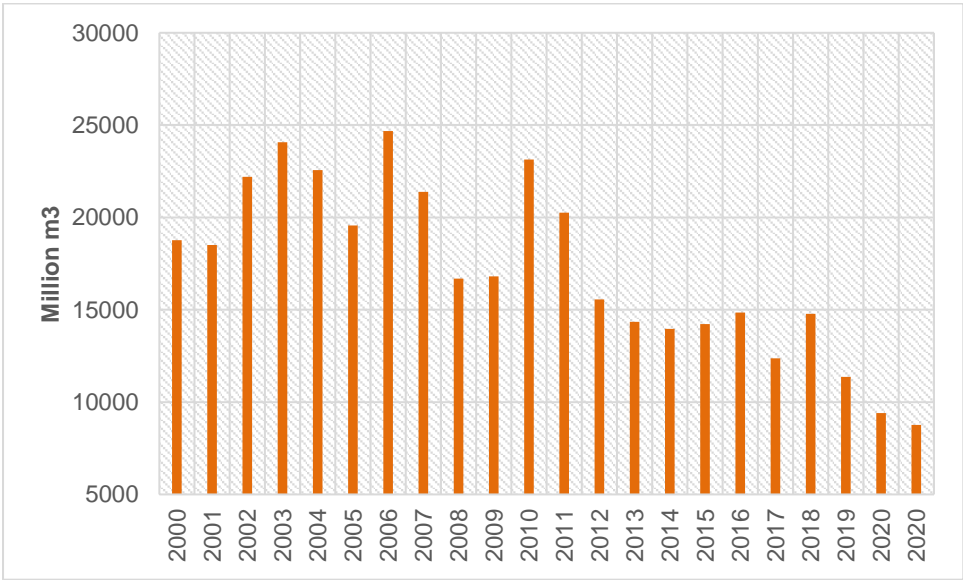
Where, ARWR is a total amount of usable renewable water resources, TRWR- is a total renewable freshwater resource, EN-is a total amount of environmental flows, TRWW- is a total transboundary water withdrawal, CCR- reduction of renewable water resources as a result of climate changes, INWD- is an increased national water demand, TWL-is a total water loss.

## **Projected future water withdrawals in upstream countries.**

Transboundary water withdrawals are the greatest real threat to the Azerbaijan's water supply in the future. In recent years, the trend of withdrawing water from major rivers from outside the country (Garayev and Rajabov, Samir Abbasov) suggests that this impact may increase in the future. Currently the amount of water entering

Azerbaijan from upstream countries, as shown in Figure 2, has decreased by more than 30%. Thus, the increasing number of reservoirs and water intakes built in the last 10 years in the upstream countries of Turkey, Georgia, Armenia and Iran allows us to predict that this effect will continue in the future. Therefore, transboundary water withdrawals will be estimated taking into consideration water use policies in upstream countries.

**Figure 2 Inflow of surface water from upstream countries**



**Future effects of climate changes on water resources**

Long-term projections show that in 2020-2100, against the background of rising temperatures in the territory of Azerbaijan, atmospheric precipitation will decrease, and water content in all freshwater basins, including rivers, lakes and ponds will decrease (FNC AZ, 2021). According to the “HadCM3 modeling of MAGİCC/SCENGEN” scenario in 2011-2040, 2041-2070 and 2071-2100 in the condition of increase in temperature and decrease in precipitation (especially in the Lesser Caucasus) the water resources over the country predicted to decrease by 10-15% in 2011-2040, by 15-20% in 2041-2070, by 20-25% in 2071-2100 years (FNC AZ, 2021).

Raising temperatures, combined with changes in rainfall will intensify the frequency and intensity of water shortages in the country. Country reliance on surface water can be dramatically affected as supply from river waters becomes more variable, and more demand is placed on other sources, such as groundwater, storm water and desalinated sea water. Given that climate change is also likely to negatively affect groundwater resources, the role of storm and desalinated waters becomes more important (Abbasov, 2018).

Climate change will also influence water needs. Warmer temperatures will likely increase evaporation rates and extend dry seasons, thereby increasing the amount of water that is needed for the irrigation of many crops, urban landscaping, and environmental water needs. Raising temperatures will also affect household water use, considerably increasing demand in potable water. This will increase expected water withdrawals from the country’s rivers and groundwater sources.

All of the above highlights the importance of water governance and water management; improved agricultural productivity, particularly water productivity in agriculture; sustainable intensification and diversification in agriculture; and better water demand management.

Projections of the 4th National Communication Report will be used to take into account the impact of climate change on water resources. In that report according to the GFDL, HADGEM and MPI models the trend of changing of water resources for the following 2 climate scenarios are assessed:

- An optimistic (RCP4.5) scenario which considers that countries will act to keep temperature increase according to agreements in Paris and Glasgow. In RCP 4.5 scenario, greenhouse gas emissions reach a maximum in 2040 and then gradually decrease (FNC, 2021).
- A pessimistic (RCP 8.5) scenario, in which no action is taken. According to RCP8.5, against the background of high population growth and low-income growth, weak technological changes and high energy demand will be maintained, which will lead to an increase in greenhouse gas emissions (FNC, 2021).

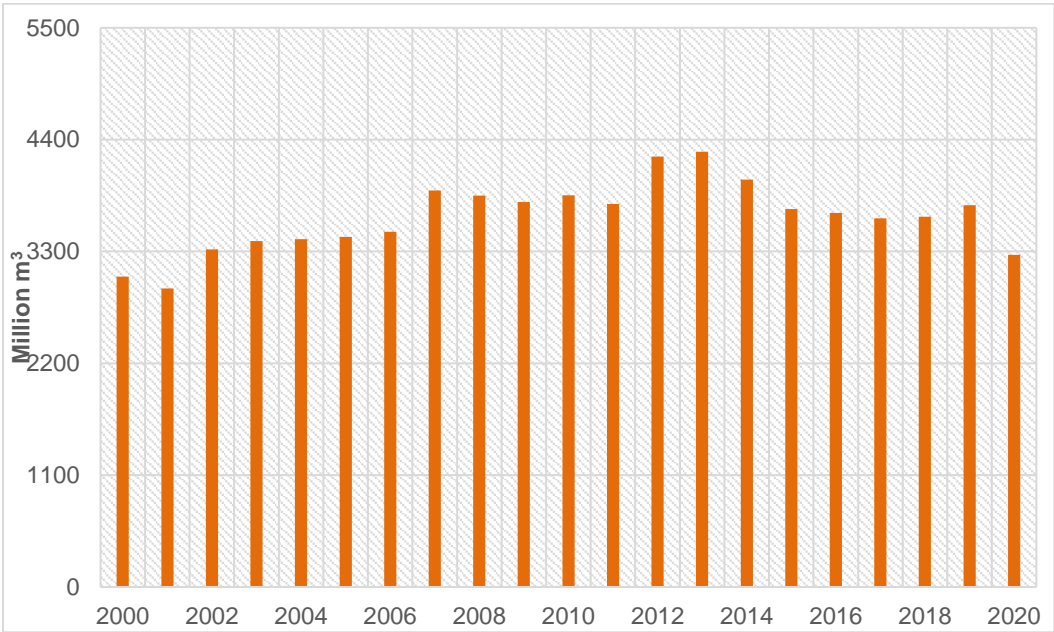
According to above models by optimistic scenario (RCP 4.5), the amount of water resources of Azerbaijan (together with transboundary water resources) will decrease by 5-10% in 2040 and by 10-15% in 2070 and by pessimistic scenario (RCP 8.5) by 10-15% in 2040 and by 15-25% in 2070 compared to current values (FNC AZ, 2021). These reductions will be taken into account in all three scenarios and climate sub-scenarios.

### Future water losses in the agricultural and drinking water sectors

The water sector of Azerbaijan has not undergone key rehabilitation work since the early 1980s and is in urgent need of complex changes, repair or replacement. Most problems are related to inadequate design, outdated network materials and construction methods, and compounded by insufficient maintenance, repair and rehabilitation. As noted in introduction part, many studies have concluded that without additional investment, the quality of the water supply will rapidly deteriorate (e.g. Scandizzo and Abbasov, 2016).

The main legacy of the Soviet and the transition period for the water system can be identified as a general condition of degraded water supply, with high rates of water losses in main and distributions canals. Irrigation in the country is mainly based on flood irrigation, which causes both salinization and large-scale water loss in the fields. According to the State Statistics Committee, the loss of water from water sources is 30-40 percent, and on average, about 4 m<sup>3</sup> of water is lost out of 12 m<sup>3</sup> (Figure 3). However, unofficial studies state that up to 60% irrigation and drinking water taken from water sources is lost.

Figure 3. Total water losses in Azerbaijan (AZ STAT 2022)



The same situation is observed in the drinking water sector. Recent studies have also confirmed that losses in the drinking water sector have reached 50%. It is expected that if no action is taken now, pipe networks, irrigation canals and irrigation networks are not upgraded, and there are no radical changes in irrigation methods, water losses will further increase in the future, and therefore water losses will be one of the main factors complicating access to water in the future. Given the large volume of water losses, the prevention of these losses can allow to increase water use efficiency by them in relevant sectors. Thus, reducing water losses by at least 50% means an additional 2 billion m<sup>3</sup> of water for the country, which is an opportunity that can play an important role in reducing water shortages in the future.

### **Environmental flow demands in surface water bodies.**

Environmental flow (Abbasov and Smakhtin, 2008; Imanov, 2003; Acreman & Dunbar, 2004; Smakhtin & Anputhas, 2006) refers to the flow regime in a river that ensures conservation of the river ecosystem. Ideally such flows should be established through a detailed quantification of the relationships between flow changes and the conditions of ecosystem components. The quantitative understanding of links between aquatic ecology and hydrology is developing worldwide and requires significant case specific field work. Many environmental flow assessment methods have been suggested over the past two decades, and a number of comprehensive reviews were written on this subject (e.g. Tharme, 2003; Acreman & Dunbar, 2004). The methods range from complex holistic ones (which examine various aspects of aquatic ecosystems, require significant amounts of study-specific information and involve a multidisciplinary team of experts) to desktop hydrological methods (which are based primarily on hydrological indices or time series). Many international organizations have also developed guidelines for calculating environmental flows (eg EU, 2015; WB 2009; FAO 2019), and one of the most widely used is the European directive (EU, 2015).

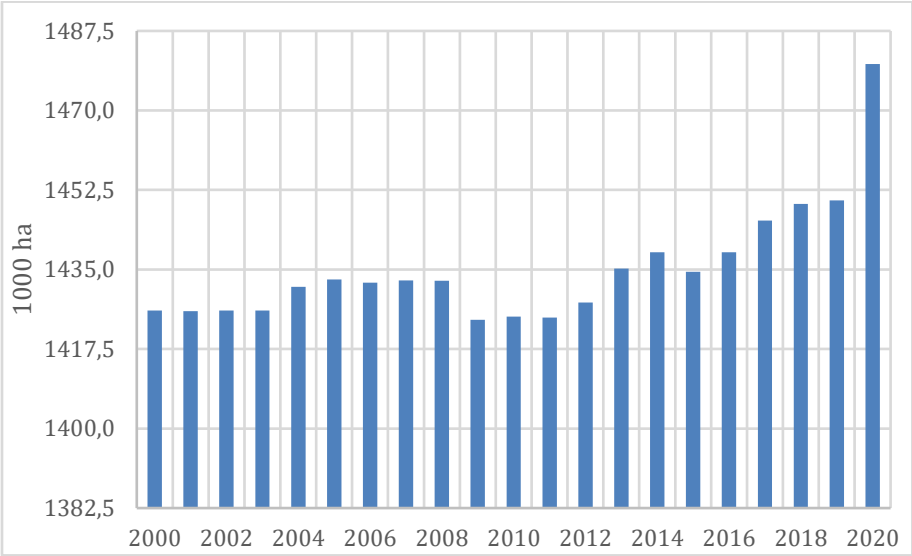
Several methods have been proposed to calculate environmental flow norms in Azerbaijan (e.g. İmanov, 2003; Abbasov and Smakhtin, 2009). According to these methods, the environmental flow should be up to a maximum of 10-15% of the average monthly flows. Currently taking into account high water demand in region in existing currently water sharing practices in region (Azerbaijan-Russia, Iran Azerbaijan), approximately one third of water is being left in rivers for the environmental needs of river ecosystems. According to the methods we currently have, natural water demand to maintain rivers' ecological functions will be estimated based on volume existing in rivers water resources, (in per cents) which will be evaluated in reference to National and International guidance documents. Therefore, when scenarios are developed, it is considered sufficient to maintain up to one third of the total water resources for environmental needs, and in all scenarios, this amount of water is excluded from public use as a natural requirement.

### **Increased demand for drinking and irrigation water in the future**

Demand for water in Azerbaijan is growing, and these increases are mainly in the agricultural and drinking water sectors. Currently the irrigated land areas are about 1.5 mln ha. The increase in the area of irrigated lands over the past 10 years suggests that this growth will continue in the future (Figure 4). The transition from rainfed agriculture to irrigated agriculture in most places due to climate change also confirms the growing demand for irrigation water. In addition, the adopted state programs are expected to support the growth of agricultural production, which will further increase the demand for irrigation water. Future demands for drinking water will be taken from available projections, while demand for agricultural water will be assessed taking into account future irrigation land increases. For example, stimulating agricultural production in Azerbaijan, increasing food security and reducing poverty in rural areas are the main goals of the Strategic Road Map for the production and processing of agricultural products in the Republic of Azerbaijan.

Future, land increases will be taking from the government programs and agriculture related road maps. According to the information of the related organizations, there is an ongoing work in relation to identifying irrigated land areas to be increased from currently used areas.

Figure 4 Irrigated lands in Azerbaijan in 2000-2020 (AZ STAT 2022)

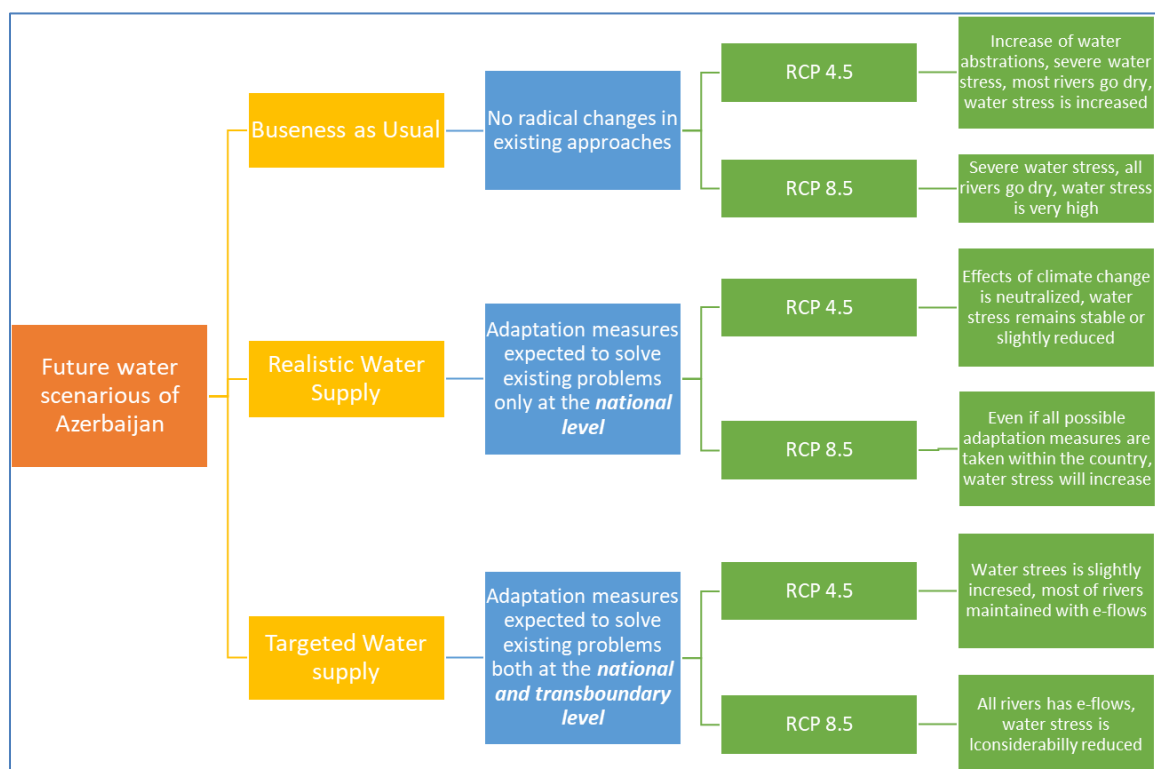


For the 1st and 2nd scenarios current and planned future water withdrawals and climate change impact on water resources in upstream countries’ territories will be taken from the existing studies to assess amount of water entering the country. No upstream water use efficiency increase will be considered under these 2 scenarios, while for the 3rd scenario, certain degree of transboundary water withdrawal reduction (as a result of water efficiency measures) will be considered.

### Water Supply Scenarios

The study uses a basic scenario analysis approach to compare future changeable scenarios with the current scenarios that may continue in the future as well. Three scenarios will be used for future water use opportunities, and one of these scenarios is to continue the current water policy without any additional action (Figure 5). According to first scenario, the current policies and practices in the country's water sector will continue in the future, and there will be no radical changes in this direction. According to one of the remaining two scenarios, the country will change the existing water supply practices in its territory, as well as achieve less water intake in upstream countries. According to the third scenario, although water use and water management will be improved in Azerbaijan, there will be no improvement in upstream countries.

**Figure 5. Water use scenarios**



### Scenario 1: Business as usual or undertaken actions are not quite sufficient.

The main premise for this scenario is that there will be no radical changes in the current water management, and almost all practices will remain the same. The main premises of this scenario are as follows:

- There are no radical changes in existing approaches to the management of surface and groundwater resources.
- In transboundary and local river basins water withdrawals, losses in the irrigation and drinking water sector remain and no substantial changes are expected.
- The negative effects of climate change reduce natural water supply will be assessed by above 2 scenarios.
- In addition, the possible increase in demand for drinking water, irrigation, and other areas, may create additional problems in water supply.

### Scenario 2: Realistic water supply scenario

The main premise in the realistic water scenario is that Azerbaijan is not able to reduce cross-border water intakes, but instead is creating a more sophisticated water infrastructure on its territory and working out as much as possible water-saving mechanisms. The main reason the scenario is called "realistic" is that it is very difficult to reduce water intake outside the country and does not seem realistic yet, instead it is up to the country to improve within the country, and these changes can be achieved gradually. The main premise of the realistic scenario is as follows:

- Adaptation measures expected to solve existing problems (with the potential to continue in the future) are evaluated only at the *national level* and no changes are expected to improve water use efficiency in the upstream countries.

- Expected future impacts of climate change will be taken into account for each of the above by considering national climate change scenarios.
- Improvements at the national level in this scenario include
  - Reduction in water losses
  - Use of water-saving methods in irrigation and other sectors
  - Evaluation of alternative use of water sources (rain waters to cover local water demands by 20-30%, treatment and reuse of wastewaters by 50% or more, desalinization of sea waters where no other water sources are available) to meet growing demand for drinking and irrigation water.

### **Scenario 3: Targeted water supply scenario-National and Transboundary scales**

The main premise of the targeted water supply scenario is that Azerbaijan is both reducing cross-border water intakes, improving water use efficiency on its territory, reducing water losses and increasing the use of non-traditional water sources. The premises of the target scenario are given below:

- Efficient use of water resources is ensured both at the national level and in transboundary water management. Transboundary water withdrawals are reduced.
- Expected future impacts of the climate change will be taken into account for each of the above by considering national climate change scenarios.
- Simultaneously, alternative water sources (use of rain waters to cover local water demands by 20-30%, treatment and reuse of waste waters by 50% or more, desalinization of sea waters where no other water sources are available) will be identified to cover the growing demand for drinking and irrigation water locally.

### **Indicator based approach**

Indicator based approaches are widely used to assess vulnerability of water resources and in assessing the environmental condition of water sources (Abbasov and Smakhtin, 2013; Babel et al, 2011). The indicator-based approach allows the assessment of the situation to be expressed in an index, because indexing allows you to visually see the future change, deterioration or improvement of the current situation (Juwana et al, 2012).

The water stress index used by the FAO is expressed as the ratio of the total water taken from water sources in all sectors of the country to the renewable water resources and is given by the following formula (FAO 2019):

Equation 2:  $WSI = \frac{TFWW}{WY} \cdot 100\%$

Where, WSI is a FAO's SDG water stress indicator, or simply water stress, TFWW is a total freshwater withdrawn, where year to which it refers will be provided, WY (water yield) is determined as difference between the total renewable freshwater resource (TRWR) and environmental flows requirements (EFR). TFWW is the total amount of water withdrawn from natural water sources for one year. The main factors that increase the TFWW are the amount of water taken for irrigation and drinking water. However, TFWW is also increasing due to losses in the water sector, and if these losses are reduced, it may also reduce the amount of total water use. According to various sources, these losses range from 40 to 50 percent. WS is the total amount of water available for use in the country for the same year. WS is formed under the influence of climate change and transboundary water intakes.

Therefore, in condition of water flow reduction under the negative effects of climate change main adaptation scenarios will be based on possible reduction of transboundary and local level water withdrawals and water losses

and switch to technologies that allow more efficient use of water. This, in turn, can have a positive effect on the value of the WSI.

## Background information

Water resources of Azerbaijan Republic together with transboundary water flow was assessed to be 30,5 billion m<sup>3</sup> according to assessments conducted in 80s of last century, according to which only one third of it was formed in rivers located on territory of the country (Rustamov and Gashgay, 1986). The FAO also assessed Azerbaijan's water resources in 2008, and according to this assessment, the water resources are 32.5 km<sup>3</sup> /year (FAO, 2008). According to the Azerbaijan Amelioration and Water Farm Company, the water use situation in Azerbaijan in 2020 is given in the table below (Table 1).

Table 1 State of water use in Azerbaijan in 2020 (million m<sup>3</sup>)

	<i>Water withdrawal</i>	<i>Water consumption</i>	<i>Recycled water</i>	<i>Water losses</i>	<i>Sewage waters</i>	<i>Wastewater</i>
<i>Total</i>	12960,8	9693,0	2243,1	3267,8	4759,0	224,5
<i>Agriculture, hunting and forestry</i>	11210,4	7235,9	-	3174,9	3037,6	0,1
<i>Industry:</i>	1737,2	2412,0	2219,2	89,7	1350,8	47,8
<i>Mining</i>	340,2	344,1	313,6	-	291,3	6,2
<i>Manufacturing industry</i>	40,7	67,9	246,1	3,3	40,2	5,4
<i>Production and use of utilities</i>	1356,3	2000,0	1659,5	86,4	1019,3	36,2
<i>Transport, storage and communication</i>	9,6	11,4	9,8	3,2	17,8	17,4
<i>Other branches</i>	3,6	33,7	14,1	0,0	352,8	159,2

In the case of the Kura and Araz Rivers, which flow through Turkey, Georgia, Armenia, the Islamic Republic of Iran and Azerbaijan, discussions are under way on a water sharing agreement. The four major river basins in Azerbaijan are:

1. The basin of the Kura and Araz Rivers is the largest basin in the country, forming the largest transboundary river system of the southern Caucasus. It originates in Turkey, and flows through Georgia and Azerbaijan into the Caspian Sea, while the Araz also crosses Armenia and Iran. The total length of the Kura River system is 1 515 km, of which 900 km is located within Azerbaijan. The total annual inflow of the Kura River from Georgia is estimated at 11.91 km<sup>3</sup>. The total inflow of the main branch of the Araz River and its tributaries from Armenia and Iran is estimated at 13.47 km<sup>3</sup>/year, bringing the total inflow into Azerbaijan to an estimated 25.38 km<sup>3</sup>/year.
2. The Samur River Basin, located in the northeast of the country, forming the border with Russia. The Samur River rises in the Russian Federation and then forms its border with Azerbaijan. Its estimated annual discharge is 2.36 km<sup>3</sup>, less than half of which is considered to be available for Azerbaijan.
3. The Caspian Sea coastal river basins in the northeast, between the Samur and Kura River Basins
4. The Caspian Sea coastal river basins in the Lankaran region in the southeast, south of the Kura River Basin.

The total reservoir capacity of Azerbaijan's dams is around 21.54 km<sup>3</sup>. Most of this capacity, 21.04 km<sup>3</sup>, comes from large dams, of more than 100 million m<sup>3</sup> each. The four largest reservoirs are the Mingacevir and Shamkir on the Kura River, the Araz dam on the Araz River, and the Sarsang on the Terter river. A full overview of the larger dams is provided in Table 2.

Table 2 Characteristics of major reservoirs of Azerbaijan

WATER RESERVOIR	AREA, KM <sup>2</sup>	CAPACITY OF RESERVOIR, KM <sup>3</sup>	INSTALLED CAPACITY OF HPP, MW	MAXIMUM AREA OF IRRIGATED LANDS, HA
<b>MINGACHEVIR</b>	605	15.73	402	970000
<b>SHAMKIR</b>	116	2.68	380	46,000
<b>YENIKEND</b>	23.2	1.58	150	6000
<b>VARVARA</b>	22.5	0.06	16	-
<b>SARSANG</b>	14.2	0.565	50	120000
<b>ARAZ</b>	145	1.254	22	400000
<b>BILAV</b>		0.1	22	-
<b>VAYKHIR</b>		0.1	5	16800

Further reduction of water resources during 2016-2020 (dry years) led to reduction of available on Azerbaijan flow values down to 17,5 billion m<sup>3</sup> (AZ STAT 2022).

## Results

### Scenario 1: Business as usual or undertaken actions are not quite sufficient

The first scenario was calculated considering two climate sub-scenarios (RCP 4.5 and RCP 8.5). As noted above, this scenario assumes that the current situation in the water sector will remain the same and that there will be no change in water management. Under this scenario, water taken from renewable water resources is expected to remain at current levels or increase slightly. Currently, 13 billion m<sup>3</sup> of water is withdrawn from renewable water resources, and in our scenarios calculations are considering that these water withdrawals will be 13.5 billion m<sup>3</sup> by 2070. At the same time, under this scenario, transboundary water intakes are expected to increase by another 1 billion m<sup>3</sup>.

This 13 billion m<sup>3</sup> of water also includes water losses of about 40% of the water taken. In other words, water losses are considered the main "consumer" of water in this scenario.

Environmental flow of Azerbaijani rivers was estimated at 10 billion m<sup>3</sup>, and this rate is maintained for all scenarios.

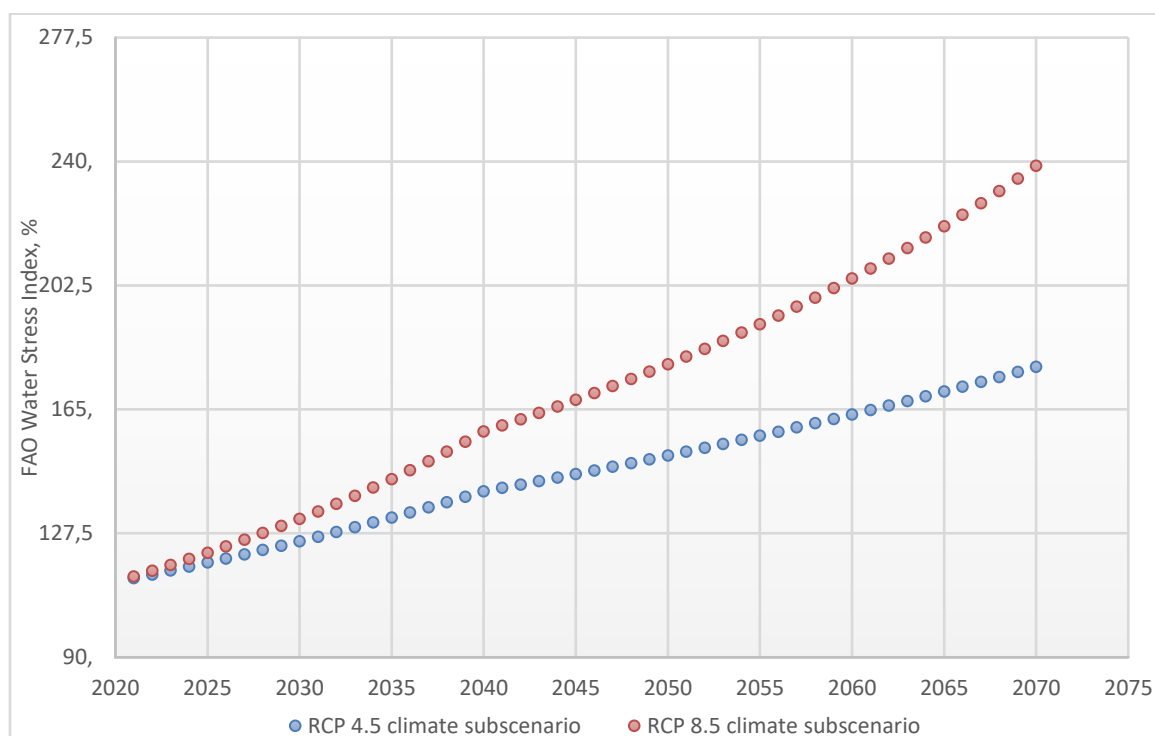
In this regards currently water yields will be equal to 11.5 km<sup>3</sup> determined as difference between available water resources (21.5 km<sup>3</sup>) and above environmental flow value (10 billion m<sup>3</sup>) . If water abstraction is equal to this value then water stress will correspond to 100% if it is more than water yields then water stress will be over 100%.

According to the first scenario, the change in the FAO water stress for 2020-2070 is shown in the graph below (Figure 6).

As can be seen from the figure, currently water stress in Azerbaijan is already above 110%. This figure does not coincide with the figure calculated by the AQUASTAT program, which is 53.7%. According to the AQUASTAT program, Azerbaijan's renewable water resources are 34, 7 billion m<sup>3</sup>(FAO and UN water, 2021), while according to the ministry, this figure was 22.01 and 17.5, respectively, in 2000-2020 and 2016-2020 (STAT AZ, 2022). The main issue to be considered is the fact that the data on water resources are estimated in AQUASTAT as long-term averages, over a period of 30 years from 1961 to 1990 (FAO and UN water, 2021).

The fact that this WSI is more than 100 percent by 10%, which means that the amount of water volume corresponding to this value is taken from the sources that are required for environmental needs of freshwater bodies. For example, if 10 million m<sup>3</sup> of water is currently needed for the environmental needs of rivers in Azerbaijan, in 2021 this figure was about 14% less than needed. This means that the water taken from the rivers is in fact the water needed to ensure the environmental flow of the rivers, and this situation has a negative impact on river ecosystems. In other words, increasing the amount of water allocated for environmental flow while maintaining existing water needs can only be achieved by reducing water losses and shifting to dry resistant technologies.

Figure 6. Scenario 1 Water stress according to RCP 4.5 and RCP 8.5 climate sub-scenarios



This figure 6 shows that, according to the RCP 4.5, if the current approach to water management does not change, the water stress will reach 178% in 2060. According to the RCP 8.5 climate scenario, water stress will reach 238% in 2070.

As was indicated above in this case for scenario RCP 4.5 extra water stress proportion which is equal to 78% will correspond to amount of extra water abstraction from rivers by reducing the water left as an environmental flow in amount of 78% of existing water yield. For scenario RCP 8.5 this will be 138% of existing water yield accordingly.

This shows that if there is no adaptation measure then there will be serious problem with environmental flow provision because of exceedance of the amount abstracted from rivers volume of water of available water yields.

Further increase of irrigation water abstraction (in result of increasing of irrigated land areas) or drinking water demands (as result of population increase) may lead to extra reduction of water left in river as an environmental flow and in some cases, rivers can dry as result.

The table 3 shows the average amounts of water resources under the influence of various factors listed above.

Table 3 Average decennial estimates of water resources and water stress obtained under the first scenario

Years	RCP 4.5 climate subscenario			RCP 8.5 climate subscenario			Total water withdrawals, $10^6 \text{ m}^3$
	Water resources	Water stress	Water deficit for environmental needs $10^6 \text{ m}^3$	Water resources $10^6 \text{ m}^3$	Water stress	Water deficit for environmental needs $10^6 \text{ m}^3$	
2020-2030	20941.38	119.3	-2103.63	20535.94	122.75	-2509.06	13045
2030-2040	19887.81	133.08	-3257.19	18692.19	145.56	-4452.81	13145
2040-2050	19077.92	145.96	-4167.08	17232.75	169.02	-6012.25	13245
2050-2060	18469.58	157.64	-4875.42	16087.75	192.29	-7257.25	13345
2060-2070	17861.25	171.12	-5583.75	14942.75	222.46	-8502.25	13445

As can be seen from the table, water resources will be declining for decades. Negative environmental flow values mean that some of the water used now and, in the future, had to be stored for the environmental needs of the rivers. Currently, the amount of water to be stored in rivers is considered to be 10 billion  $\text{m}^3$ , but it is possible to store only 8 million  $\text{m}^3$ , and this figure will decrease in the future. For example, according to RCP 4.5 scenario, only 50% of the water that should be stored in rivers in 2060-2070 will be retained. According to the RCP 8.5 scenario, environmental flows will comprise of 20% of the total requirements.

## Scenario 2: Realistic water supply scenario

The second scenario (Figure 7) envisages the gradual improvement of water resources management in the country and the reduction of water losses. This will allow water abstraction from rivers to be reduced from the current 13 billion  $\text{m}^3$  to 10.4 billion  $\text{m}^3$  in 2040 and 8.3 billion  $\text{m}^3$  meters in 2070. Reducing water losses by reducing the amount of water withdrawn from water sources will help minimize the negative effects of climate change under RCP 4.5, and even improve the situation slightly. Thus, the water stress will decrease from 114% in 2021 to 110% percent in 2040 and 109% in 2070. This means that by Improving water management and implementing best practices in all water use sectors, it will be possible to completely neutralize the negative effects of climate change under RCP 4.5 sub-scenario. However, this is not the case with RCP 8.5. However, according to the RCP 8.5 climate sub-scenario, the FAO water stress will be 124% and 147% in 2040 and 2070, respectively. This means that even if all possible adaptation measures are taken within the country, water stress will increase according to the RCP 8.5 sub-scenario. However, at the same time, the second scenario does not seem to be much different

from the current one, and it will be possible to minimize the impact of climate change by achieving effective approaches to national water management.

Figure 7 Scenario 2 Water stress according to RCP 4.5 and RCP 8.5 climate sub-scenarios

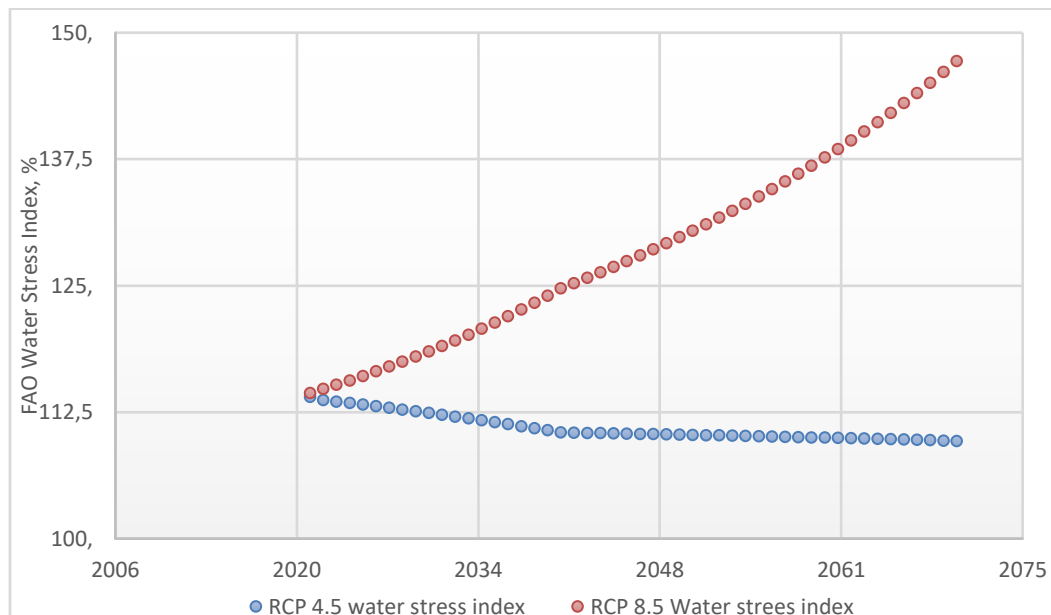


Table 4 shows the estimates of water resources, water stress and water to be stored in rivers for environmental needs in the second scenario. The table shows that in the second scenario, the water stored for environmental needs will be lower than needed amount of water. For example, the value of minus 1735.77 mln m<sup>3</sup> shown in the table for 2020-2030 means that there will be a shortage of 1,735 mln m<sup>3</sup> of 10000 mln m<sup>3</sup> of water for environmental needs. This deficit will increase and reach minus 2576.75 mln m<sup>3</sup> in 2060-2070 according to RCP 8.5. According to RCP 4.5, this figure will be significantly lower - minus 770 mln m<sup>3</sup>.

A comparison of the first and second scenarios reveals the advantages of the second scenario, which is reflected in the reduction of the cost of water stress. For example, in the second scenario, the maximum value of water stress for RCP 8.5 appears to be 145%, whereas in the first scenario, this figure rises to 279%. At the same time, in the second scenario, we see a significant improvement in water supply for both RCP 4.5 and RCP 8.5. This, of course, is mainly due to the reduction of water losses.

Table 4 Average decennial estimates of water resources and water stress obtained under the second scenario

Years	RCP 4.5 climate subscenario			RCP 8.5 climate subscenario			Total water withdrawals
	Water resources	Water stress	Water deficit for environmental needs	Water resources	Water stress	Water deficit for environmental needs	
2020-2030	20941.38	113.16	-1442.84	20648.44	116.36	-1735.77	12384.21
2030-2040	19887.81	111.39	-1127.98	19054.69	121.75	-1961.10	11015.79

2040-2050	19077.92	110.36	-940.75	17845.25	127.76	-2173.42	10018.67
2050-2060	18469.58	110.10	-855.75	16950.25	134.25	-2375.08	9325.33
2060-2070	17861.25	109.80	-770.75	16055.25	142.67	-2576.75	8632

As one can see from tables because of existing current and future water deficits both climate scenarios don't allow further increase of irrigation water abstraction (as a result of increasing of irrigated land areas) or drinking water use as it may lead to extra reduction of water left in the rivers for environmental flow requirements and in some cases rivers can dry as result.

### Scenario 3: Targeted water supply scenario-National and Transboundary scales

The third scenario is called the Targeted water supply scenario (Figure 8). According to this scenario, Azerbaijan, a downstream country, must both improve water management on its territory and prevent the increase in transboundary water intakes, and reduce them if possible. This scenario, like other scenarios, was calculated based on RCP 4.5 and RCP 8.5 semi-scenarios.

As can be seen from the figure, in the third scenario, the water stress is expected to decrease from 115% to 90% in 4.5 climate sub-scenarios. This decrease is mainly due to the gradual reduction of water abstraction from rivers. 4.5 Even if the natural water supply for climate sub-scenario is reduced, a gradual reduction in water losses will not only prevent the negative effects of climate change, but also help reduce water stress by more than 20 percent. In other words, water conservation will not only prevent the negative effects of climate change in the future, but will also provide renewable water sources with better environmental flow.

However, the situation is slightly different in the RCP 8.5 climate semi-scenario. Thus, despite adaptation measures, water stress in the country will gradually increase from 115% to 121%. Even in this half-scenario, the situation will not worsen and the impact of climate change will be minimized. This type of change in the water stress in the third scenario shows that the country has a strong potential to adapt to the effects of climate change, and the proper use of this potential will both improve water supply in the future and provide more environmental flow for water sources.

Figure 8 Scenario 3 Water stress according to RCP 4.5 and RCP 8.5 climate scenarios

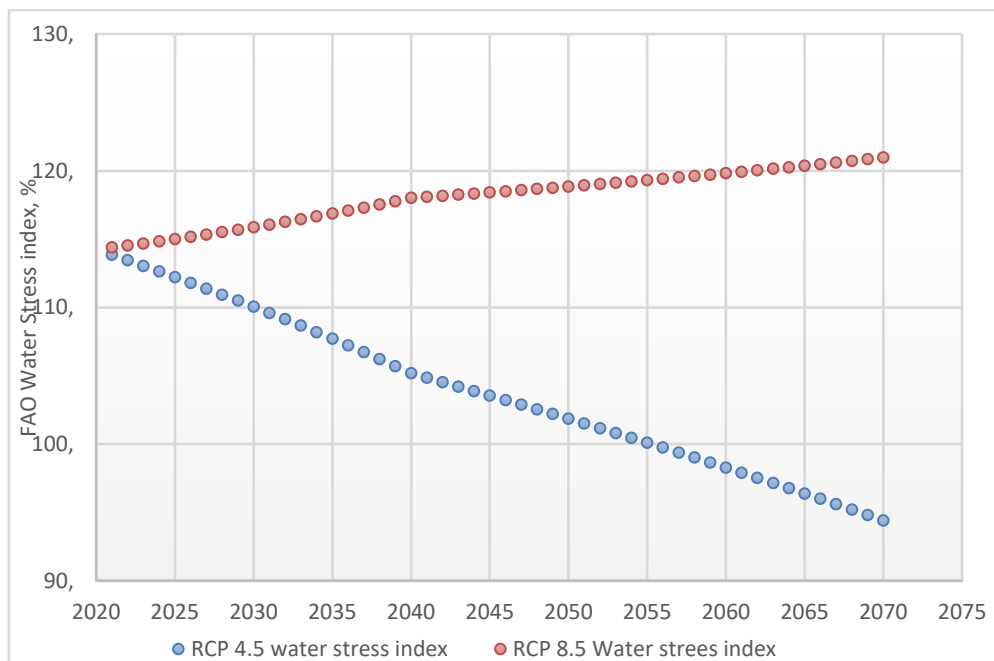


Table 5 shows the changes in water stress and water resource prices for the third scenario. It is stated that the fact that water intakes are 30-40 percent lower than today will prevent an increase in the water stress. According to the RCP 4.5 semi-scenario, water left in river will be by 341.75 thousand m<sup>3</sup> more than one is needed for environmental flow. Excess water for environmental needs means that there will be enough water for all other needs.

Table 5 Average decennial estimates of water resources and water stress obtained under the third scenario (mln m<sup>3</sup>)

Years	RCP 4.5 climate subscenario			RCP 8.5 climate subscenario			Total water withdrawals
	Water resources	Water stress	Water deficit for environmental needs	Water resources	Water stress	Water deficit for environmental needs	
2020-2030	21056.56	111.98	-1327.65	20760.94	115.1	-1623.27	12384.21
2030-2040	20250.31	107.44	-765.48	19417.19	117	-1598.6	11015.79
2040-2050	19690.42	103.38	-328.25	18457.75	118.46	-1560.92	10018.67
2050-2060	19332.08	99.92	6.75	17812.75	119.37	-1512.58	9325.33
2060-2070	18973.75	96.18	341.75	17167.75	120.44	-1464.25	8632

The table also shows that according to RCP 8.5, water resources in Azerbaijan will be 17.1 km<sup>3</sup> in 2060-2070. While 10 billion m<sup>3</sup> should be stored in rivers for environmental needs, 1.4 billion m<sup>3</sup> less water will be stored. Of course, this will create some stress for renewable freshwater sources, but the situation will not be on the verge of crisis. It should be noted that currently the amount of environmental flow for the rivers of Azerbaijan is slightly

more than 2 billion m<sup>3</sup> This means that in the third scenario, even with the severe effects of climate change, the level of environmental supply will partially improve.

It should also be noted that because of this water deficits by RCP 8.5 climate scenario there won't be possible further increase of irrigation water abstraction(in result of increasing of irrigated land areas) or drinking water use as it may lead to extra reduction of water left in river as an environmental flow and in some cases rivers can dry as result.

## Conclusions

The analyzed scenarios show that in order to fully meet the water needs of the country and reduce water shortages, effective water management must be established in the country, as well as transboundary water cooperation with upstream countries.

The analysis of the first scenario shows that if no action is taken, Azerbaijan will become a country experiencing severe water stress, which in turn will have a negative impact on all water-related livelihoods.

This shows that if there is no adaptation measure then there will be serious problem with environmental flow provision because of exceedance of the amount of abstracted from rivers over the volume of available water.

Further increase of irrigation water abstraction (as a result of increasing of irrigated land areas) or drinking water demands (as a result of population increase) may lead an extra reduction of environmental flow left in river or in some cases rivers can dry as result.

The analysis of the second scenario shows that even if there are no changes in transboundary water intake, significant results can be achieved by improving water management in the country. That is, even if deficiencies in transboundary water management have negative consequences, these effects can be balanced by implementing effective water policies within the country. Scenario analysis shows that effective water policy can be achieved, first of all, by reducing water losses.

According to the third scenario, water management can be significantly improved both by strengthening domestic and cross-border water cooperation. If cross-border water intakes do not increase in the future and remain at current levels, effective water management in the country and the elimination of water losses will help to successfully minimize the negative effects of climate change.

It should be noted that further increase of irrigated land areas should happen depending of degree of adaptation measures by scenarios to avoid an extra reduction of environmental flow left in river.

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## **SENSITIVITY ANALYSIS OF PHYSICAL PROCESS AND SIMULATION IN WRF-ARW MODEL FOR MEDICANE IN WEST OF TÜRKİYE**

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### **Abstract**

*The increased cyclone activity in the Mediterranean in recent years has highlighted the need for various measures in Mediterranean countries. On September 25, 2018, a tropical-like cyclone developed in the Eastern Mediterranean. The storm made landfall on September 29 with its highest intensity, causing significant material damage to infrastructure, air transportation, and agricultural areas in the surrounding countries. Additionally, the sudden and intense rainfall led to floods*

*in residential areas. In this study, using various atmospheric boundary layer parameterizations of the WRF-ARW (Weather Research and Forecasting-Advanced Research WRF) numerical weather prediction model, the development of predictions for these systems, particularly affecting the western and southwestern parts of Türkiye during the times when they affect the coastal region in Mediterranean countries, is aimed to be assessed. Specific meteorological observation stations on the western coasts of Türkiye were determined, and through 6 experimental groups, the relationship between meteorological variables observed and predicted values was examined using Pearson, Spearman, Root Mean Square Error, and Bias methods. The parametrization result successful on a regional scale among the experimental groups was presented through mathematical evaluations. Overall, considering the evaluations at the stations, it is observed that EXP03 and EXP06, along with EXP02, EXP04, and EXP05, show stronger correlations with low error values.*

**Keywords:** Mediterranean Cyclone, Medicane, WRF-ARW, Sensitivity of Physical Process, Parameterization, Turbulence, Extreme weather conditions.

## 1. Introduction

Mediterranean cyclones are deep low-pressure systems that form as a result of the interaction between climatic characteristics, topography, and environmental factors in the Mediterranean region. This article examines the formation, development, and movement mechanisms of Mediterranean cyclones, as well as triggering factors and occurrence times. Mediterranean cyclones are significant meteorological events that greatly influence the climate in the Mediterranean region. These cyclones form through complex processes guided by temperature gradients, sea surface temperatures, wind patterns, and other environmental factors. Several fundamental mechanisms contribute to the formation of Mediterranean cyclones. These mechanisms include thermal temperature gradients, the movement of cold air masses over warm sea surfaces, orographic effects, and convergence-tilting mechanisms. The convergence of these factors results in the formation of low-pressure centers and initiates cyclonic rotation. Primary occurring factor of these cyclonic motions is horizontal temperature gradients and difference between sea surface temperatureatmospheric temperature (850, 700 and 500 hPa). Among the triggering factors of Mediterranean cyclonic movements, sea surface temperatures reaching critical values of 26°C-27°C can be mentioned. Especially after the late arrival of the summer season, water masses experience delayed energy loss compared to land, resulting in significant temperature differences between land and water masses during autumn and winter months. During these seasons, continuous lowpressure areas centered around Northern Europe and Russia start to deepen and strengthen. The strengthening of these cold-low centers leads to the descent of atmospheric jet streams, particularly the polar jet streams, down to 30° latitudes. This situation results in a large-scale interaction between the relatively warm water masses in the Mediterranean and the cold air masses, leading to significant instability and water vapor formation. Mediterranean cyclones are a significant part of meteorological events in the Mediterranean region. The mechanisms of formation, triggering factors, and occurrence times interact in a complex manner. A more detailed analysis of these factors can help better understand the predictability and impacts of Mediterranean cyclones. Factors such as atmospheric instability, a moisture source, and irregularity are necessary for the intensification and increased intermittency of Mediterranean cyclones over time. These cyclones or storms can also be referred to as "Medicanes," a term coined because they are defined as hurricanes in the Mediterranean (Mediterranean Hurricane). Mediterranean cyclones are generally more pronounced during the autumn and early winter months. This is due to the more significant temperature gradients in the atmospheric layers during the seasonal transition processes following summer, and the interaction of cold air masses with warm sea surfaces. These conditions encourage cyclonic development. However, Mediterranean cyclones can occur throughout the year with varying intensities and frequencies.

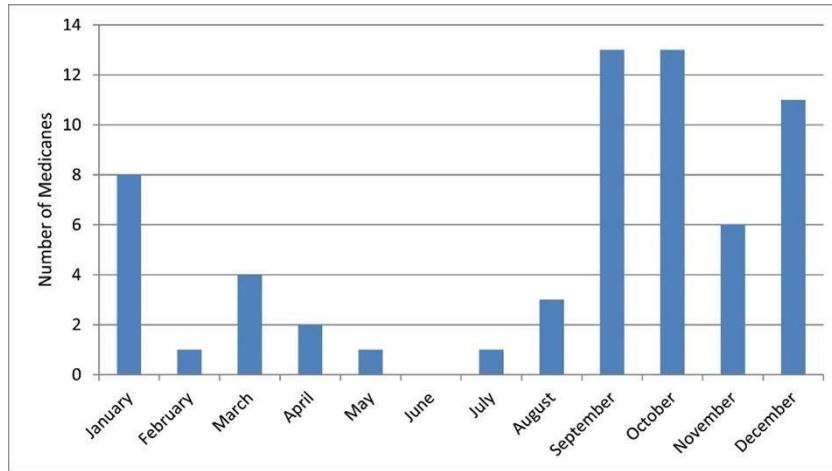


Figure 1. Seasonal number of medicane on Mediterranean basin [1].

This cyclonic system results in various effects such as intense rainfall, large cumulonimbus cells, strong winds, massive waves, and in some cases, highly destructive storm surges. These conditions can cause significant damage to inland areas, leading to catastrophic structural damage and infrastructure issues in cities. From the perspective of urban safety and emergency planning management, it is important to predict where hurricanes will make landfall and how severe they will be. The forecasting and categorization methods developed play a crucial role in determining the roles governments need to play in such situations and in overcoming disasters with minimal damage. These destructive hurricanes result in extremely powerful winds (>80 knots) and, under suitable conditions, lead to the formation of windstorms. Hurricanes lead to adverse conditions such as extreme injuries, fatalities, and forest disarray, forming a mesoscale vortex and particularly affecting the central and western regions of Türkiye [2]. The rise in cyclonic activity in the area can be attributed to the assessment of processes within the formation mechanisms, especially due to climate change. Forecasts suggest that the surface temperature of the Mediterranean Basin will increase due to climate change, with a projected decrease in precipitation by the year 2050. The rise in surface temperature in the region is estimated at 1.54°C, while the increase in sea surface temperature stands at 0.4°C. This encompasses changes in temperatures, precipitation patterns, and the occurrence and intensity of extreme weather events. Additionally, it implies alterations in land and sea usage, pollution levels, air quality, and other contributing factors. While most climate models converge on a significant reduction in Mediterranean rainfall, there are some findings that indicate notable discrepancies in both magnitude and direction for these anticipated changes. Even if future global warming is limited to the 2°C target outlined in the UNFCCC Paris Agreement, there's a risk of a 10-30% decrease in summer rainfall in certain regions. Such a decline would exacerbate existing water scarcity issues and heighten the demand for irrigation to maintain agricultural productivity, especially in countries situated along the southern rim of the Basin [3]. Mediterranean hurricanes have shorter lifespans as they are not fueled by open ocean waters; the Mediterranean Sea is surrounded by landmasses. Therefore, they are typically observed at Category 1 or maximum Category 2+ levels, similar to hurricanes occurring in the Americas. However, the World Meteorological Organization has decided that for such hurricanes occurring in the Mediterranean, wind speeds should be evaluated over shorter durations. As shown in Table-1, classification is determined by considering jumps in wind speeds over minutes or 10-minute intervals, enabling the determination of the stage at which a structure forms over the sea.

Table 1. Mediterranean hurricane wind classification and forms.

Maximum Wind Observation Scale	Mediterranean Tropical Depression	Mediterranean Tropical Storm	Medicane
	hr( $\leq 17$ m/s; $\leq 38$ mps; $\leq 33$ knot)	63–111 km/h (18–30 m/s; 34 knots) m/s; 39–	hr ( $\geq 31$ m/s; $\geq$ 70 mps; $\geq 61$ knot) $\geq$
1 Minute Mean			

10 Minute Mean

$\leq 54 \text{ km/h}$  ( $\leq 14 \text{ m/s}$ ;  $\leq 33 \text{ mps}$ ;  $\leq 29 \text{ knots}$ )

$56\text{--}98 \text{ km/h}$  ( $15\text{--}27 \text{ m/s}$ ;  $35\text{--}61 \text{ mps}$ ;  $30\text{--}53 \text{ knots}$ )

$\geq 99 \text{ km/hr}$  ( $\geq 28 \text{ m/s}$ ;  $\geq 62 \text{ mps}$ ;  $\geq 54 \text{ knot}$ )

This study aims to evaluate the consistency of experiment groups created using various atmospheric boundary layer options of the WRF-ARW numerical weather prediction model concerning the real weather event of the Zorbas Mediterranean Hurricane. The study utilizes meteorological observation station datasets obtained from the Turkish State Meteorological Service to determine the most optimal regional conditions for Mediterranean hurricanes. Figure 2 and 3 represented tilting factor parameters of cyclonic motion and level data taken by ERA5 (European Centre for Medium-Range Weather Forecasts Reanalysis 5) reanalysis  $0.25^\circ \times 0.25^\circ$  spatial resolution monthly reanalysis data.

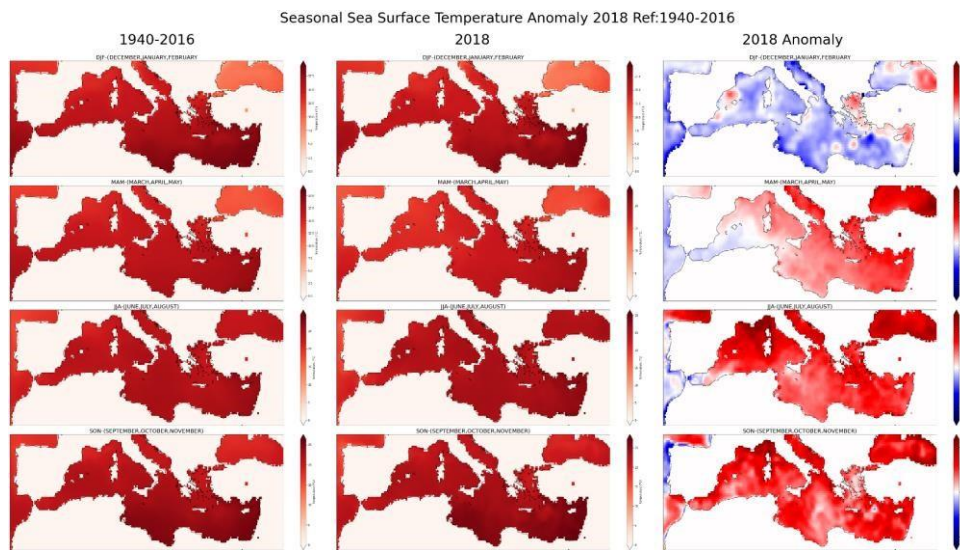
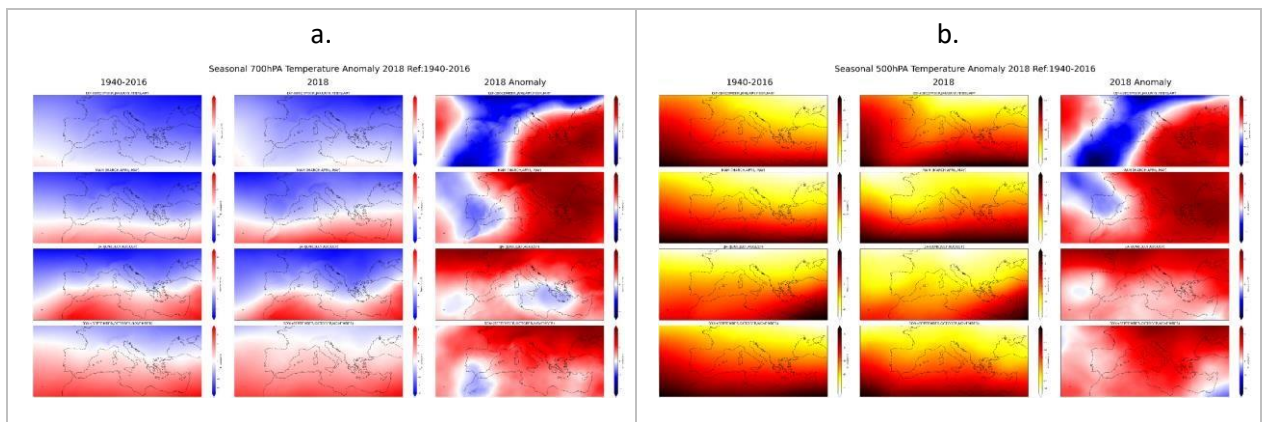


Figure 2. Mediterranean basin 1940-2016 sea surface temperature average and 2022 comparison.

When evaluating sea surface temperature assessments, the Mediterranean generally appears filled with red in anomaly maps, except during the winter season. This signifies a warming of between  $1^\circ\text{C}$  to  $2^\circ\text{C}$ . In the summer months, temperature increase values exceeding  $2^\circ\text{C}$  have been observed for all years. Particularly high sea surface temperatures have been detected in the northwest of Libya, off the coast of Tunisia, along the southern coast of Italy, and along the southern coast of France compared to the reference period. A notable feature of the points where temperatures increase in anomalies is that they correspond to areas where Mediterranean hurricanes are known to intensively form.



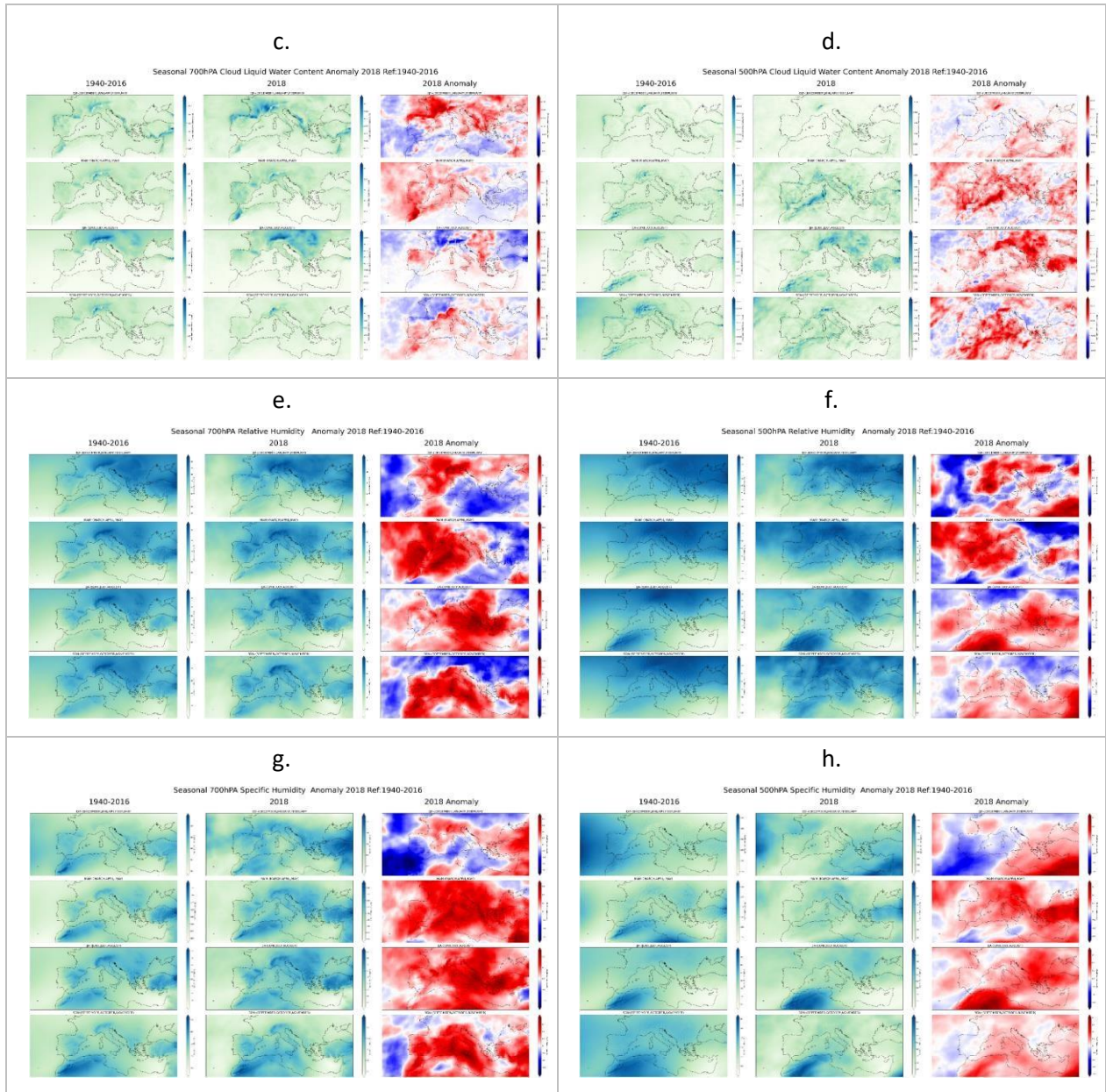


Figure 3. According to reference period 1940-2016 seasonal evaluations, a. 700hPa temperature anomaly, b. 500hPa temperature anomaly, c. 700hPa cloud liquid water content anomaly, d. 500hPa cloud liquid water content anomaly, e. 700hPa relative humidity anomaly, f. 500hPa relative humidity anomaly, g. 700hPa specific humidity anomaly, h. 500hPa specific humidity anomaly.

When examining anomalies in cloud water content, a general decrease is observed over terrestrial areas during the winter and spring seasons, while increases are observed during the summer and autumn seasons. Looking at the averages, values evaluated at 0.0035 kg/kg show approximately 33% changes with an increase or decrease of 0.0010. Increases in averages at the 700hPa level represent an increase in cloud water content in the atmosphere, hence an indication of the availability of moisture conducive to precipitation. The inference drawn from areas experiencing increases aligns with areas where sea surface temperatures have increased, indicating that in addition to the increased sea surface temperature, the amount of water at a certain altitude in the atmosphere has also increased, leading to reaching critical values of water content and sea surface temperature required for hurricanes. Thus, the conditions necessary for increased cyclonic activity are increasing in some areas, which partly explains the frequency of events in recent years. However, these variables alone are not sufficient to explain the increase in this activity. Looking at the evaluations of specific and relative humidity at 700hPa, it indicates a decreasing trend in humidity values in relatively stable terrestrial areas during the winter seasons. Specific humidity values in kg/kg, especially when looking at the coastal areas of the Mediterranean Sea, show an increasing trend in areas

matching the locations of hurricane activities during the summer and autumn seasons. Relative humidity values are relatively lower and stable. However, looking at the areas experiencing increases, they include the Ionian Sea, off the coast of Libya, southwestern Türkiye, and southern Italy. These areas are noteworthy as they are regions where hurricane development can occur during the summer and autumn, as mentioned at the beginning of the article.

## 2. Data and Methods

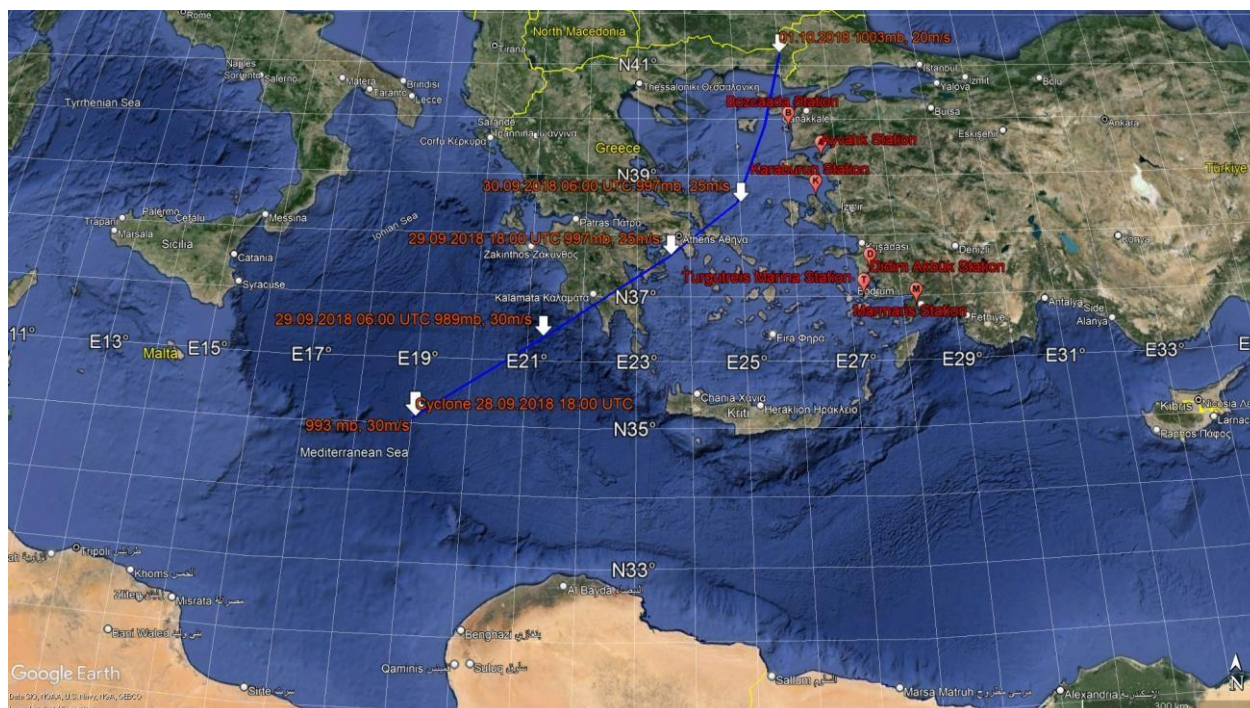
The results obtained from numerical weather prediction models need to be statistically compared with real observational data for meteorological variables that are important in atmospheric processes. This comparison is crucial to assess the forecasting accuracy of the models in predicting weather events and the accuracy of model outputs in simulating past events. Comparing model outputs with real observations helps understand how well the model can predict. It indicates how accurate and precise the model predictions are. The comparison is made to determine how accurately the model predicts or approximates the real values. Verification scores can be used to quantitatively evaluate these comparisons. Comparisons are made to identify the weaknesses and errors of the model. This information can guide the updating and improvement of the model. New training methods or parameter adjustments can be attempted to reduce the difference between model outputs and real observations.

### 2.1. Observation Stations and Parameters

According to selected station data obtained from the Turkish State Meteorological Service (MGM), the nearest points to station locations have been reduced to station latitude and longitude using the interpolation method. Table 3 provides the latitude and longitude information of the MGM stations examined in comparison with the model. Meteorologically, the relationships between model outputs and observation points have been examined in terms of 2-meter temperature, 10-meter wind speed, total and hourly precipitation amounts, 2-meter relative humidity, and surface pressure values using root mean square error, Pearson, Spearman correlation coefficients, and bias method. Observation data and model experiment results were compared hourly for the time period from September 29th, 2018, to October 2nd, 2018.

Table 2. Observed meteorological station information table.

Station National Code	Station Name	City	Latitude (N)	Longitude (E)
17111	Bozcaada	Çanakkale	39.8326°	26.0728°
17175	Ayvalık	Balıkesir	39.3113°	26.6861°
17298	Marmaris	Muğla	36.8395°	28.2452°
17627	Bodrum/Turgutreis Marina	Muğla	37.0003°	27.2595°
18032	Karaburun	İzmir	38.6401°	26.5081°
18808	Didim Akbük	Aydın	37.4128°	27.4289°



#### 2.4. Bias Correction

It is a method based on the difference between the means of independent variables, expressing the deviation of prediction results from actual values. It is a statistical expression showing deviation. When interpreting the deviation values obtained by calculating bias, the proximity to zero and the positive or negative conditions are analyzed. If the calculated value is close to zero, the model does not exhibit a deviation towards the actual values and makes a neutral prediction. A negative BIAS value indicates that the model makes lower predictions than the actual values, while a positive BIAS value indicates that it makes higher predictions.

$$BIAS = \sum_{i=1}^N s_o / N - \sum_{i=1}^N s_f / N$$

#### 2.5. Pearson Correlation

The Pearson correlation is a statistical metric used to measure the relationship between two continuous variables. It determines whether there is a linear relationship between the two variables and the strength of that relationship. The Pearson correlation takes on a value between -1 and +1. A positive Pearson correlation (+1) indicates a positive linear relationship between the variables. This means that as one variable increases, the other variable also increases. A negative Pearson correlation (-1) indicates a negative linear relationship between the variables. This means that as one variable increases, the other variable decreases. If the Pearson correlation is 0, there is no relationship between the variables. The Pearson correlation measures the relationship between variables linearly.

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

#### 2.6. Spearman Correlation

Hypothesis tests and confidence intervals can be used to assess the statistical significance of results and to estimate the strength of the relationship in the population from which the data are sampled. The correlation coefficient is also scaled between -1 and +1, where 0 indicates no linear or monotonic relationship, and the coefficient becomes stronger as its absolute value approaches 1, ultimately representing a straight line or a continuously increasing or decreasing curve expressed by Spearman correlation. Spearman's rank correlation can be used as a measure of monotonic relationship for continuous data deviating from normal distribution, ordinal data, or data with relevant outliers [4].

$$\rho = 1 - \frac{6 \sum D^2}{n(n^2 - 1)}$$

#### 2.7. Mann-Whitney U Test

The Mann-Whitney U test is a non-parametric test used to assess whether there is a statistically significant difference between two independent sample groups. This test is used to determine whether the median values between two variables are different. The Mann-Whitney U test does not require the assumption of normal distribution of data, making it an appropriate option for non-parametric data.

$$Z_c = \frac{\sum_{i=1}^{n_1} R(y_i) - n_1(n_1 + n_2 + 1)/2}{[n_1 n_2 (n_1 + n_2 + 12)]^{0.5}}$$

### 3. Numerical Weather Prediction (WRF-ARW) Pre-Processes

The WRF-ARW model was used to simulate the Zorbas Mediterranean Hurricane, which occurred off the coast of Benghazi in the Mediterranean Sea on October 28-29-30, 2018, and affected Turkey as well. The hurricane initially impacted the southern coast of Greece and later progressed towards the central Aegean Sea. The model was run from October 24, 2018, at 00:00 to November 2, 2018, at 00:00. In the literature, the main working domain resolution for such hurricanes is commonly stated as 27 km. Two nested domains were defined for this

study. These sub-areas were intended to be run at higher resolutions than the main working domain. In this research study, the resolutions of the hurricane simulation in the WRF ARW model for the main working domain, d02, and d03 domains were set as 27 km, 9 km, and 3 km, respectively.

### Zorbas Medcane Case Study WRF-ARW Model Domain and Nested Domain



Figure 5. Case study WPS domain.

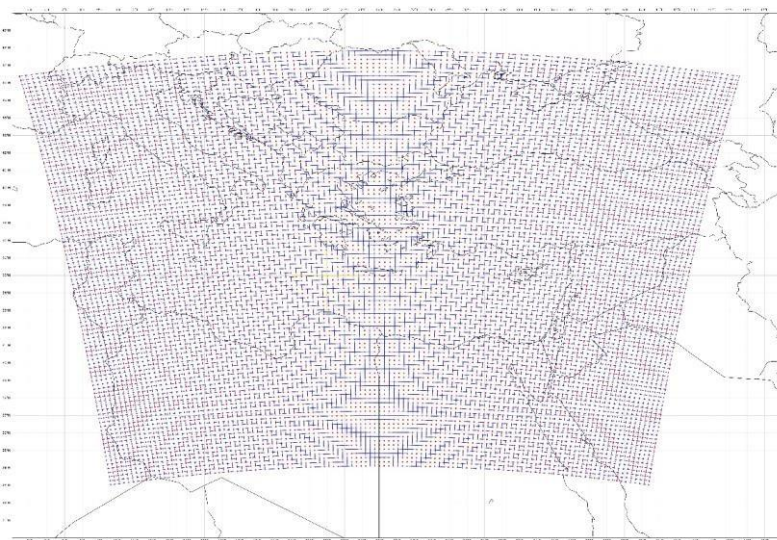


Figure 6. Grid distribution on main domain lambert projection.

The necessary working domain resolution, size, and projection settings were configured using the WRF-ARW atmospheric model. In this study, initially, evaluations were conducted to identify the differences in various atmospheric boundary layer parameterizations in the real-event study as provided in Table 2. Subsequently, the aim was to determine which atmospheric boundary layer parameterization exhibits high accuracy in Mediterranean hurricanes by assessing its compatibility with some meteorological variables obtained through the reanalysis method in the high-resolution dataset.

Table 3. Study WRF-ARW experiment and parametrization table.

Experiment Number	Microphysics Scheme [5]	Planetary Boundary Layer (PBL) Scheme	Cumulus Scheme [12]	Radiation Scheme [13]	Land Surface Scheme [14]	Surface Layer Scheme [15]
EXP01	Thompson	YSU [6]	GrellFreitas	RRTMG	NOAH	Revised MM5
EXP02	Thompson	MYJ [7]	Grell-Freitas	RRTMG	NOAH	Eta Similarity
EXP03	Thompson	MYNN 2.5 Order [8]	Grell-Freitas	RRTMG	NOAH	Eta Similarity
EXP04	Thompson	ACM2 [9]	Grell-Freitas	RRTMG	NOAH	Eta Similarity
EXP05	Thompson	MYNN 3 Order [10]	Grell-Freitas	RRTMG	NOAH	Eta Similarity
EXP06	Thompson	MRF [11]	GrellFreitas	RRTMG	NOAH	Eta Similarity

Turbulence is a scale-dependent process in medium-scale models, meaning that it is typically resolved at higher resolutions in nested domains, which are subdomains within the main modeling area. However, its presence in the planetary boundary layer (PBL) can directly modulate the depiction of mass fields related to forecast problems in a simulation. Accurate representation of turbulent mixing within the lower troposphere is necessary to depict the vertical thermodynamic and kinematic profiles of the atmosphere in medium-scale model predictions (Cohen et al., 2015) [15]. Therefore, turbulence plays a significant role in modeling mass fields related to forecast problems in medium-scale models. Turbulence computation involves calculating both horizontal and vertical wind components, but computing vertical wind components in areas where cyclonic movements occur yields more accurate results. Turbulence kinetic energy is computed by taking the average of all time steps the model runs and then computing the differences in mean wind components for each time step, resulting in  $u'$ ,  $v'$ , and  $w'$ . In fact, the obtained wind components are evaluated as the difference between the wind values at each time step and the mean, i.e., as the standard deviation.

$$\bar{u} - u_i = u'$$

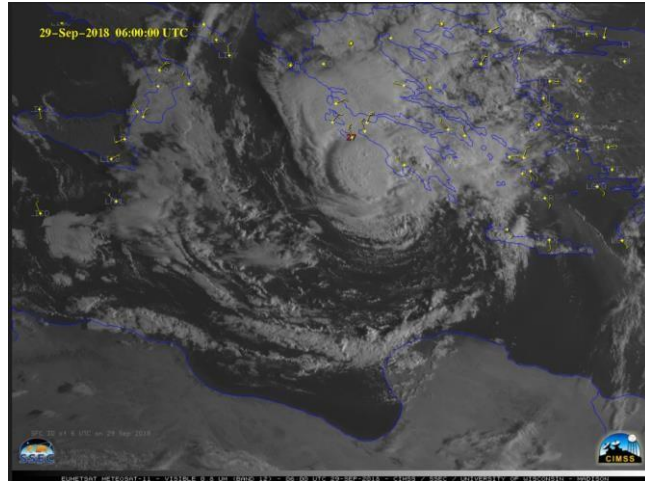
$$\bar{v} - v_i = v'$$

$$\bar{w} - w_i = w'$$

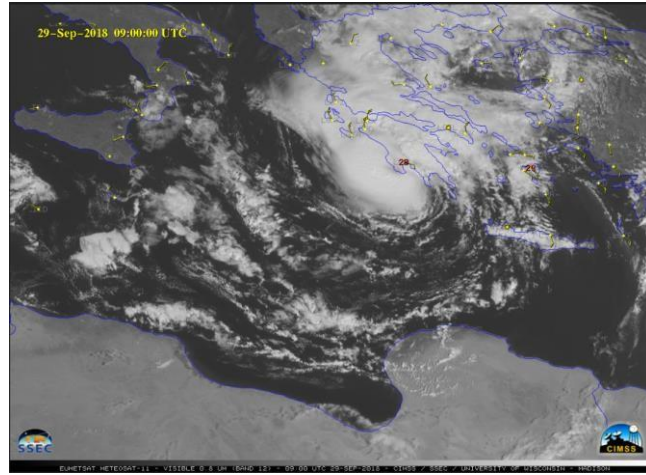
$$tke = \sqrt{u'^2 + v'^2 + w'^2}$$

#### 4. Developed Mediane Cross Section Evaluations

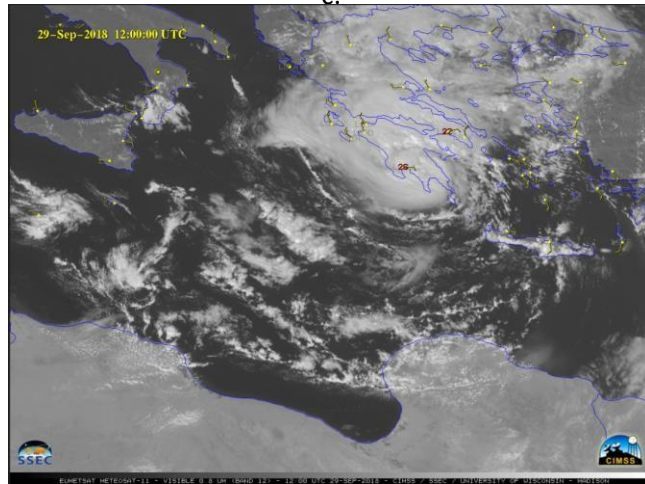
Based on the reported historical track of the Mediterranean cyclone, simulation results have been utilized using 12kilometer resolution WRF-ARW outputs. A cross-section line has been drawn from point 35°N-19°E, which marks the beginning, to point 34°N-24°E, located towards the middle of the island of Crete. The reason for having different latitude and longitude endpoints for this cross-section is due to the simulation results obtained with Lambert projection.



a.



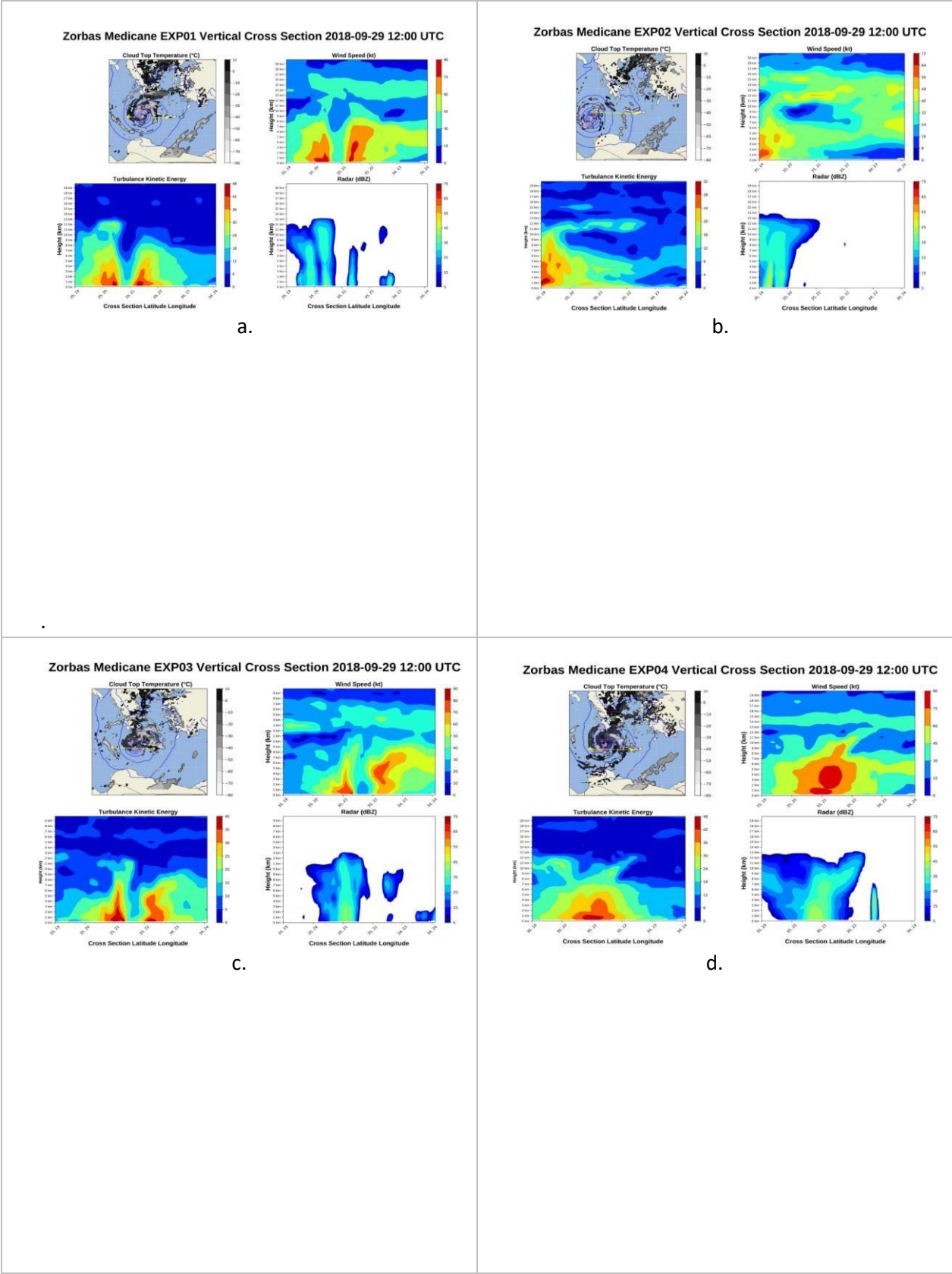
b.



c.

Central pressure of 992 hPa was measured, the cyclone moved westward and then northeast towards Athens and the middle of the Aegean Sea. By October 1st, at 12 UTC, it dissipated near the coast of Gökçeada. The total lifespan of the cyclone was defined from September 28th, at 12 UTC, to October 1st, at 12 UTC, totaling 96 hours. Using the visible 0.8  $\mu\text{m}$  12th band of the EUMETSAT (European Organization for the Exploitation of Meteorological Satellites) METEOSAT-11 satellite, images at 06:00 UTC, 09:00 UTC, and 12:00 UTC on September 29th, 2018 were compared with the locations at the same time step in the model. Additionally, vertical section evaluations included cloud top temperatures, horizontal wind intensity, vertical radar simulation, and calculations of turbulent kinetic energy based on 3D (horizontal, vertical, and cross-sectional) winds.

Figure 7. Case study event satellite images on 29 September 2018, a. 06:00 UTC, b. 09:00 UTC, c. 12:00 UTC.



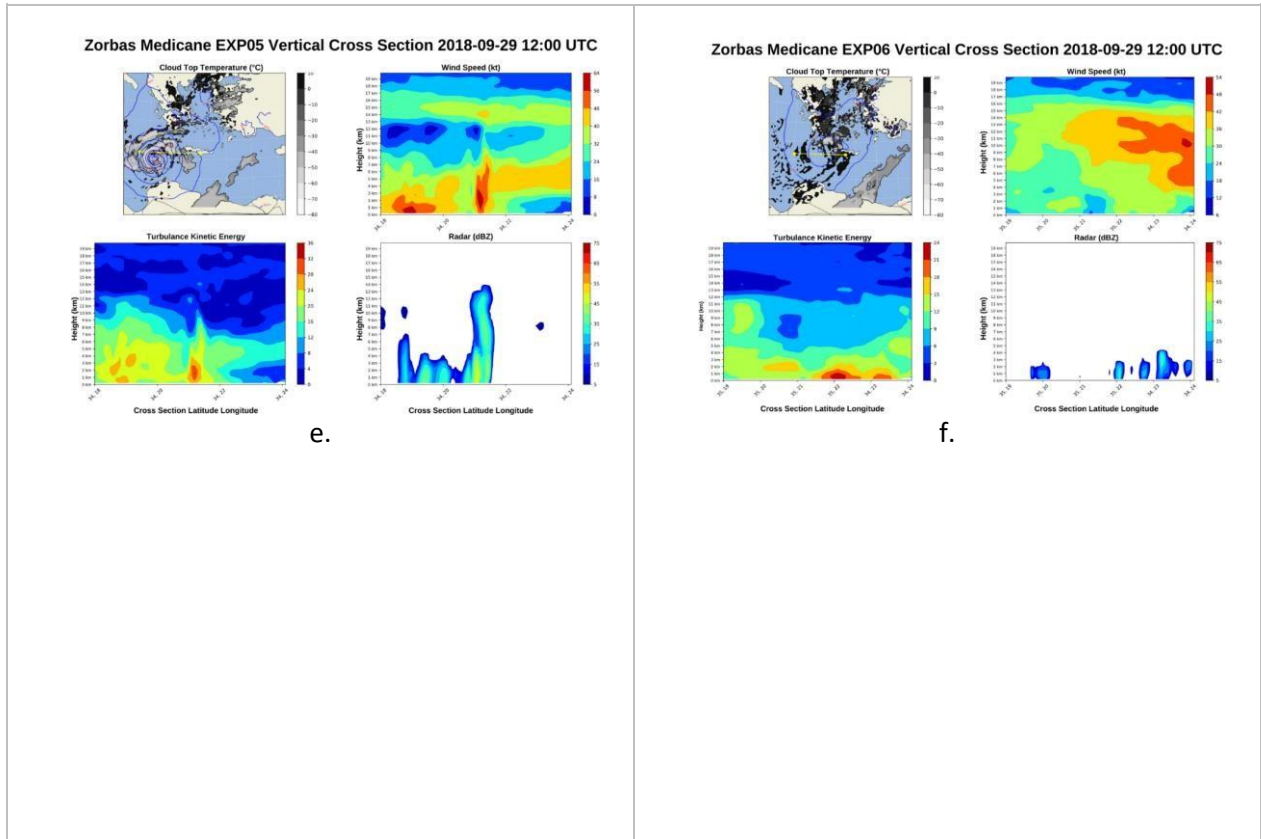
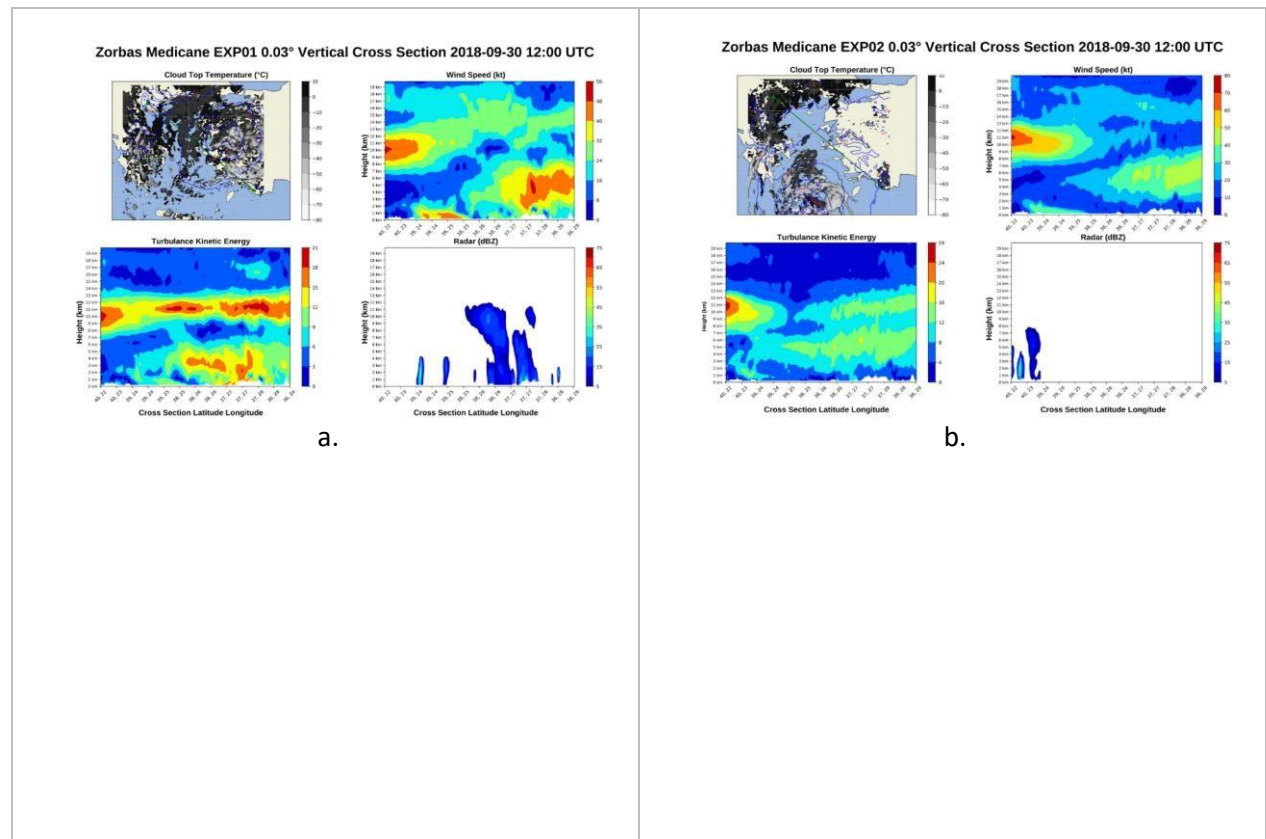


Figure 8. Event described Mediterranean Hurricane time step model evaluations with cross-section, a. EXP01, b. EXP02, c. EXP03, d. EXP04, e. EXP05, f. EXP06.

The EXP01 experiment depicts a cyclone that moved away from the cross-section area. In the simulation results, the cross-section line remained south of the cyclone, and high wind speeds ranging from 90-105 knots were observed near the surface in the region between 35°N-22°E and eastward, where pressure gradients were between 1008, 1004, and 1000 hPa. The wind speed decreased in the western part of the cyclone, west of the 35°N-21°E point, due to the northeastward movement of the cyclone. The expectation of stronger winds in the eastern and northeast-directed sectors of the cyclone was met. The eastern part of the section extends to the middle of Sirte Island, where the cyclone center passed just northwest of the island. However, cloud masses with cloud top temperatures of -80°C were detected over the island due to anticyclonic air movement. EXP02 can be described as a cyclone that did not move as fast as EXP01 and had a centralized pressure gradient of 980 hPa in the simulation results. In this experiment, pressure gradients intensified rapidly, and the storm exhibited a slower northeastward movement pattern. In the area west of the cross-section line, severe winds accompanied by high turbulent kinetic energy were observed at 0-3 kilometers vertical height. Although there were no clear transitions between layers in the general wind profile of the section, wind speeds remained moderately limited, indicating a more stable vertical profile. Radar reflectivity values exceeding 45 dBZ were observed in the western part of the section. Cloud top temperatures of -50°C or colder were detected northeast and southwest of the cyclone center. EXP03 showed that the cyclone moved northeastward by 29/12 UTC, and increased cloudiness was observed in this direction as the cyclone settled in the northeast region. Wind speed and energy processes between layers were compatible. Differences in cloud activity were detected, particularly in the westernmost part of the section. Changes in wind speed and energy with altitude at 0-3 kilometers and 0-6 kilometers were presented together with vertical height values for energy, radar reflectivity, and wind speed. The impact of vertical turbulence on precipitation is indirect. High vertical turbulence increases atmospheric movements, which can promote cloud formation. Clouds are regions where precipitation occurs. Therefore, areas where precipitation intensifies generally coincide with areas where high turbulence values are calculated. EXP04 highlighted a cyclone centered farther north compared to other experimental groups. The centralized pressure gradient value was observed as 984 hPa. Since the section line was positioned 0.5° latitude north, when viewed from the center line to the section line, winds maintained their pattern from west to east even at levels up to 15 kilometers in altitude. The section line intersects pressure gradients of 996, 1000, and 1004 hPa. Especially between the 996 and 1000 hPa gradients, strong winds and turbulent kinetic energy were observed near the surface and up to 7-8 kilometers in altitude,

particularly in the southwest of the center. EXP05 used MYNN 3-level atmospheric boundary conditions and simulated wind speeds between layers and associated turbulence values in the sections as a more mixed and turbulent atmosphere. Cloud top temperatures and cloud density around the eye of the storm were higher compared to other experiments. According to the simulation results, upper-layer wind speeds in the section profiles remained limited in terms of turbulent kinetic energy. EXP06 did not show significant variations in vertical profiles compared to previous times, representing weak vertical movements in the section area. Although the cyclone remained quite distant from the section area, severe winds between layers were observed at the eastern end of the section line. The findings based on the evaluation of kinetic energy along with wind intensity suggested that under normal conditions, radar reflection values would have reached 35-40 dBZ between the points of 35°N-22°E and 34°N-23°E, and cloud top would have reached levels up to 8 kilometers. However, the experimental simulation did not meet this meteorological expectation.



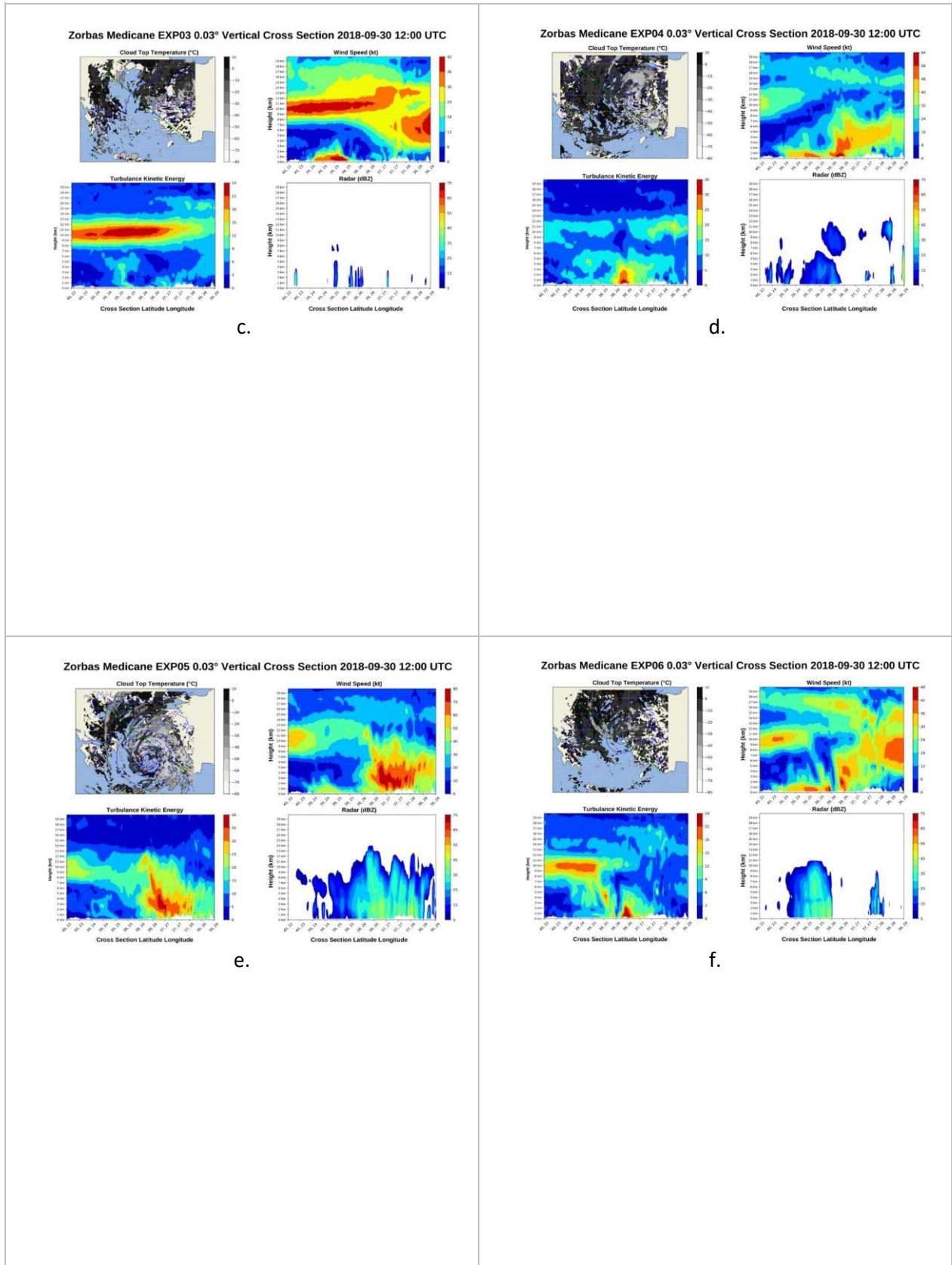


Figure 9. West Türkiye model Medicane movement and behavior  $0.03^{\circ} \times 0.03^{\circ}$  spatial resolution results, a. EXP01, b. EXP02, c. EXP03, d. EXP04, e. EXP05, f. EXP06.

The WRF-ARW experiment outputs were obtained using the nested domain (d03) with a resolution of  $0.03^{\circ} \times 0.03^{\circ}$ . These high-resolution outputs were reduced to point values using the nearest neighbor method for comparison with observation data collected at station locations.

### 5. Precipitation Evaluation

During the evaluation of precipitation, the hourly measured rainfall between 24/09/2018 and 02/10/2018 was cumulated to obtain total daily rainfall. These cumulative rainfall values were used to assess both the total and hourly precipitation performances of the model experiments. Hourly evaluations aimed to determine the models' performance in capturing sudden rainfall events observed in the hourly data. Total rainfall evaluations, on the other hand, were used to assess how well the model simulated the total accumulated rainfall at station points over the entire period.

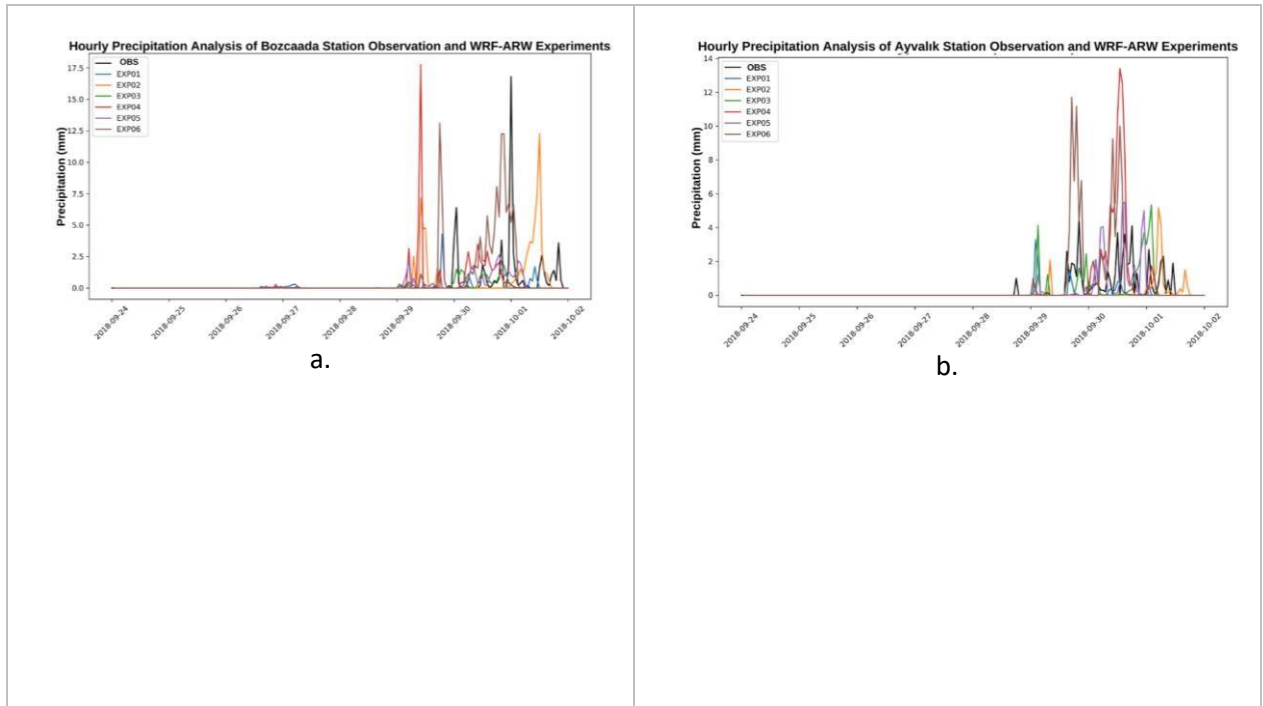
Table 4. Hourly precipitation statistical evaluation between model experiments and stations.

EXP01	EXP02	EXP03	EXP04	EXP05	EXP06	Method
<i>Ayvalık</i>						
0.8	0.92	0.93		1.02	1.64	RMSE
			1.67			
0.15	0.03	0.23	0.35	0.19	0.46	Pearson
0.65	0.28	0.64	0.55	0.55	0.56	Spearman
0.6529	0.1296	0.9455	0.9364	0.6856	0.9944	Mann/Whitney
-0.19	-0.17	-0.07	0.16	-0.06	0.22	Bias
<i>Bozcaada</i>						
1.48	1.97	1.38	2.02	1.43	2.14	RMSE
-0.04	0.01	0.25	-0.01	0.15	0.31	Pearson
0.19	0.23	0.28	0.29	0.26	0.3	Spearman
0	0.0538	0.0026	0	0.0006	0.0001	Mann/Whitney
-0.23	0.07	-0.19	0.03	-0.1	0.34	Bias
<i>Bodrum/Turgutreis</i>						
<i>Mari</i>						
1.84	2.09	1.07	1.1	1.55	1.07	RMSE
-0.03	0.07	0.04	-0.02	-0.03	-0.02	Pearson
0.13	0.29	0.17	0.09	0.01	-0.09	Spearman
0	0.002	0.0002	0.0298	0.0001	0.0006	Mann/Whitney
0.13	0.18	-0.04	-0.04	0.12	-0.04	Bias
<i>Karaburun/İzmir</i>						
1.13	1.73	1.54	2.78	1.48	2.01	RMSE
0.52	-0.03	0.29	0.14	0.12	0.15	Pearson
0.4	0.07	0.44	0.49	0.49	0.33	Spearman
0.0003	0.0208	0	0	0.0001	0	Mann-Whitney
-0.11	0.01	0.04	0.34	0.03	0.13	Bias
<b>Didim Akbük Beldesi</b>						
2.88	3.28	1.78	2.88	2.06	1.77	RMSE
-0.01	0.05	0.42	0.07	0.02	0.02	Pearson
0.25	0.17	0.51	0.36	0.11	0.31	Spearman
0.0066	0.0019	0.0001	0.0744	0.0005	0.0019	Mann-Whitney
0.12	0.14	-0.13	-0.05	-0.05	-0.26	Bias

**Marmaris**

2.74	2.52	2.54	3	2.91	2.36	<b>RMSE</b>
0.35	0.3	0.06	-0.01	0.2	0.48	<b>Pearson</b>
0.39	0.26	0.31	0.19	0.26	0.2	<b>Spearman</b>
0	0.0806	0.0001	0.0304	0.0001	0.0664	<b>Mann-Whitney</b>
-0.06	-0.27	-0.37	-0.37	-0.06	-0.34	<b>Bias</b>

The comparison of different WRF-ARW experiment results with observed data at various meteorological stations reveals notable insights. At the Ayvalık station, while EXP01 had the lowest Root Mean Square Error (RMSE), EXP03 displayed a slightly higher RMSE but demonstrated lower bias and good correlation according to the Spearman's method. Moving to the Bodrum/Turgutreis Marina station, both EXP03 and EXP06 experiments exhibited low RMSE values, with EXP02 showing the highest correlation coefficients. However, the Mann-Whitney U test results favored EXP02 and EXP03 with the lowest p-values. For the Bozcaada station, EXP03 outperformed other experiments with the lowest RMSE and higher correlation coefficients. Similarly, at the Didim Akbük Beldesi station, EXP03 showcased the lowest RMSE and the highest correlation, indicating its superior performance. The Karaburun İzmir station also favored EXP03, showing the lowest error and good correlation. Finally, at the Marmaris station, EXP05 demonstrated the lowest error and good correlation, suggesting its effectiveness. These findings collectively highlight the robustness and reliability of EXP03 across various meteorological stations, indicating its potential for accurate weather predictions.



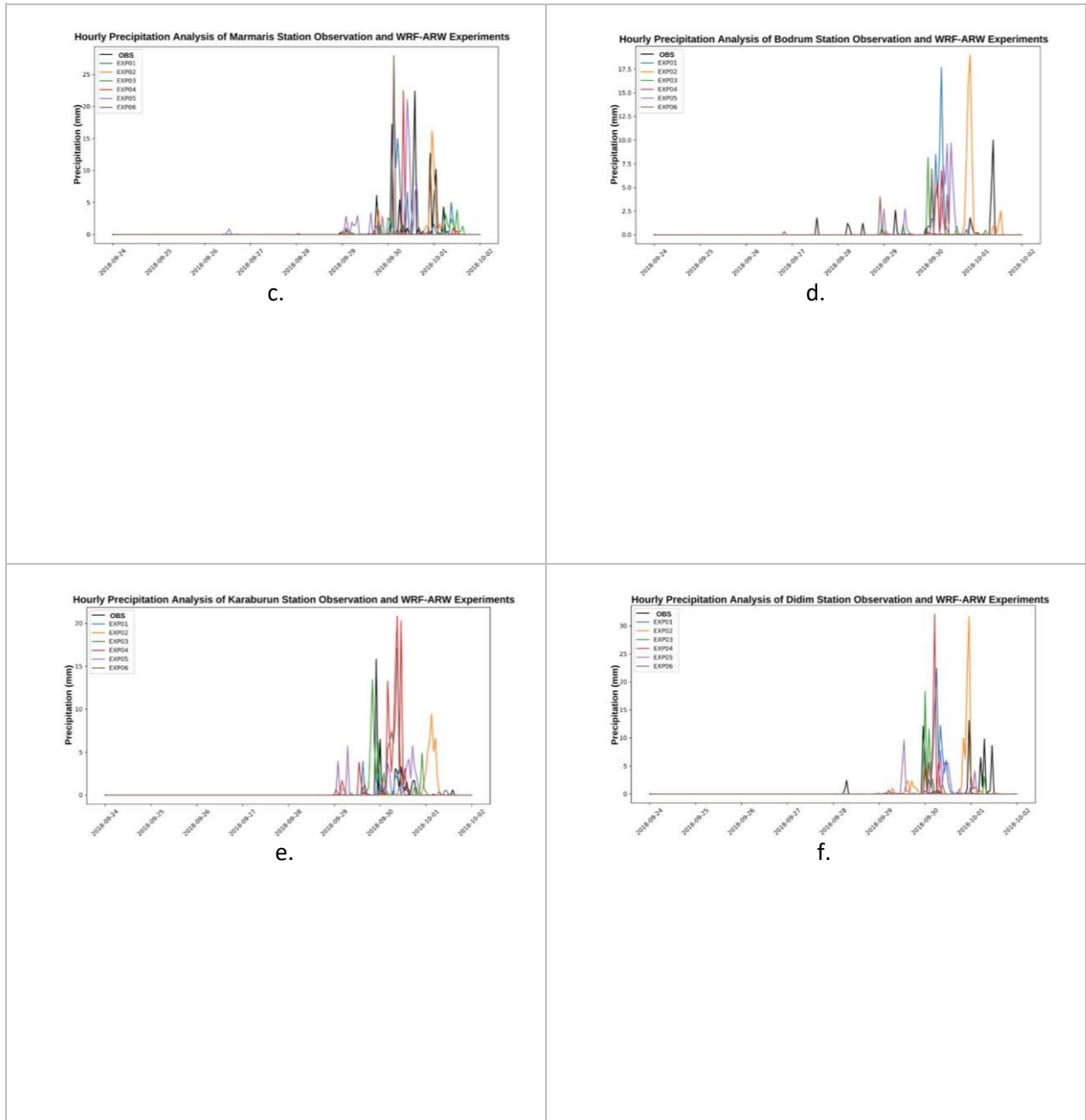
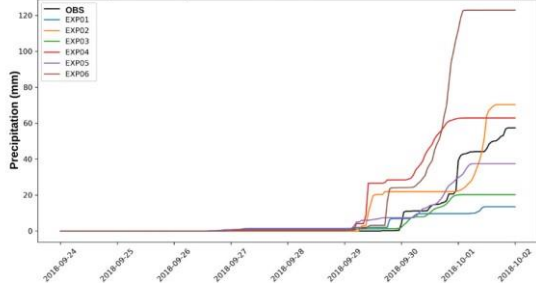


Figure 10. Hourly precipitation comparison on time series model experiments and station observations results, a.

Bozcaada station, b. Ayvalık station, c. Marmaris station, d. Bodrum station, e. Karaburun station, f. Didim station.

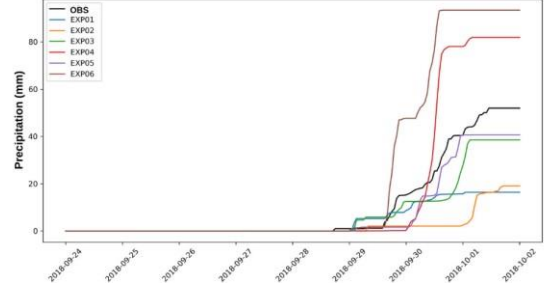
At the Ayvalık station, the EXP03 experiment yielded the lowest RMSE value, signifying its superior performance in accurately predicting rainfall. This experiment also demonstrated the highest correlation coefficients, both Pearson and Spearman, further confirming its reliability. Similarly, at the Bodrum/Turgutreis Marina station, the EXP06 experiment emerged with the lowest RMSE value, showcasing its effectiveness in rainfall prediction along with strong correlation coefficients. Bozcaada station favored the EXP05 experiment, which not only achieved the lowest RMSE but also exhibited a lower bias compared to other experiments, indicating its precision in predicting rainfall values. Didim Akbük Beldesi station echoed similar results, with the EXP05 experiment displaying the lowest RMSE and bias values alongside the highest correlation coefficients. Lastly, at the Karaburun İzmir station, the EXP05 experiment stood out with the lowest RMSE and bias values, coupled with high correlation coefficients, solidifying its position as the most successful experiment in accurately predicting rainfall.

Cumulative Precipitation Analysis of Bozcaada Station Observation and WRF-ARW Experiments



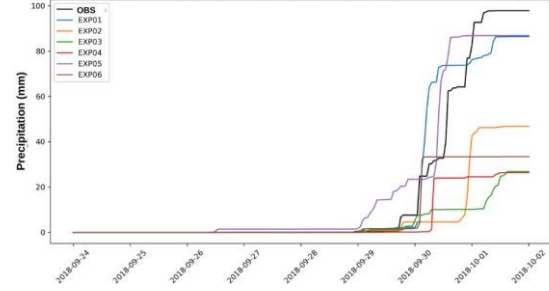
a.

Cumulative Precipitation Analysis of Ayvalık Station Observation and WRF-ARW Experiments



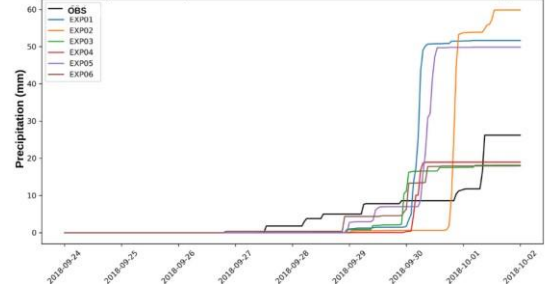
b.

Cumulative Precipitation Analysis of Marmaris Station Observation and WRF-ARW Experiments



c.

Cumulative Precipitation Analysis of Bodrum Station Observation and WRF-ARW Experiments



d.

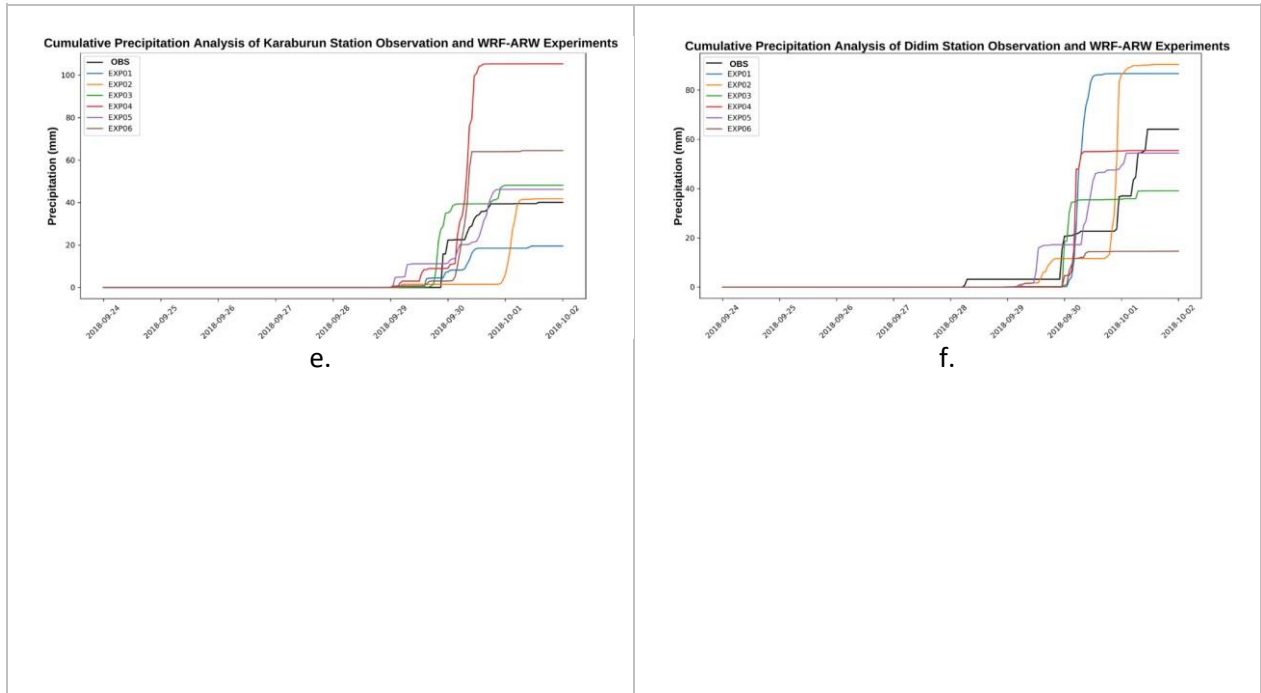


Figure 11. Cumulative precipitation comparison on time series model experiments and station observations results, a.

Bozcaada station, b. Ayvalık station, c. Marmaris station, d. Bodrum station, e. Karaburun station, f. Didim station.

Table 5. Cumulative precipitation statistical evaluation between model experiments and stations.

EXP01	EXP02	EXP03	EXP04	EXP05	EXP06	Method
<i>Ayvalık</i>						
13.13	15.71	6.81	15.32	5.01	23.7	RMSE
0.95	0.86	0.97	0.97	0.98	0.97	Pearson
0.97	0.96	0.97	0.99	0.89	0.98	Spearman
-5.77	-7.96	-2.93	5.44	-2.52	12.35	Bias
<i>Bozcaada</i>						
13.36	8.45	10.37	14.79	5.23	30.34	RMSE
0.89	0.91	0.96	0.88	0.97	0.98	Pearson
0.82	0.82	0.82	0.82	0.82	0.82	Spearman
-4.59	2.88	-3.78	8.09	-0.43	14.56	Bias
<i>Bodrum/Turgutreis Marina</i>						
17.19	14.47	4.56	5.04	15.13	4.12	RMSE
0.8	0.85	0.82	0.79	0.83	0.84	Pearson
1	0.91	0.94	0.96	0.99	0.95	Spearman
6.58	3.17	-0.68	-0.97	5.85	-0.33	Bias
<i>Karaburun İzmir</i>						
9.64	11.4	5.72	30.04	4.72	12.21	RMSE
0.99	0.74	0.98	0.98	0.96	0.97	Pearson
0.87	0.87	0.89	0.85	0.88	0.86	Spearman
-4.69	-4.04	2.69	14.12	1.36	4.97	Bias
<i>Didim Akbük Beldesi</i>						
21.48	13.97	8.49	10.91	7.81	15.92	RMSE

0.89	0.95	0.9	0.89	0.93	0.89	<b>Pearson</b>
0.92	0.9	0.92	0.99	0.92	0.93	<b>Spearman</b>
8.13	3.57	-1.62	1.92	1.51	-7.37	<b>Bias</b>
<i>Marmaris</i>						
9.68	23.26	30.74	27.76	8.91	24.05	<b>RMSE</b>
0.96	0.94	0.94	0.95	0.97	0.92	<b>Pearson</b>
0.92	0.91	0.94	0.94	0.91	0.92	<b>Spearman</b>
0.23	-11.2	-14.19	-12.8	2.37	9.98	<b>Bias</b>

## 6. Conclusion

In summary, evaluations were conducted on the hourly rainfall simulation results at various meteorological stations. At the Bozcaada station, EXP03 experiment exhibited the lowest RMSE value of 1.38, with Pearson and Spearman correlation coefficients measuring 0.25 and 0.23, respectively. According to the Mann-Whitney U test, EXP01 and EXP04 experiments had p-values of 0.0538 and 0.0026, respectively. Examining bias values, EXP02 had the lowest deviation (0.07). Moving to the Bodrum/Turgutreis Marina station, both EXP06 and EXP03 experiments showed the lowest RMSE values of 1.07. However, EXP05 and EXP03 experiments had the lowest p-values according to the Mann-Whitney U test. Bias analysis revealed that EXP03 and EXP04 experiments had the lowest deviation (-0.04).

At the Karaburun İzmir station, EXP05 experiment attained the lowest RMSE value of 1.13, with Pearson and Spearman correlation coefficients measuring 0.29 and 0.44, respectively. Regarding bias values, EXP03 exhibited the lowest deviation (0.04). Similarly, at the Didim Akbük Beldesi station, EXP03 experiment showcased the lowest RMSE value of 1.77, with Pearson and Spearman correlation coefficients measuring 0.42 and 0.51, respectively. Marmaris station favored EXP02 experiment with the lowest RMSE value of 2.36. Overall, Ayvalık, Bozcaada, Didim Akbük Beldesi, Karaburun İzmir, and Marmaris stations showed that EXP02 experiment performed best, demonstrating low RMSE values and biases, indicating more reliable and consistent predictions. Furthermore, Bodrum/Turgutreis Marina station favored EXP03 experiment, while Karaburun İzmir station favored EXP06 experiment, and Marmaris station favored EXP02 experiment, all showing low RMSE values, reflecting accurate predictions. In addition to hourly rainfall, the consistency of cumulative rainfall was also evaluated, providing further insight into the reliability of predictions. EXP05 experiment performed best at the Ayvalık station, while EXP05 experiment also excelled at the Bozcaada station. At the Bodrum/Turgutreis Marina station, EXP06 experiment showed superior performance. Similarly, EXP04 experiment performed well at the Karaburun İzmir station, while EXP05 experiment excelled at the Didim Akbük Beldesi station. Finally, EXP04 experiment performed best at the Marmaris station. Overall, different experiments showed varying degrees of success at different stations, with each experiment exhibiting strengths in certain locations, enhancing the accuracy of weather predictions in those areas.

Table 6. Optimum statistical value for each stations and each meteorological parameters with model experiment codes.

	<b>Ayvalık</b>	<b>Bozcaada</b>	<b>Bodrum</b>	<b>Karaburun</b>	<b>Didim</b>	<b>Marmaris</b>	<b>Method</b>
<b>Pressure</b>	6.07 (EXP01)	2.08 (EXP02)	5.65 (EXP06)	16.65 (EXP03)	1.69 (EXP04)	38.45 (EXP03)	<b>RMSE</b>
	0.93 (EXP02)	0.98 (EXP02)	0.48 (EXP04)	0.92 (EXP02)	0.51 (EXP04)	0.71 (EXP06)	<b>Pearson</b>
	0.94 (EXP02, EXP05)	0.98 (EXP02)	0.51 (EXP01)	0.92 (EXP02, EXP05)	0.58 (EXP02)	0.71 (EXP06)	<b>Spearman</b>
	-5.41 (EXP06)	1.61 (EXP04)	5.44 (EXP03)	16.38 (EXP04)	0.04 (EXP05)	-38.42 (EXP03)	<b>Bias</b>

Meter 2 <sup>Temperature</sup>	1.69 (EXP06)	0.74 (EXP02)	1.8 (EXP03)	1.69 (EXP06)	2.7 (EXP06)	2.27 (EXP02)	<b>RMSE</b>
	0.9 (EXP06)	0.8 (EXP02, EXP05, EXP06)	0.82 (EXP03)	0.9 (EXP06)	0.83 (EXP04, EXP06)	0.84 (EXP01, EXP03, EXP06)	<b>Pearson</b>
	0.88 (EXP04)	0.74 (EXP01, EXP05, EXP06)	0.83 (EXP03)	0.88 (EXP04)	0.83 (EXP04)	0.83 (EXP04)	<b>Spearman</b>
	-0.22 (EXP04)	-0.08 (EXP06)	0 (EXP01), -0.02 (EXP03)	-0.22 (EXP04)	-1.34 (EXP02)	-1.34 (EXP02)	<b>Bias</b>
Hourly Precipitation	0.8 (EXP01)		1.07 (EXP03, EXP06)				<b>RMSE</b>
	0.46 (EXP06)	1.38 (EXP03)	0.07 (EXP02)	1.13 (EXP01)	1.77 (EXP06)	2.36 (EXP06)	<b>Pearson</b>
	0.65 (EXP01)	0.31 (EXP06)	0.29 (EXP02)	0.52 (EXP01)	0.42 (EXP03)	0.48 (EXP06)	<b>Spearman</b>
	-0.06 (EXP05)	0 (EXP01, EXP04)	0 (EXP01)	0.49 (EXP04, EXP05)	0.51 (EXP03)	0.39 (EXP01)	<b>Bias</b>
Cumulative Precipitation	5.01 (EXP05)						<b>RMSE</b>
	0.98 (EXP05)	5.23 (EXP05)	4.12 (EXP06)	4.72 (EXP05)	7.81 (EXP05)	8.91 (EXP05)	<b>Pearson</b>
	0.99 (EXP04)	0.82 (All Experiment)	1 (EXP01)	0.89 (EXP03)	0.99 (EXP04)	0.94 (EXP03, EXP04)	<b>Spearman</b>
	-2.52 (EXP05)	-0.43 (EXP05)	-0.33 (EXP06)	1.36 (EXP05)	1.51 (EXP05)	0.23 (EXP01)	<b>Bias</b>
Relative	15.32 (EXP01)			10.96 (EXP06)	15.79 (EXP03)	14.05 (EXP06)	<b>RMSE</b>
	0.64 (EXP01)	-2.69 (EXP02)	15.97 (EXP03)	0.6 (EXP06)	0.71 (EXP06)	0.81 (EXP06)	<b>Pearson</b>
	0.63 (EXP01)	0.84 (EXP06)	0.58 (EXP06)	0.63 (EXP02)	0.71 (EXP06)	0.81 (EXP06)	<b>Spearman</b>
	7.62 (EXP02)	0.82 (EXP06)	0.57 (EXP06)	0.35 (EXP06)	-4.24 (EXP01)	-1.15 (EXP05)	<b>Bias</b>
Wind Speed	3.93 (EXP03)						<b>RMSE</b>
	0.82 (EXP02)	5.2 (EXP03)	3.37 (EXP06)	5.15 (EXP01, EXP05)	-	2.7 (EXP01)	<b>Pearson</b>
	0.78 (EXP01, EXP02)	0.83 (EXP03)	0.44 (EXP04)	0.82 (EXP02)	-	0.27 (EXP01)	<b>Spearman</b>
	2.93 (EXP03)	0.86 (EXP03)	0.45 (EXP05)	0.77 (EXP02)	-	0.3 (EXP03)	<b>Bias</b>
		4.03 (EXP06)	2.12 (EXP06)	2.78 (EXP03)	-	1.72 (EXP06)	

Taking into account the evaluations at the stations, it is observed that EXP03 and EXP06 exhibit low error values, while EXP02, EXP04, and EXP05 show stronger correlations. Generally, it is observed that different experiments perform best at different stations. In pressure evaluations, although EXP02 and EXP03 experiments are more consistent in northern regions, EXP06 has yielded more successful results in the southern regions. In terms of precipitation consistency, both hourly and cumulative evaluations have found EXP05 and EXP06 to be successful. In a broad generalization, experiments that consistently present the lowest error values and strongest correlations for the selected six stations emerge as EXP03 and EXP06. The combination of the MYNN 2.5-degree atmospheric boundary layer scheme and the MRF scheme has produced results that are highly consistent with observations, especially regarding rainfall and wind variables.

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# GLOBAL RAMIFICATIONS OF INADEQUATE SOLID WASTE MANAGEMENT AND ITS INFLUENCE ON CLIMATE CHANGE

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## ***Abstract***

On a global scale, the growth in population and rising income levels has led to the immense generation of solid waste posing a significant threat to both human well-being and the environment. The majority of solid waste generated is composed of organic content, making up 65% of global waste, including food and other green waste. It is projected that annual waste generation will reach 3.88 billion tonnes by 2050. Climate change is evident and the generation of GHGs like methane (CH<sub>4</sub>), carbon dioxide (CO<sub>2</sub>) and nitrogen oxide (NO<sub>2</sub>) are increasing significantly due to inadequate waste management practices. Methane and other gases are emitted through the breakdown of biodegradable materials in the waste stream, including items such as paper, food scraps, and yard trimmings. However, methane is 25 times more potent than carbon dioxide (CO<sub>2</sub>) and has a notable impact on the global climate. The GHG emissions from the waste sector contribute around 5 % which is quite minor. In developing nations, the unavailability of data makes it challenging to estimate and formulate mitigation policies and strategies for reducing greenhouse gas (GHG) emissions from the waste sector. Nonetheless, the waste sector is globally quite large, highlighting that prevention and recovery are significant to mitigate emissions by analyzing the current waste management system. Diverse models created by various international organizations, such as the Intergovernmental Panel on Climate Change (IPCC Tier-1), United Nations Climate Change (UNCC), and Environmental Protection Agency (EPA), offer simplified GHG emission calculators. It is advisable to enhance resource recovery, promote recycling, implement composting, adopt landfill gas collection and energy recovery technologies, and adhere to environmental regulations. These measures can effectively contribute to the reduction of greenhouse gas emissions and environmental impact, fostering the attainment of a carbon-neutral society.

**Keywords:** Solid waste, climate change, management, pollution, environment.

# SUSTAINABLE WATER MANAGEMENT: RAINWATER HARVESTING

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## ABSTRACT

*It is becoming more difficult to access clean water resources day by day due to reasons such as population growth, increasing industrialization and global warming. This situation necessitates innovative approaches to the management of sustainable water resources. In recent years, green technological solutions have become very important in terms of their low cost and positive environmental effects. One of the methods that provide a more sustainable water supply solution to water scarcity in the world and in our country is rainwater harvesting. Rainwater harvesting embodies sustainability with its collection, storage and design features. Although rainwater harvesting is widely used for purposes such as agricultural irrigation in some arid regions of the world, it can also be used as drinking water and utility water with appropriate treatment technologies. Especially as a result of global warming and natural disasters, living beings have difficulty meeting their drinking water needs as a result of disruption in the use of network water and deterioration of water quality. The rainwater harvesting system, created by integrating different treatment technologies and process designs, makes sustainable drinking water use possible. After rainwater harvesting, the water is purified by making it compatible with drinking water standards. Sustainable management of water resources has an important role in long-term economic development. In this sense, recycling rainwater is of great importance.*

**Keywords:** *Sustainability, Rainwater Harvesting, Sustainable Water Management.*

## INTRODUCTION

Many studies are being carried out on environmental and climate change that threatens the world and life. Chief among these are the activities of the United Nations. In 2015, the United Nations proposed 17 Sustainable Development Goals in order to draw attention to sustainability, raise awareness and create solutions that will mobilize the world's countries on this issue (Dahlmann et al., 2019). With these targets, social, environmental, economic and institutional indicators have been tried to be determined for sustainable development. The set goals are as follows (Hosagrahar, 2016; Biermann et al., 2017):

1. End poverty,
2. No more hunger,
3. Healthy individuals,
4. Quality education,
5. Gender equality,
6. Clean water and sanitary conditions,
7. Accessible and clean energy,
8. Decent work and economic growth,
9. Industry, innovation and infrastructure,
10. Reducing inequalities,
11. Sustainable cities and living spaces,
12. Responsible production and consumption,
13. Climate action,
14. Life in water,
15. Terrestrial life,
16. Peace and justice,
17. Partnerships for goals.

When UNDP targets are examined (Target 6. Clean water and sanitary conditions), (Target 7. Accessible and clean energy), (Target 11. Sustainable cities and living spaces) and (Target 13. Climate action, actions to avoid the effects of climate change), these The four targets appear to be related to water sustainability and water security.

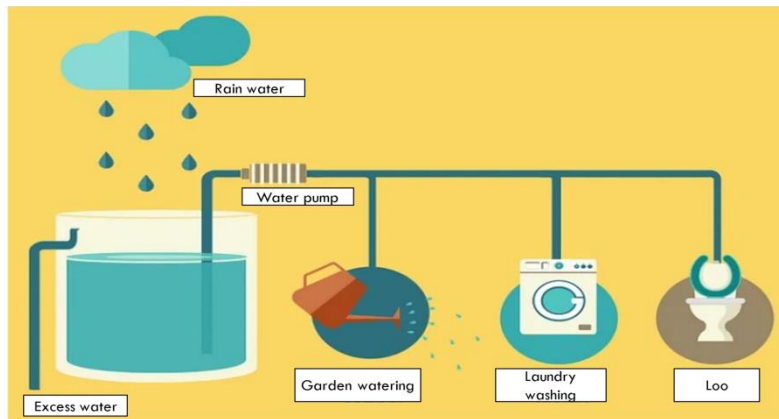
The European Union has also drawn a road map covering the structural and technological changes required to transition to a sustainable economy by 2050 (Bianco 2018: 238). For this purpose, "An Action Plan for Circular Economy" has been prepared (Browne & Weiss, 2014). It is recommended that processes be carried out in accordance with the circular economy at every stage, from the design of the products to their consumption. The European Union has also implemented the Zero Waste project for the circular economy. For this purpose, it is recommended to reduce packaging waste and give priority to green products in public procurement (Biermann et al., 2014). The focus of achieving these goals is on the safety and sustainability of drinking, domestic and irrigation water. It is necessary to ensure water security to create a sustainable future and realize the circular economy.

A number of measures can be taken and projects can be developed to ensure water sustainability, reduce environmental impact and make life more sustainable (Abdulla & Al-Shareef, 2009). Rainwater harvesting is a promising and sustainable technology that will contribute to achieving the stated goals (Correa et al., 2018). Rainwater harvesting can be a solution to water needs in cities and rural areas (Vargas-Parra et al., 2013). Benefits such as decentralized water supply and local water security can also be achieved. The study is based on a comprehensive literature review on rainwater harvesting.

## RAINWATER HARVESTING

Ensuring sustainable use of rainwater can help minimize the effects of climate change (Shadmehri Toosi et al., 2020). It can reduce the effects of climate change during long drought periods by storing rainwater during heavy downpours (Li et al., 2017). Rainwater harvesting is a process that involves collecting, storing, purifying and distributing rainwater (Campisano et al., 2017).

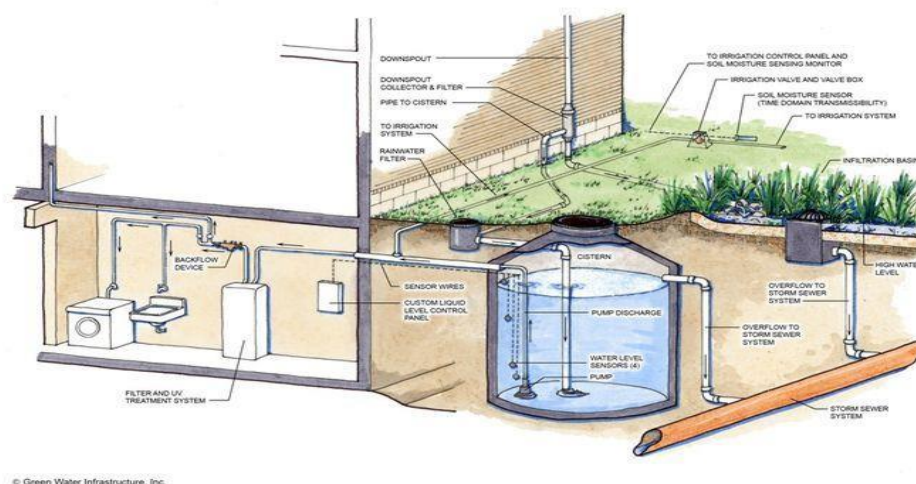
**Figure 1.** Rainwater Usage Areas



**Reference:** İnanç, 2021

Rainwater harvesting method is a method that will contribute to sustainable water management. Rainwater collected in tanks can be used as utility, irrigation and drinking water (Stephan & Stephan, 2017). Ensuring water security is possible by diversifying water resources from today to tomorrow and discovering new ways to provide water (Marlow et al., 2013).

**Figure 2.** Rain Water Harvesting



**Reference:** Özman, 2018.

Rainwater is collected from roofs, roof terraces, impermeable surfaces or with the help of various devices made for this purpose (Lee et al., 2016). This collected and stored water is distributed to the water network as an additional resource after being purified in accordance with its intended use (Haque et al., 2016). Rainwater can be used as an alternative to solve water scarcity and save money (Taffere et al., 2016).

Rainwater harvesting is one of the solutions to adapt to climate change, reduce water stress and create sustainable water supply (Jiang et al., 2013). It can reduce soil erosion caused by rain and prevent floods caused by uncontrolled urbanization (Campisano & Modica, 2016). Water obtained through rainwater harvesting eliminates the need to build new infrastructure for centralized water infrastructure (Lopes et al., 2017).

The perspective on the rainwater harvesting method may vary from country to country. Japan, the United States, Germany, and Australia have allowed the use of rainwater for non-potable purposes (Costa Pacheco et al., 2017). In France, the use of rainwater for general purposes such as drinking and personal hygiene is not allowed (Vialle et al., 2015).

## CONCLUSION

Rainwater harvesting is one method of providing healthy water in places without safe surface or groundwater sources. Healthy water supply ensures that society's water needs are met, food needs are met through agricultural irrigation, and animals' water needs are met (Vargas-Parra et al., 2013). In this context, rainwater harvesting may be a key strategy to provide water and food needs in developing countries (Amos et al., 2016). Rainwater harvesting improves water security and energy use efficiency. Therefore, government incentives are essential for the system to be financially attractive (Wanjiru & Xia, 2018). Expanding rainwater harvesting is economical. It reduces floods in cities and excessive water flow caused by rainwater in flood risk areas. (Deitch & Feirer, 2019). It is one of the primary measures to be taken against extreme events such as drought and flood that may occur due to climate change. Rainwater harvesting can be considered an important strategy in ensuring sustainability.

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# THE EFFECT OF CLIMATE CHANGE ON FLOOD WATER LEVELS

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## ABSTRACT

*Climate change is expected to increase the gap between the extremes in weather events. The effect of it on hydrology can be seen in the increase of probable maximum flood discharge values, which will eventually increase the flood water levels. Urban floods in Türkiye are among the deadliest disasters that the cities face. In this study, a numerical hydrodynamic model of a drainage channel in Kötekli, which is a growing neighborhood in Muğla, Türkiye, was constructed and executed for normal and extreme weather conditions. A hydrologic model was developed to generate the inflow hydrographs of the model using a regular and an extreme rain event for the region. Due to the growing dynamics of the neighborhood, the channel underwent human interventions like contraction in the section, increase in bed elevation due to uncontrolled dumping of wastes and increase in flow resistance due to the same reason. These effects were included in the model. The model results reveal the regions in danger of flooding in case of an extreme rain event.*

**Keywords:** Urban Floods, Hydrodynamic Model, Hydrologic Model

## INTRODUCTION

Climate change is associated with varying weather patterns due to natural and human factors [1, 2]. United Nations showed that the last decade (2011-2020) had been the warmest among all the recorded ones and the trend is ongoing as the last four decades was the highest four among all the recorded ones since 1850 [2]. IPCC Sixth Assessment Report shows the effect of climate change on the weather extremes [3]. The effects of it are observed as increases in temperature as well as precipitation. The increase in precipitation intensity causes flooding and it can be deadly when it is near the cities. In 2021, in the Western Black Sea region of Türkiye, a flooding catastrophe led to the loss of more than 80 lives. Although it has direct relation with the lack of infrastructure [4], the weather records show that almost half of the total annual precipitation occurred in two days as measured by the gauging stations in the area [5]. Rapid and excess urbanization is another agent for urban floods along with climate change. Turkish Statistical Institute shows that the population of Türkiye has been doubled in the last 44 years [6]. In addition, with the development in industry, the population in the villages decreased leading to a much more increase in the city population. An example of a population increase in a small area was observed in the Kötekli neighborhood in Muğla which is very close to Muğla Sıtkı Koçman University and hosting thousands of students nowadays. The historical satellite pictures of the region indicate that the settlements have increased from almost none to hundreds in 40 years [7]. Being located inside Muğla, which is receiving the second highest precipitation annually in Türkiye, Kötekli is under the effect of urban floods in the last years. Inside of it, there is a drainage channel built to discharge rainwater safely outside the area. However, with the increase of the number of buildings around it, the sections of it got narrower and several bridges and culverts were added to it which all decrease the discharge capacity of the channel. It is still questionable whether this channel can discharge the increasing flood rates with the effect of climate change. The behavior of the channel against a known precipitation can be observed by first making a hydrological model and then by forming a hydrodynamic model. For these purposes, there exist some methods available in the literature. The open access software HEC-HMS and HEC-RAS are known to be used widely and safely to apply these methods [8, 9]. In this study, the aim is to test whether this channel will be capable of discharging the amounts when the precipitation will be in extreme limits as dominated by the climate change. To achieve this aim, site investigations were conducted first to increase the quality of the terrain data that we had from the satellite images. Then, a hydrological model was formed and executed to estimate the flow rate amounts during normal and extreme conditions. A two-dimensional hydrodynamic model was constructed to run the discharges and observe the flood water levels. The results indicated the regions that can be flooded under extreme conditions.

## METHOD

The satellite images of the region were obtained from the open access NASA ASTER Global Digital Elevation Map repository [10]. The region of the present study is located in Muğla Türkiye. Two pictures from the site investigation are given in Figures 1 (a) and 1 (b).



Figure 1. (a) Channel portion passing through the buildings with a bridge over it (b) The channel portion outside the settlement area

The downloaded digital elevation map does not include the information related to the hydraulic structures like bridges and culverts. Before starting the modeling work, the research team conducted a site investigation to determine the locations and the dimensions of the hydraulic structures. Besides, the overall quality of the satellite images was tested by visually observing the elevation changes in the area and comparing them with the map results. The terrain information that is to be extracted from the satellite maps was obtained after the corrections. Then, the hydrological model was developed as a means of estimating the streamflow amount from the precipitation data. For this purpose, an open-source rainfall-runoff modelling software (HEC-HMS) developed by the US Army Corps of Engineers was used. As transferred by [8], HEC-HMS simplified the hydrologic cycle into four elements. Having the precipitation data as input, basin model operation is applied first to define the losses through the basin as infiltration, evaporation and transpiration considering the soil and land cover properties of the basin. Then, the precipitation to the basin is transformed into outlet hydrograph by using direct runoff technique. The third step is to add the groundwater effects to runoff by using a base flow method. The last step of the analysis is to route the flood discharge into the subbasins of the basin. In our model, hydrological model was constructed for two conditions: Normal and Extreme precipitation. The precipitation amount for the normal condition was obtained from the data of the Meteorological Services of Turkey as the daily average of the rainy days in the wettest month (December) of Muğla. This estimation resulted in a precipitation amount of 20 mm. For the extreme condition, this value was multiplied by 9. It was observed that when the extreme value multiplier was increased further, all the region was flooded and special attention to the channel could not be given. Therefore, it was kept as 9. The hydrological model was set by first defining the basin after defining the inflow location. This location was estimated on site. The curve number (CN) of the land was used as 70. The Muskingum method was used with parameter values,  $k$  and  $x$  as 0.25 and 0.5. The output hydrographs were estimated from the software for two conditions to use them as the inflow condition of the hydrodynamic model.

The hydrodynamic model was set up and executed by using the open-source HEC-RAS software of the US Army Corps of Engineers. An unsteady, two-dimensional modelling approach was selected to apply in the model which assumes the accelerations in the vertical direction are negligible [9]. This modelling approach has two alternatives in HEC-RAS which are shallow water equations and diffusive wave approaches. The shallow water equations (SWE) neglect the vertical momentum equation of the well-known Navier-Stokes equations and replace it by the hydrostatic pressure approximation in the vertical direction. The diffusive wave (DW) approach is a simpler approach than SWE and generally used to save computational time. It neglects unsteady, advection and viscous terms of the Navier-Stokes equations besides hydrostatic pressure approximation in the vertical direction. SWE approach was selected to use in this study to be on the safe side in terms of computational accuracy. Besides, HEC-RAS uses sub-grid bathymetry approach to converge to the correct results in coarse grids. The preliminary tests were conducted to estimate an optimized grid in terms of convergence and run time. The decision on the cell size of the model was given considering the largest cell size which is not leading to errors in the numerical solution due to diffusion and the use of sub-grid technology in HECRAS. The converged computational grid has 1 m cell size in the refinement region which is inside

the channel and 10 m cell size outside of the channel. This procedure resulted in a total of around 28000 cell counts in the grid. The hydraulic structures in the channel reach are added manually by defining the dimensions of them in the terrain. For bridges and culverts HEC-RAS applies a one-dimensional approach by adding their added friction losses to the energy equation. The outlet boundary condition was defined as infiltration through the farmland by following the physical realities of the region. The used 2D grid, with the refinement region, inlet and outlet locations are given in Figure 2. Land cover data of the region was downloaded from the European Space Agency (ESA) website which is freely available [11]. The land cover data was used to assign Manning numbers of the region which are used to estimate the added friction when establishing the momentum equation. Total simulation time of the hydrodynamic model was selected as 24 hours with 1 second of time step size.

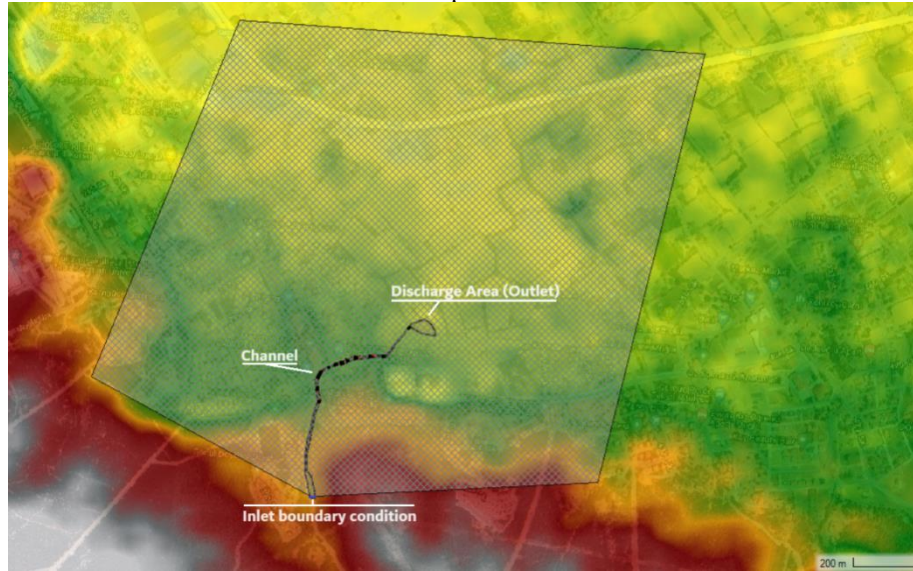


Figure 2. Numerical computational grid used in the study. The refinement region which is used inside the channel is indicated in the figure

## RESULTS

The hydrological model was conducted to estimate the resulting hydrographs by following the procedure defined above. The hydrograph of the Extreme condition is given in Figure 3 on the right and that of Normal condition is given in Figure 3 on the left. The maximum values of the hydrographs were estimated as 0.26 and 6.2 m<sup>3</sup>/s in normal and extreme conditions respectively.

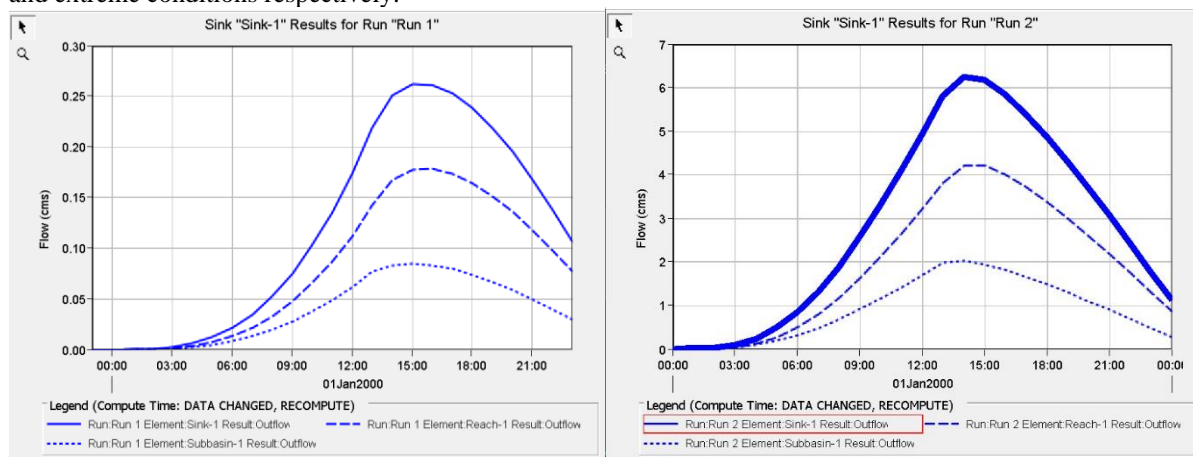


Figure 3. Hydrograph outputs of hydrological modelling. Normal condition on the left panel and extreme condition on the right panel. The top curve corresponds to the hydrograph of the whole basin

The hydrodynamic model was simulated for two conditions using the hydrographs as given in Figure 3 as their inlet conditions. The method which is defined above was applied to run the model for the two test conditions. The flood inundation maps obtained for the two conditions and they are given in Figure 4. It was observed that in the normal condition the channel can successively discharge the maximum flow rate without any spill outside. However, in the extreme condition, the channel is not enough to carry the maximum flow rate and flooding occurs in several locations of the area leading to water depths extending up to 1 m outside the channel. The estimations show that around 2 hm<sup>2</sup> area and more than 20 residential buildings will be affected from this flood that can happen under Extreme conditions.

However, it should be noted that we assumed that all the spilling discharge from the channel will be discharged as infiltration through soil only neglecting the additional drainage elements among the streets considering the accuracy of the map and model resolution. Therefore, the flood inundation map obtained for the Extreme condition can be developed further by adding the additional hydraulic structures in the area. The model results for the Extreme Condition can be regarded as an indicator showing if there will be overflow in the channel.



Figure 4. Flood inundation maps: Normal condition result on the top panel and extreme condition result on the bottom panel

## CONCLUSION

The effect of climate change on hydrology is observed as the increase in the absolute extreme values of some important parameters like temperature and precipitation. The rise in the extreme high precipitation magnitudes results with more flood water levels as is demonstrated in this study by applying the conditions at a case study. A small neighborhood in Muğla, Turkey, which was once a small village, underwent an excess population increase in the last 20 years. A flood analysis at this area was conducted by using a probable extreme value of precipitation. A hydrological model and a two-dimensional unsteady hydrodynamic model were constructed by using open access software. The resulting flood inundation map of the Extreme condition reveals the potentially affected areas in the neighborhood from floods. It should be noted however that the streamflow from the Extreme precipitation was assumed to be conveyed via one channel neglecting the other elements of the region. Therefore, the results were used as only an indicator of overflowing condition. For a more detailed study, the validation of the model results should be done.

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# HIGH-RESOLUTION FUTURE SSP 8.5 SCENARIO RESULTS OVER TÜRKİYE: THE IMPACT OF CLIMATE CHANGE ON WATER BUDGETS OF SNOW-DOMINATED BASINS

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## Abstract

This study focuses on the impacts of climate change on surface water budget components of seven snow-dominated basins (Tigris, Euphrates, Aras, Coruh, Western Black Sea, Eastern Mediterranean, and Susurluk) in Türkiye. A comparative analysis was conducted between a 20-year reference period (1995-2014) and a corresponding pseudo-future period (2081-2100), examining the observed changes between the two intervals. The high resolution (4 km) data used in this study were obtained by Weather Research and Forecasting (WRF) simulations using ERA5 reanalysis data for the 1995-2014 and using perturbed ERA5 reanalysis data by the Pseudo Global Warming (PGW) method (with 13 Coupled Model Intercomparison Project Phase 6 (CMIP6) GCMs under Shared Socio-Economic Pathway, SSP5-8.5 emission scenario) for 2081-2100.

Precipitation, Evapotranspiration (ET), and Snow Water Equivalent (SWE) maps for the reference period throughout Türkiye and anomaly maps showing the difference between the future and reference periods were created. Then, water budget analyses were carried out for the catchments selected in this study. According to the water budget analysis, a 1.4%, 4%, and 1% decrease in precipitation is expected in the Tigris, Eastern Mediterranean, and Susurluk basins, respectively. In comparison, an increase of 6.3%, 33%, 29%, and 3.8% is expected in the Euphrates, Aras, Coruh, and Western Black Sea basins. Focusing on the SWE variable, the changes in the average SWE values and inter-annual variability were examined. It has been determined that there will be a substantial decrease in peak SWE values and a shrinkage of approximately 20%-40% in all selected basins during the snow season.

Additionally, the study scrutinized how terrestrial water storage anomaly (TWSA) is influenced by variables such as snow water equivalent anomaly (SWEA) and soil water storage anomaly (SWSA). Based on TWSA graphs, it has been predicted that the impact of snow will be substituted by soil water storage. Moreover, the Eastern Mediterranean and Tigris basins will experience the most significant reduction in peak storage values in March, with a decline of 36% and 25%, respectively. Finally, the evaluation of surface runoff fraction values indicates that peak values occurred earlier in the future, especially in the Tigris and Euphrates basins. These findings suggest that snowmelt periods will occur earlier in the future period, and precipitation type will change from snow to rain.

# THE POTENTIAL OF OLIVE PRODUCTION IN THE KEÇİBORLU DISTRICT

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## ABSTRACT

*Originating in the Eastern Mediterranean, the olive is seen as an indicator species in defining the Mediterranean climate due to its ecological characteristics. Climate change also constitutes the factors that will result in the survival, increase, or extinction of olives in areas where they were or were not grown before. In this respect, areas where olives were not traditionally grown before are transforming into environments where olive production can be carried out efficiently due to climate change. The most important indicator for the identification of these environments is the determination of appropriate temperature values. With this determination, oil or table production can be decided according to the characteristics of the existing cultivars and the yield can be maximised. For this reason, the Keçiborlu district, which is not famous for olive production, was considered in our research. Considering the past temperature values, there has been an increase in production in recent years in the district where efficient production is not thought to occur. As a result, pioneering research was carried out in the district in terms of its potential place in olive production because of climate change and the possibility of being an example for other arable areas.*

**Keywords:** Rainfall regime, Olive tree, Olive quality.

## INTRODUCTION

Phenology - the study of the timing of seasonal and life cycle events - is an interdisciplinary field. It is defined as a fundamental way in which ecologists, biologists, bio geographers, bio meteorologists and climatologists investigate ecological relationships over time, (Schwartz, 2013). Phenology is also described as "the study of the timing of recurrent biological events, the causes of their timing in relation to biotic and abiotic forces, and the interrelationships between the stages of the same or different species" (Badeck et al. 2004; Cleland et al. 2012; Van Vliet et al. 2003).

Phenology is an important structuring element in almost all areas of ecology and evolution. Historically, due to its practical importance for plant breeding, most phenological research has focused on agricultural applications such as pest management, agricultural meteorology and agricultural biology. In the time period between 1990 and 2010, the growing concern for documenting and predicting the effects of climate change has led to increased interest in the role of phenology in ecology and evolution. Phenological changes are among the most prominent and extensively documented biological responses to climate warming in the last 150 years (Parmesan & Yohe, 2003; Beebe, 1995; Fitter & Fitter, 2002; Crick & Sparks, 1999; Myneni et al., 1997).

As the global climate continues to warm and more temperature and precipitation extremes are experienced, our understanding of relevant plant life cycle responses is expected to become increasingly important in the context of future agricultural planning and species conservation (Fitchett et al., 2015).

Most of Turkey's relief is characterised by high plateaus and mountain ranges rising sharply above the surrounding seas. Inland, the summit heights of the plateaus increase towards the highlands of Eastern Anatolia, which are connected to the Caucasus and Zagros mountain ranges. On the seacoasts, the low-lying coastal areas are narrow, mostly confined to deltas or large rivers and wide valleys whose sediments are travelling towards the sea. Because of this distribution, the average altitude of the country is 1132 metres, which is quite high (Kuzucuoğlu et al., 2019). Phenology is not specific only to a certain area. Since growing conditions are directly related to geographical conditions, Phenological characteristics vary from valley to valley (Kassam et al., 2011). Considering this situation, Phenological observations have a striking importance for Turkey to increase agricultural production data compared to other countries. Therefore, the characteristics and timing of flowering phenology is an area that cannot be neglected due to the database it will create in documenting the climate change in Turkey, which is located in the Mediterranean region, and in producing new policies accordingly.

Considerable work has been done in recent years to understand the location- and species-specific Phenological responses of plants to climate variability and change. The most notable research gaps are spatial, including Africa, South America and the Middle and Near East (Fitchett et al., 2015). The limited Phenological research in these regions is detrimental to the discipline as a whole, as it limits comparisons between regions or on a global scale. Furthermore, the Phenological responses of endemic species to climate change in such understudied regions have yet to be assessed. Many of these regions include economically less developed countries, which are likely to be more adversely affected by climate change due to their low societal adaptive capacity and may also be highly dependent on agriculture (Hegland et al., 2009; Blanc, 2012). Considering that 3,649 of the 11,707 plant species found in Anatolia are endemic (Güner, 2012), it is obvious that phenology is an area in which data must be obtained through research for Turkey.

## 2. PHENOLOGICAL FACTORS AND CLIMATE REQUIREMENTS OF OLIVE PLANT

Of the best-studied factors known to influence the phenology of plants and animals, the most important are genes, photoperiod, rainfall and temperature. Although endotherms such as birds can use temperature, like photoperiod, only as a cue that provides information about possible future food availability, in other organisms temperature directly affects phenology by influencing the rates of biochemical processes (Gillooly et al., 2002).

The accumulation of a certain number of heat units (e.g. degree-days) usually gives a good estimate of flowering date in plants, and flowering phenology often follows inter annual variation in air temperatures (Jackson, 1966; Diekmann, 1996; Fitter et al., 1995; Sparks et al., 2000; Miller-Rushing et al., 2007). However, there is often more to the temperature effect than simple heat accumulation. Many plants have a chilling requirement such that subsequent development is delayed or inhibited if they have not experienced cold winter temperatures (Murray et al., 1989; Morin et al., 2009). When this requirement is applied to flowering, it is referred to as vernalisation (Henderson et al., 2003). The need for cold temperatures has the counterintuitive effect of delaying phenology in warm years (Zhang et al., 2007).

The olive tree is a species of very important agricultural and economic value, especially in terms of olive oil production. But at the same time, olive phenology is recognised as an important indicator of climate change in the Mediterranean region (Orlandi et al., 2005). This is because olive flowering is highly dependent on spring temperatures (Avolio et al., 2012).

The expected warming with climate change may lead to a reduction in bio thermic requirements and faster development of flower buds, leading to earlier flowering peak dates (Aguilera et al., 2013). Therefore, olive is an important indicator species in climate change research due to its response to climatic change.

The olive tree typically cannot survive for more than a week at temperatures below -8°C (Pallioti and Bongi, 1996). At temperatures exceeding 30°C, pollen tube growth is inhibited and the tree is unable to pollinate (Bonofiglio et al., 2008). Vegetation stops when temperatures exceed 32°C and cellular damage can occur when temperatures exceed 44°C (Mancuso and Azzarello, 2002). An increase of 0.25°C in mean air temperature caused minor changes in olive phenology, while an increase of 0.5°C caused early development, especially in the last phenophases (from fruit set to ripening and colour change) (Mancuso and Azzarello, 2002). In the Mediterranean, spring temperature has increased by 1-2 °C in the last two decades (Jones et al., 1999). Since 1850, the global climate has set a record by increasing by 1.46 °C in 2023 (The Copernicus Climate Change Service, 2024). This means the potential expansion of olive production areas in Anatolia.



Figure1- Olive branch with uninterrupted chilling period on the left and with interrupted chilling period on the right. (World olive encyclopaedia, 1996).

According to (Hartmann and Whisler, 1975), trees that spend a winter period of 70-80 days around a maximum of 15°C and a minimum of 2°C fulfil their chilling requirements and have a good flowering period; however, the longer the olive tree is exposed to natural winter cold, the greater the number of inflorescences that develop. The transition between the growth and resting (chilling) period is triggered by temperatures below 14.4°C (Lopez-Bernal et al., 2020). If the olive tree cannot fulfil its need for chilling, it cannot bear fruit as in the tropics (Ayerza and Sibbett, 2001). In addition, if there is an unexpected temperature increase during chilling and chilling is interrupted, shoot development is interrupted and shoots from the previous year sprout vegetatively. The shoots of trees whose chilling is not interrupted sprout by budding, Figure 1 (World olive encyclopedia, 1996).

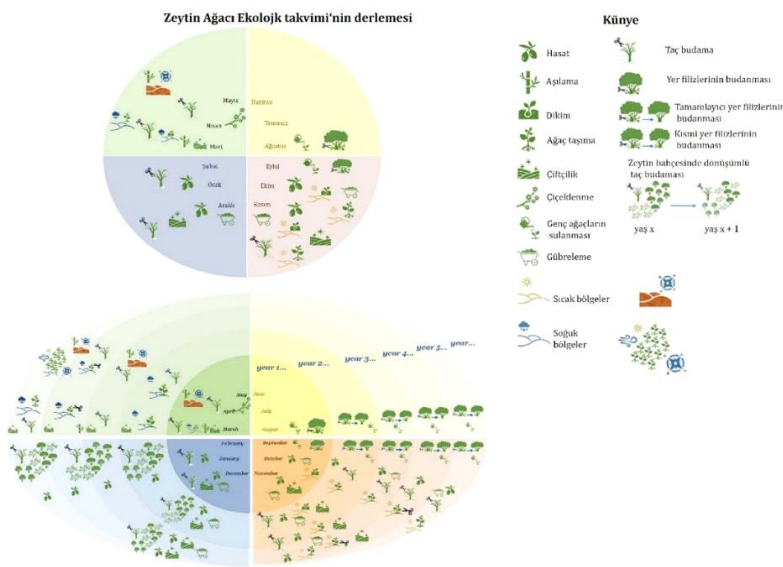


Figure 2. Compilation of the olive tree ecological calendar (Ferrara and Ingemark, 2023).

These results also indicate that the phenological stages of olive are mainly influenced by temperature and not by photoperiodic phenomena. A significant correlation between altitude and onset of flowering was also found. For every 100-meter increase in altitude, flowering started 2.5 days later. However, by analysing flowering branches of the same tree, it was also found that pre-flowering and flowering started a few days later on north-facing branches than on south-facing branches (Rojo and Pérez-Badia, 2014). Therefore, olive trees in northern regions will require lower temperatures for flowering than those in southern regions (Edwards et al., 2006; Foley et al., 2009; Ramos et al., 2005). In addition, some studies have indicated that annual variations in the onset of the pollen season may be due to the North Atlantic Oscillation (NAO) being stronger in the north than in southern Europe (D'Odorico et al., 2002; Galán et al., 2005). Sanz-Cortés et al. (2002), in their study, adapted the BBCH scale to olive trees and demonstrated the development process of olive trees during the growing season. Ferrara and Ingemark (2023) established the compilation of the ecological calendar of the olive tree in Figure 2.

### 3. GEOGRAPHICAL CHARACTERISTICS OF THE RESEARCH AREA

The study area is a district of Isparta province, which has a surface area of approximately 532 km<sup>2</sup> within the borders of the Mediterranean region Figure 3. The physical geography is mostly faulted and the northern extensions of the western Taurus Mountains extend to the district. While the altitude of the district centre is 1010 metres, the highest point in the district is Akdağ with an altitude of 1890. There are Kılıç, Senir and Baladız plains around it. Although there are no important rivers in the district, the rivers in the region are small streams and they emerge with winter precipitation and dry up with summer heat. A 22 km coastline of Lake Burdur is located in the south of Keçiborlu district and within the borders of the district. A pond for agricultural irrigation purposes has been established in the northeast of the district and has been in use since 1989. Although Keçiborlu district is considered to be in the Mediterranean Region, it has a continental climate with harsh and cold winters and dry and hot summers. The annual

average of precipitation is 615 mm and generally precipitation is concentrated in winter and spring months. In this study, it was tried to predict the phenology of olive in Keçiborlu district of Isparta province, which is not included in the phenology atlas of the State Meteorological Service, but which is expected to increase the potential for olive production in the future due to climate change and in relation to which olive groves are currently planted. For this reason, the only data that can be used to predict the flowering stage is the temperature and precipitation data obtained from DMİ Figure 4.

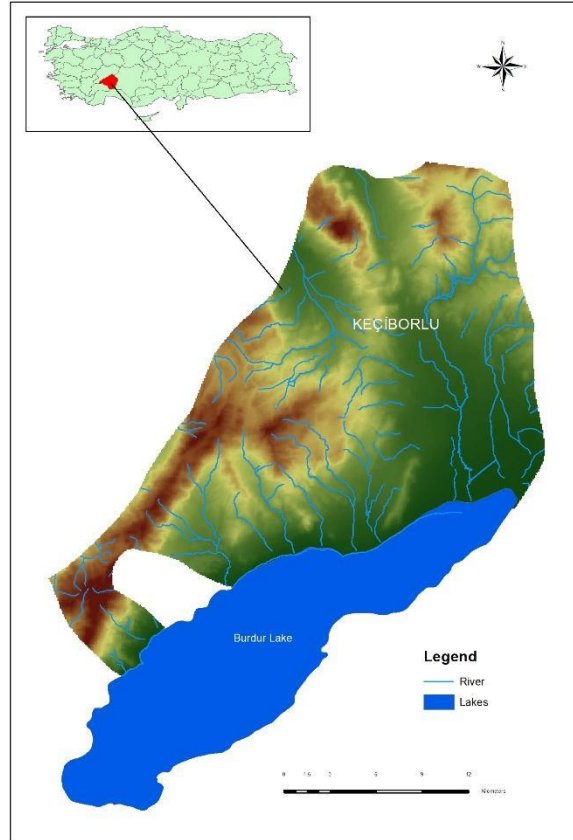


Figure 3. Location Map

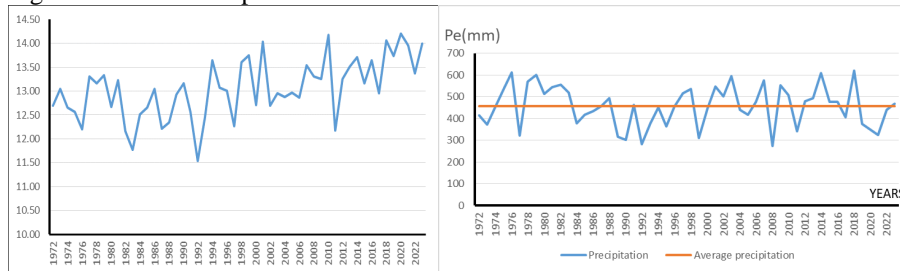


Figure 4 Long-term averages of temperature and precipitation in Keçiborlu

#### 4.1. MATERIAL AND METHOD

In order to predict the phenology of olive in Keçiborlu BBCH (Biologische Bundesanstalt für Land-und Forstwirtschaft, Bundessortenamt und Chemische Industrie) Scale was tried to be predicted. For this purpose, firstly, the temperature values of Keçiborlu district were reached, and the values that could not be reached were obtained from the nearest stations. The meteorological station in Keçiborlu started to measure for the first time in 1972 but was closed in 1989. The date of resumption of measurement is 2014. In order to reach the closest meteorological data in the interim period, the data obtained from Süleyman Demirel Airport between 2006-2014 were used, and the temperature data of Burdur city centre between 1990-2006 were evaluated. The annual average temperature of Keçiborlu, which is the result of the calculation of monthly temperatures measured from 1972 to the present, is 13.02°C (Figure 4).

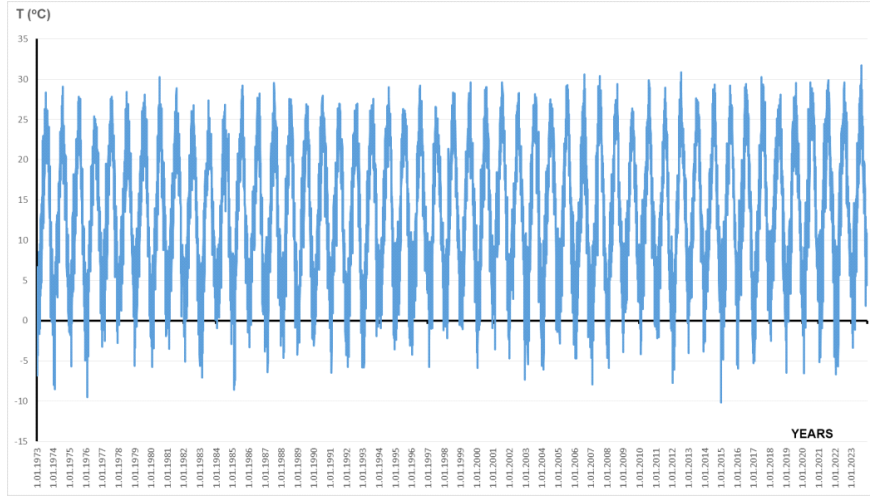


Figure 5 Daily Average Temperature in Keçiborlu for many years (1973-2023)

Since 1973, as a result of the observations made in Keçiborlu, the daily temperature averages exceeded 30°C only 6 times and reached -10°C only 2 times. In this process, as stated by , Palliotti and Bongi (1996), , it is seen that it was not exposed to -8°C for more than a week and thus could not be potentially damaged. It is noteworthy that temperatures exceeding 30°C have been observed in the last 20 years.

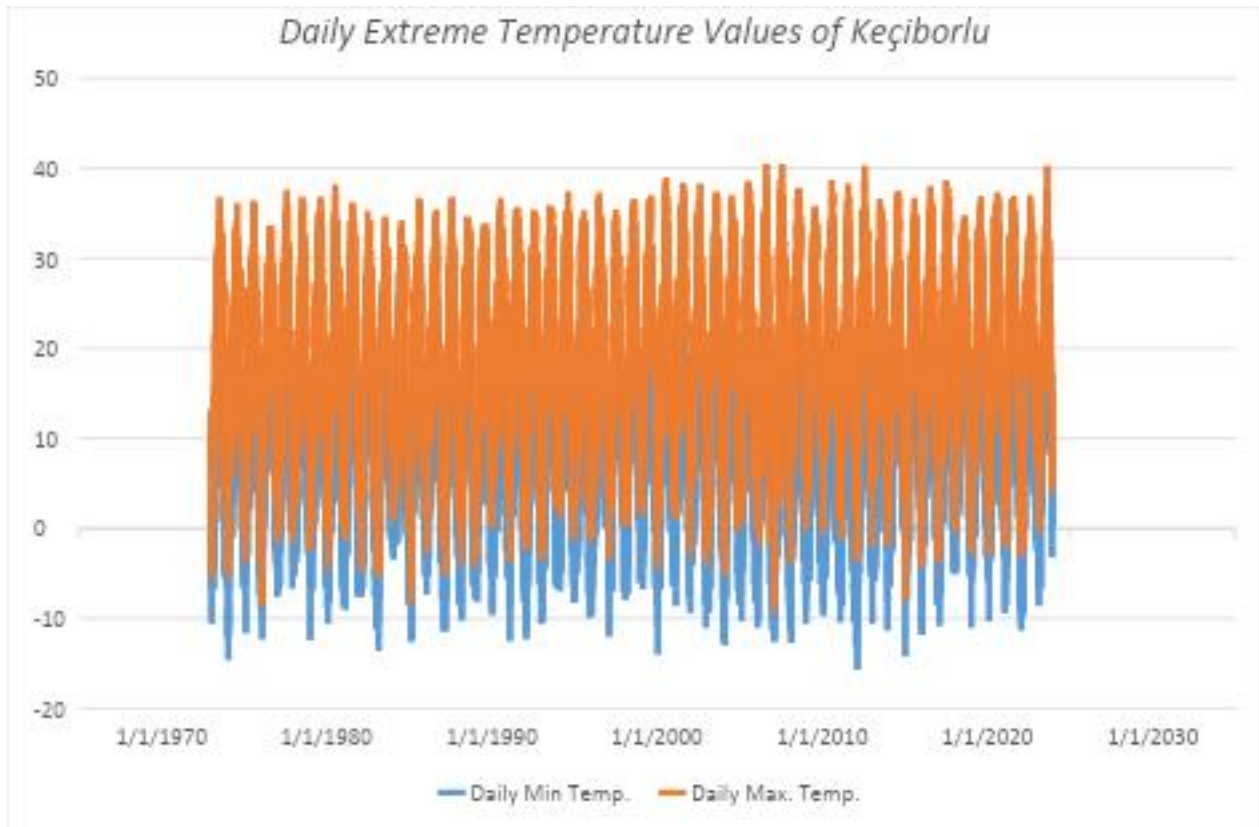


Figure.6 Daily Extreme Temperature Values of Keçiborlu

When we look at the daily exremum temperature values in Keçiborlu, it is seen that the temperature values exceeding 40°C have been reached in the last 20 years. Temperatures exceeding -15°C, which may damage olives, were reached only in 2012. Although drought is on Turkey's agenda, Keçiborlu's precipitation graph shows a significant drought only in the early 90s, and there are no notable signs of drought before and after. With an average annual precipitation of 457 mm, the district has a precipitation regime that can meet the water needs of Zeytin (Figure 4.).

Olive production in the district has existed in the past, but not in the form of a large and industrial production. In 2018 and 2019, a total of 14000 olive trees were planted by the General Directorate of Forestry in 2 different villages and after 3 years of maintenance, they were sold to the villagers for a very small fee (OGM website access date 11.02.2024, Ispartamhaber website, access date 11.02.2024). This situation can be seen in Figures 7 and 8.

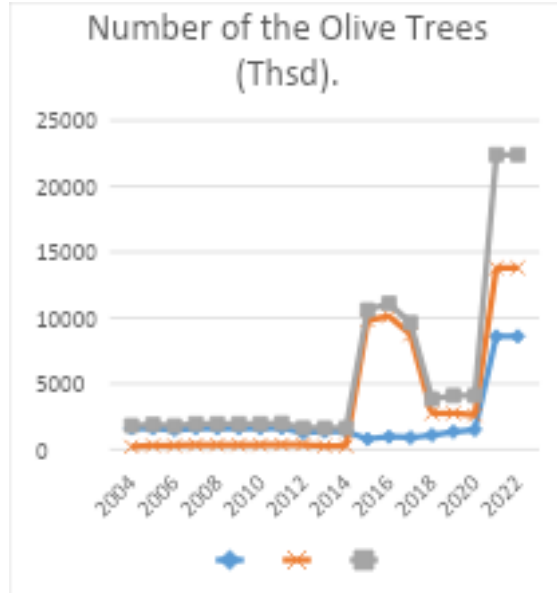


Figure 7. Number of Olive Trees in Keçiborlu (Tüik)

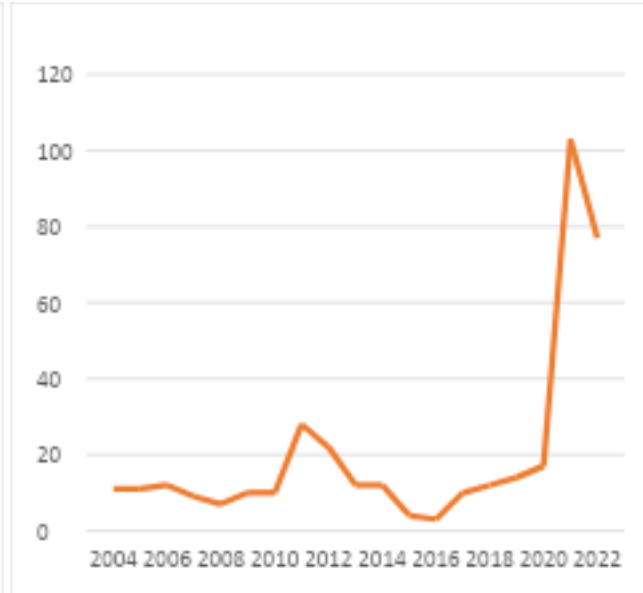


Figure 8. Olive Production in Keçiborlu (Tüik)

In parallel with the increase in the number of olive trees in Keçiborlu, production also increased and reached a record high of 103 tonnes in 2021. When the production conditions are evaluated and the temperature data of Keçiborlu are taken into consideration, the phenological development of olives in Keçiborlu district can be predicted according to the BBCH Scale and the following list emerges.

Date of onset of somnolence	→ (equivalent to 51 on the BBCH scale)	20 April
Start of flowering	→ (equivalent to 60 on the BBCH scale)	20 May
Date of full flowering	→ (equivalent of 65 on the BBCH Scale)	1 June
Date of the end of flowering	→ (equivalent 68 on the BBCH scale)	15 June

Ripening												
Fruit development												
Flowering												
Inflorescence development												
Leaf development												
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.

Figure 9. Development of olive trees during the growing season in Keçiborlu

## 5. RESULTS AND CONCLUSION

Considering the phenological observations, it is seen that Anatolia has been investigated very little compared to the plant species it has. Considering the global climate change, it is obvious that the phenological timelines of plants have changed and will change. From this point of view, it will not only be the temperature that changes, but also the areas that were previously suitable for olive production will lose their suitability, while unsuitable areas will become suitable. This potential will lead to an important distinction in the determination of olive production areas, in the

change of crop production areas and in making related decisions and reviewing previously taken decisions. Considering that the productive yield of the olive plant starts approximately 15 years after it is planted, the results of the decisions to be taken today will appear at least 15 years later. From this point of view, the decisions taken by the General Directorate of Forestry (OGM website access date 11.02.2024, Ispartamhaber website, access date 11.02.2024) have proven to be correct. These results constitute a precedent in terms of the revitalisation of other areas in the region and can be evaluated in order to prevent the pollution of lakes and the decrease in water levels as a result of irrigation due to the water demands of fruit trees other than olives. It would be appropriate to use or increase the existing use of the flowering time in order to increase the yield or to take precautions against damaging atmospheric events such as frost by making the necessary pesticides as a result of the observation to be made in the fields and temperature monitoring with local meteorological stations to be actively established.

This study was carried out as a research to understand the phenological factors affecting olive production in Keçiöborlu, which was thought not to be possible to grow olives potentially, but turned into a potential production area due to the increase in temperatures as a result of global climate change.

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# SAFRAN, THE GOLDEN PLANT GROWED IN THE DRY SEASON

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## ABSTRACT

*Saffron (Crocus Sativus L.) is a bulbous cultivated plant of the crocus genus, 20-30 cm tall, from the Iridaceae family, blooming in autumn. The spice obtained from this plant is called saffron.*

*Saffron is one of the cultural plants used by different civilizations since ancient times. This plant has been used in many areas, from folklore to eating habits, from textiles to cosmetics.*

*Today, saffron is produced in major producers such as Iran, Afghanistan, India (Kashmir), Spain, Italy, Greece and Morocco, as well as in a few countries that produce locally (Turkey, Israel, such as Algeria, France) cultivation is involved.*

*Turkey is one of the richest countries in the world in terms of cultural plants such as saffron. Today, it appears as one of the almost forgotten cultural plants.*

*aromatic plant species that has been alienated from us, forgotten, and most importantly, can be grown in dry periods, should be grown and introduced in our environment, and especially in the Isparta-Burdur region, the most suitable Saffron growing areas should be determined with GIS (Geographic Information Systems) and the optimum areas that can be produced should be found and dry agriculture. To find suitable areas for the project and determine it with the Arcgis program.*

*How saffron has surpassed the feature of being a flower throughout the historical process and how it can be cultivated by finding suitable areas in arid climate conditions by examining it as an aromatic plant used in areas such as health, dye plant and spice.*

**Keywords:** Saffron, (Crocus sativus L.), Medicinal-Aromatic Plant, Isparta, Burdur, Agricultural Geography, CBS.

# IMPACT OF VARYING CLIMATIC CONDITIONS ON IRRIGATION WATER DEMAND AND FOOD AVAILABILITY

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## ABSTRACT

*Food is one of the main components for our survival. Without food we cannot imagine our life as it is the main source of our energy. Irrigation is an agricultural process to grow different crops under varying conditions like the seasonal nature of rainfall. But during the period of climate change, there is a change in demand of water required for irrigation. This increase or decrease in irrigation water demand affects the yield of crops and therefore an imbalance in the availability of food. This study performs an analysis of different climatic conditions like temperature, humidity, rainfall, precipitation, etc. which mainly affect the water demand for irrigation. Different statistical tools are used for this analysis of these parameters. Then, CROPWAT model is used to estimate the demand of irrigation water in different regions under the change in most affecting climatic conditions. This work also studies the impact of climate change and improper irrigation on the quality and availability of food in market.*

**Keywords:** CROPWAT model, climate change, crop water requirement

## INTRODUCTION

Food and water are the basic and unavoidable requirements for the survival of any living being on this planet. The major portion of eatable items that we intake, are mainly produced through various agricultural practices, performed by farmers in their agricultural fields and farms. According to the data of year 2021, almost 1/3<sup>rd</sup> amount of overall food requirement is produced by small farms [16]. Farming has a great impact on the economics of rural areas as it reforms the rural society in an effective manner [4]. The world's biggest, 1% of farms run over than 70% of the world's farming land and they are bigger than 120 acres. Almost 40% of agricultural land is supported by the farms with size more than 2500 acres [16]. Some of the major items produced by agricultural practices are: vegetables, cereals, grains, fruits, pulses, sugarcane, fibres, fuels and many others. The production of all these items immensely depends on the proper availability of water on the agricultural farms.

Sufficient irrigation and proper arrangement of water sources are the main factors for agricultural productivity. In India, crop production is totally dependent on rainfall in many regions, as no methods of manual irrigation are developed in these areas. Irrigation is an application, generated artificially to control the amounts of water required on agricultural lands, providing assistance for crop production [6]. Ponds, lakes, dams, tube wells, and wells are some of the sources used for irrigation purpose. There are different methods of irrigation including sub surface irrigation, micro irrigation, surface irrigation, etc. The change in climate is being observed all over the globe [14]. Over many past years, sufficient amount of greenhouse gases (like CO<sub>2</sub>) has been released due to the burning of fossil fuels. Due to this reason, an increase has been observed in world's temperature and the decades are warmer than before [11]. Rise in sea levels, melting of glaciers, change in precipitation have been observed as a result of change in climate.

In India, any change in monsoon affects the pattern of seasonal rainfall which has a noticeable impact on the agricultural production and economy. In the case of agricultural production, climate is a deciding factor and so the climate change has an impact on the growth of crops, yield, and water requirement. These effects on crop production give rise to the development of different irrigation methods. Proper irrigation systems can help to control the situation of drought and famines effectively [6]. These systems use more land for cultivation and the scheme of multiple cropping on irrigated land leads to higher productivity. The climate data including minimum and maximum temperature, humidity, solar radiation, rainfall, wind speed is required to study the impact of climate change on agricultural sector. The variations in climate data also affect the requirement of water for irrigation, which is referred as irrigation water demand. This effect was first estimated by Fischer et. al [2], who gave a warning that there would be a rise in irrigation water demand of 40% [1]. Different studies have been performed to deal with the impacts of

climate change, some of them are as mentioned: farmer adaptation [18], shifting farming practices [3], sowing date readjustment [9,19], shifting of growing season [13]. Many studies have also showed that the increase or decrease in demand for irrigation water depends on the type of crop and land area in future region of climate change [1]. Requirement of paddy water is estimated by Achyadi et. al [8] at various vegetative stages in South Kalimantan of Indonesia. In Northwest Bangladesh, Shahid et. al [17] informed that the increase in temperature will lead to a notable variation in total irrigation in future. Some of the studies have also focussed on identifying the contribution of some climate parameters (temperature and humidity) to increase the water demand for irrigation [15]. According to Ullah et. al [7], it is required to get the past pattern of irrigation system, using trends of land, and the future behaviour of parameters as evapotranspiration, humidity, rainfall, seepage, solar radiation, temperature, etc. Mahmood et. al [10] has applied some of the data mining techniques on a pre-processed dataset in order to predict the demand for irrigation water. The continuously increasing global population has considerably increased the demand for food production. The change in behavioural pattern of climate parameters challenges to manage the current levels of production along with the objective to increase the production level [1]. This is a major issue for regions which are highly dependent on agriculture for their survival and needs. Saputra et. al [14] has used CROPWAT model for estimating the irrigation water demand in Indonesia for Lombok river basin, under the variations in behaviour of climate parameters.

In India, the climate varies as we move from one region to another and as a result agricultural production gets affected. In this study, we have considered three regions of India, Meerut, Aligarh, and Bulandsehar to assess the effect of climate parameters on irrigation water demand. Firstly, the data on different climatic variables is collected from POWER Data Access Viewer for the period 2005-2015. Then, an analysis of these parameters is performed to get the variation trend in climate over this period. CROPWAT model is used to estimate the irrigation water demand for three different years particularly, 2005, 2010, and 2015. Four crops including maize, sugarcane, pulses, and wheat are considered for the irrigation purpose. Lastly, the impact of climate change on estimated irrigation water demand and food availability is analysed.

## METHODOLOGY

### CROPWAT MODEL

CROPWAT 8.0 is the model mainly used to determine the water requirement for irrigation of different crops in any particular field. It was developed by Food and Agriculture Organization (FAO) in 1991. This model is based on the application of Penman-Monteith method for the estimation of evapotranspiration ( $E_t$ ), crop evapotranspiration ( $E_{t_{crop}}$ ), and water requirement for irrigation [1]. The  $E_{t_{crop}}$ , measured in mm/ day is calculated as given in equation (1).

$$E_{t_{crop}} = E_t \times K_c \quad \dots (1)$$

, where  $K_c$  is the crop coefficient at a particular stage of growth,

$E_t$  is the evapotranspiration measured in mm/ day.

### IRRIGATION WATER REQUIREMENT

Crop water requirement (CWR) – it is the total amount of water needed for the growth and development of any crop, without considering the source in a given time span and under various field characteristics at the growing region. It is simply that water which is required to maintain any properly irrigated crop by meeting the losses faced due to evapotranspiration (ET), irrigation water application, and usage of more water in performing operations as transplanting, treatment of salts present under the roots of crop, preparing the land for cropping, frost control, etc. [5]. It can be simply expressed as:

$$CWR = ET + \text{Losses in application} + \text{Special operations} \quad \dots (2)$$

Net irrigation requirement (Nir) – it is the quantity of water used in irrigation to bring the soil moisture (available in root zone of the crops) to the growing field capacity. This process can be expressed as:

$$Nir = \sum_{i=1}^n \frac{M_{fi} - M_{bi}}{100} \rho_{bi} d_i \quad \dots (3)$$

where,  $M_{fi}$  is the moisture content in  $i^{\text{th}}$  layer of soil at the field capacity (%),  $M_{bi}$  is the moisture content in  $i^{\text{th}}$  layer of soil before the implementation of irrigation (%),  $\rho_{bi}$  is the bulk density soil present in  $i^{\text{th}}$  layer ( $\text{g/cm}^3$ ),  $d_i$  is the depth of  $i^{\text{th}}$  layer of soil within root zone (cm),  $n$  is the total number of soil layers in root zone [5].

Gross irrigation requirement (Gir) – it is the total amount of water used in the process of irrigation, including all losses faced during this implementation [5]. It is calculated as given in eq (4).

$$\text{Gir} = \frac{Nir}{\text{irrigation efficiency}} \quad \dots (4)$$

## STUDY AREA

Mainly, three stations are considered for this study, which are located in Uttar Pradesh, India. The region of Meerut which is observed for climate change has longitude  $77.70^\circ\text{E}$  and latitude  $28.97^\circ\text{N}$  with a height of 247m. Region of Aligarh city to collect observations on climate parameters has longitude  $78.09^\circ\text{E}$  and latitude  $27.88^\circ\text{N}$  with a height of 178m. Climate parameters of Bulandsahar city are considered for region having longitude  $77.85^\circ\text{E}$  and latitude  $28.41^\circ\text{N}$  with a height of 195m. Agricultural land used for irrigation of different crops in Aligarh, Meerut, and Bulandsahar are 1039.61 ha, 1447.71 ha, and 1023.29 ha respectively. The distribution of this land is explained in table (1) for different crops. The sandy and loamy soil is considered for agricultural practices in these regions.

	Aligarh			Meerut			Bulandsahar		
Crops (ha)	2005	2010	2015	2005	2010	2015	2005	2010	2015
Maize	32.3	25.54	19.42	4.32	2.56	1.8	59.89	54.4	36.94
Pulses	9.78	8.31	11.69	3.73	4.42	5.85	4.91	5.44	4.86
Sugarcane	9.41	7.75	5.34	254.86	245.71	235.31	67.46	64.08	58.41
Wheat	307.25	310.34	292.48	240.33	232.38	216.44	218.54	225.6	222.76

Table 1: Distribution of land for irrigation

## CLIMATE PARAMETERS

There are different parameters responsible for any change observed in climate. Some of them are used by the Cropwat model to calculate  $E_t$  and solar radiation (Rad). Power Data Access Viewer is used to collect the data on climate parameters for time period 2005-2015. The main parameters which are observed or collected to study the effect of change in climate on irrigation water demand are minimum temperature (Min temp), maximum temperature (Max temp), humidity, wind, sun hours, and rainfall. Effective rainfall is also calculated by this software on the basis of already collected rainfall data.

## SOIL AND CROP DATA

The soil and crop related data (stored in FAO database) is also utilised by the model in order to calculate the overall water requirement. The loamy soil also named as medium soil in the FAO database has been considered for irrigation purpose. Depth of soil and availability of water content in soil are used to determine the total requirement of irrigation water [1]. Mainly four crops including maize, pulses, sugarcane, and wheat are analysed under this study. Particular values of  $K_c$  coefficient are used for different development stages of crops.

## EFFECTIVE RAINFALL

It is calculated by the FAO/ AGLW formula as:

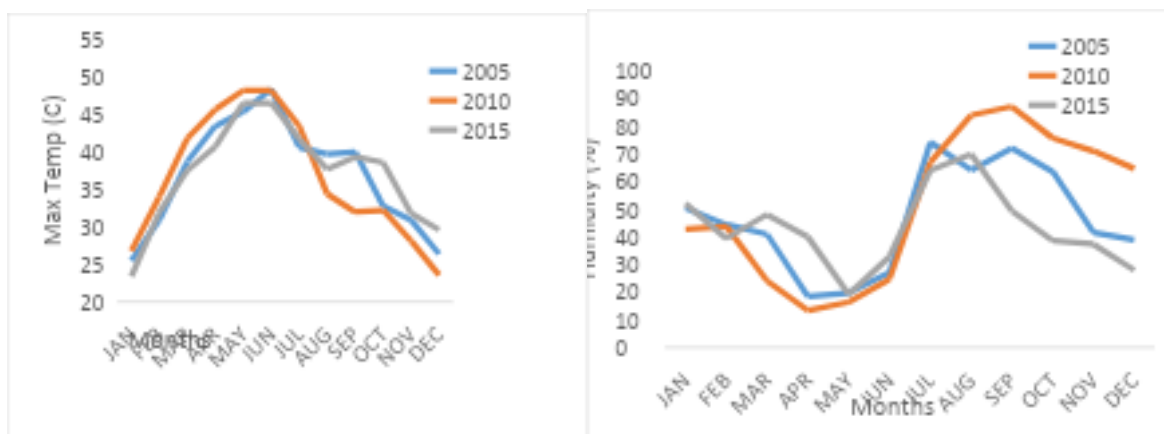
$$P_{\text{eff}} = 0.6 * P_{\text{mon}} - 10 \quad ; \quad \text{if } P_{\text{mon}} \leq 70\text{mm} \quad \dots (5)$$

$$P_{\text{eff}} = 0.8 * P_{\text{mon}} - 24 \quad ; \quad \text{if } P_{\text{mon}} > 70\text{mm} \quad \dots (6)$$

where,  $P_{\text{eff}}$  is the effective rainfall in mm, and  $P_{\text{mon}}$  is the observed monthly rainfall in mm.

## RESULTS AND DISCUSSION

Variations have been observed in the pattern of different climate parameters which are responsible for the corresponding change in climate during the period 2005-2015. The changes observed in Aligarh city are clearly represented in fig. (1). The max temp has varied from the month of july to december. In the month of october, relative humidity was 63.44% (2005), increased to 75.56% (2010) and then reduced to 38.5% (2015). Wind speed has also shown continuous variations over this time period as shown in fig. (1). In 2010,  $E_t$  is high as observed in april and low from august to december as compared to the other years. Amount of rainfall varied mainly from june to october, which is 290.04 mm/day in 2010, whereas 36.91 mm/day in 2015 for the month of september.



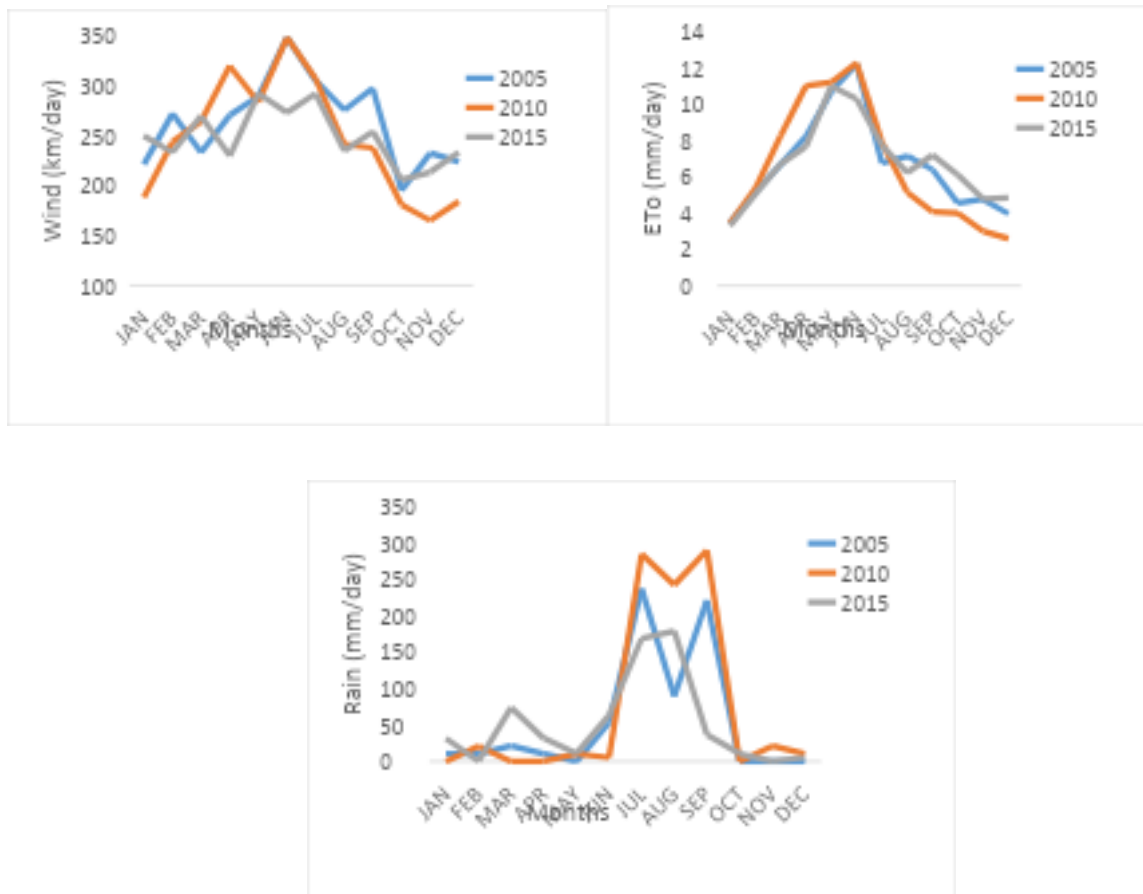


Fig. (1): Variations of climate parameters in Aligarh

Next if we come to the city of Meerut, many changes are observed here also as represented in fig. (2). The variations seen in max temp are quite similar to those in Aligarh. Continuous variations in relative humidity which are quite high for the months of march and october. The sun hours has delineated these changes from july to october. Maximum number of diversified peaks are observed in wind speed, which is 295.48 km/ day (2005), 335.23 km/ day (2010), and 241 km/ day (2015) in april. Rainfall has shown continuous high and low points all over the period. The highest amount of rainfall is collected in the month of august in 2010, which is 379.69 mm/ day.  $E_{t_o}$  varied continuously almost all over the years, except for some of the months, when the changes were quite negligible.

Lastly, climate changes observed in the city of Bulandsahar are given in fig. (3). The values of max temp varies significantly from august to december. Relative humidity varies with 88.31% (2010) whereas increased to 51.25% (2015) in September. The variations in sun hours are observed mainly from july to december. Diversified peaks can be seen for the observations of wind speed, which is highest in june for years 2005 and 2010, i.e, 344.73 km/day and the lowest speed is 161.56 km/day in october (2010). Substantial variations of rainfall are noticed in march and from june to october, which is highest 379.69 mm/day in June, 2010. Some changes are detected in the behaviour of  $E_{t_o}$  from july to december and also in the month of march and april. These notable variations in climate parameters clearly points out the change in climate over the period 2005-2015.

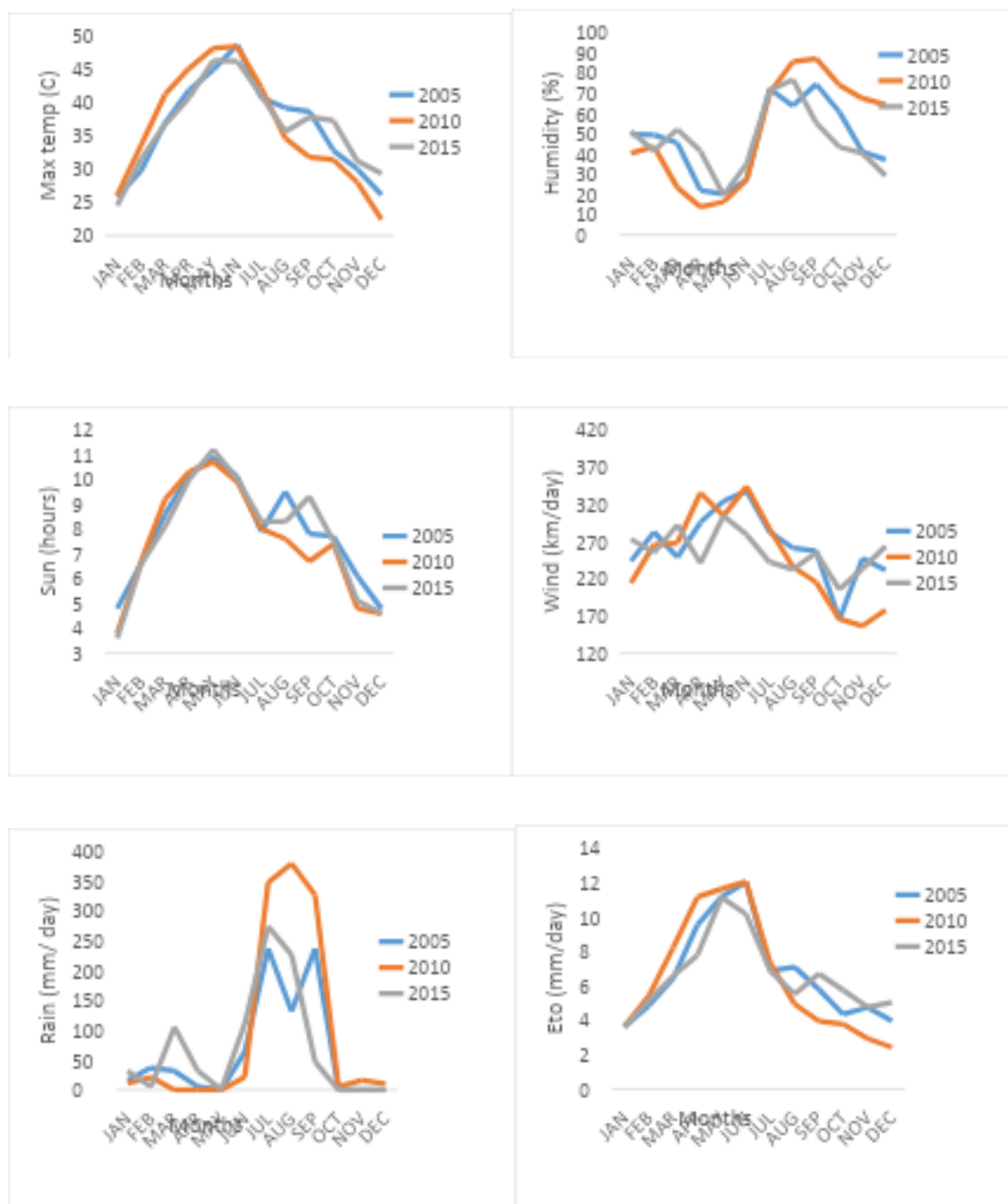


Fig. (2): Variations of climate parameters in Meerut

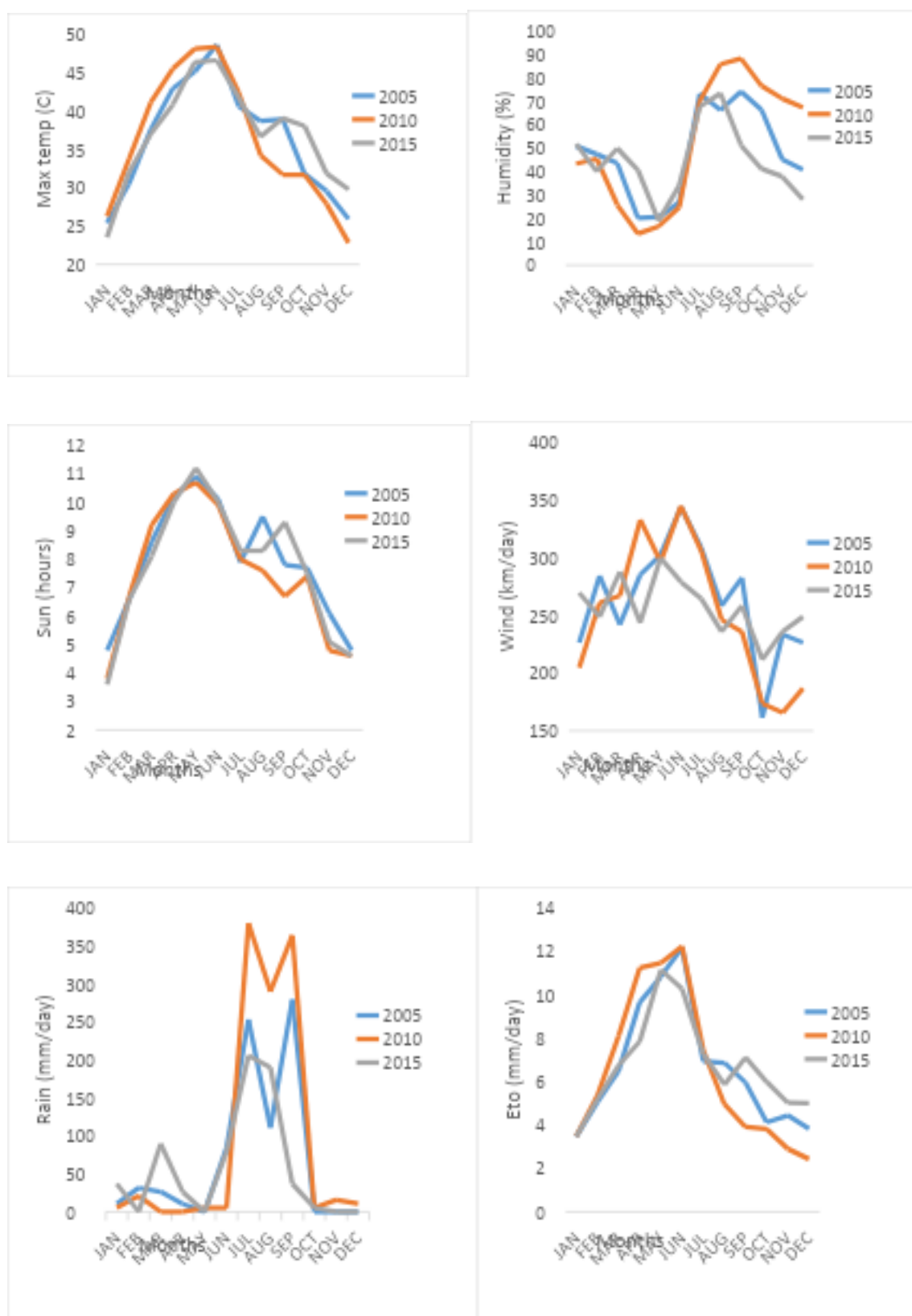


Fig. (3): Variations of climate parameters in Bulandsahar

Table 2, table 3 and table 4 depict the coefficients of correlation calculated for different climate parameters against solar radiation and  $E_t$  in Aligarh, Meerut, and Bulandsahar respectively. In Aligarh, all the parameters are highly correlated with solar radiation and  $E_t$ , but humidity has shown the lowest correlation with solar radiation. In 2010, humidity and  $E_t$  are more negatively correlated as compared to the other years. In Meerut and Bulandsahar, sun hours and temperature have shown very high correlation with solar radiation and  $E_t$ , whereas wind speed is almost uncorrelated in the year 2015. Humidity has shown the same behaviour (low and negative correlation) in both the

cities as in Aligarh. These values suggest that the parameter humidity has the lowest effect on amount of solar radiation and  $E_t$  available for the irrigation of different crops.

	2005		2010		2015	
Parameters	Solar radiation	$E_t$	Solar radiation	$E_t$	Solar radiation	$E_t$
Sun hours	0.667438	0.899503	0.899274	0.93622	0.918137	0.96152
Min temp	0.842939	0.803181	0.909566	0.737727	0.865759	0.790883
Max temp	0.723018	0.931996	0.948509	0.971379	0.946926	0.952882
Humidity	0.088717	-0.48367	-0.46322	-0.76967	0.030241	-0.31741
Wind speed	0.644253	0.799904	0.879862	0.922552	0.643981	0.50566

Table 2: Correlation coefficients of climate parameters in Aligarh

	2005		2010		2015	
Parameters	Solar radiation	$E_t$	Solar radiation	$E_t$	Solar radiation	$E_t$
Sun hours	0.975057	0.889282	0.965693	0.911549	0.976421	0.878264
Min temp	0.8846955	0.757161	0.920450	0.710972	0.8789308	0.708802
Max temp	0.96862	0.928598	0.956748	0.963503	0.940726	0.933014
Humidity	-0.20504	-0.55423	-0.42726	-0.76454	0.069495	-0.40543
Wind speed	0.636265	0.817181	0.833049	0.932157	0.221307	0.485996

Table 3: Correlation coefficients of climate parameters in Meerut

	2005		2010		2015	
Parameters	Solar radiation	Et <sub>o</sub>	Solar radiation	Et <sub>o</sub>	Solar radiation	Et <sub>o</sub>
Sun hours	0.975456	0.885898	0.966234	0.912379	0.977628	0.901619
Min temp	0.893357	0.760439	0.915986	0.72295	0.8653773	0.88785
Max temp	0.967738	0.942033	0.953754	0.96786	0.937204	0.939587
Humidity	-0.2494	-0.58037	-0.47416	-0.78955	0.047053	-0.36932
Wind speed	0.646662	0.781424	0.862593	0.914892	0.392564	0.549539

Table 4: Correlation coefficients of climate parameters in Bulandsahar

Then the CROPWAT model is used to calculate the irrigation water demand i.e., CWR and Gir in all the considered cities. Fig. 4, fig. 5, and fig. 6 depicts the water requirement for irrigation of crops in Aligarh, Meerut, and Bulandsahar respectively. In 2010, the highest demand of water is observed for the irrigation of maize, pulses, and wheat, whereas sugarcane has the least demand. The crops of Sugarcane require more water in Aligarh as compared to other cities and the CWR of other crops is more in Bulandsahar. The yielding of different crops after irrigation practices is given in table 5.

In Aligarh, water requirement for sugarcane crop is more in 2015, hence the yield of sugarcane is lowest (32910.05 kg) as compared to 50509.96 kg (in 2005) and 45699.9675 kg (in 2010). More Gir for sugarcane in 2015 results in lowest yield of 32910.0462 kg. On the other side in Aligarh and bulandsahar, more Gir for crops of wheat, maize, and pulses is observed in 2010 with more yield in the same year as compared to 2005 and 2015. In Meerut, the wheat yield is more in 2015 as compared to 2005 as the demand for irrigation water is quite more in 2005. The CWR for maize is 1126.6 mm (highest) in 2010 which results to more crop production in another year, 2005. In 2005, the yield of maize crop is 6430.3632 kg due to less required Gir (923.8 mm) in that year. In 2005, 2494.4 mm Gir produces 1635431.5228 kg of sugarcane but the less Gir of 2374.1 mm produces more sugarcane 1813482.4018 kg in 2015. In Bulandsahar, CWR for wheat, maize, and pulses is highest in 2010, the yield of these crops has not been affected by irrigation water but produced more in the same year. In 2015, 2235.7 mm Gir produces 392235.4161 kg of sugarcane but more Gir of 2250.6 mm results in less production of sugarcane i.e., 377667.3894 kg in 2005.

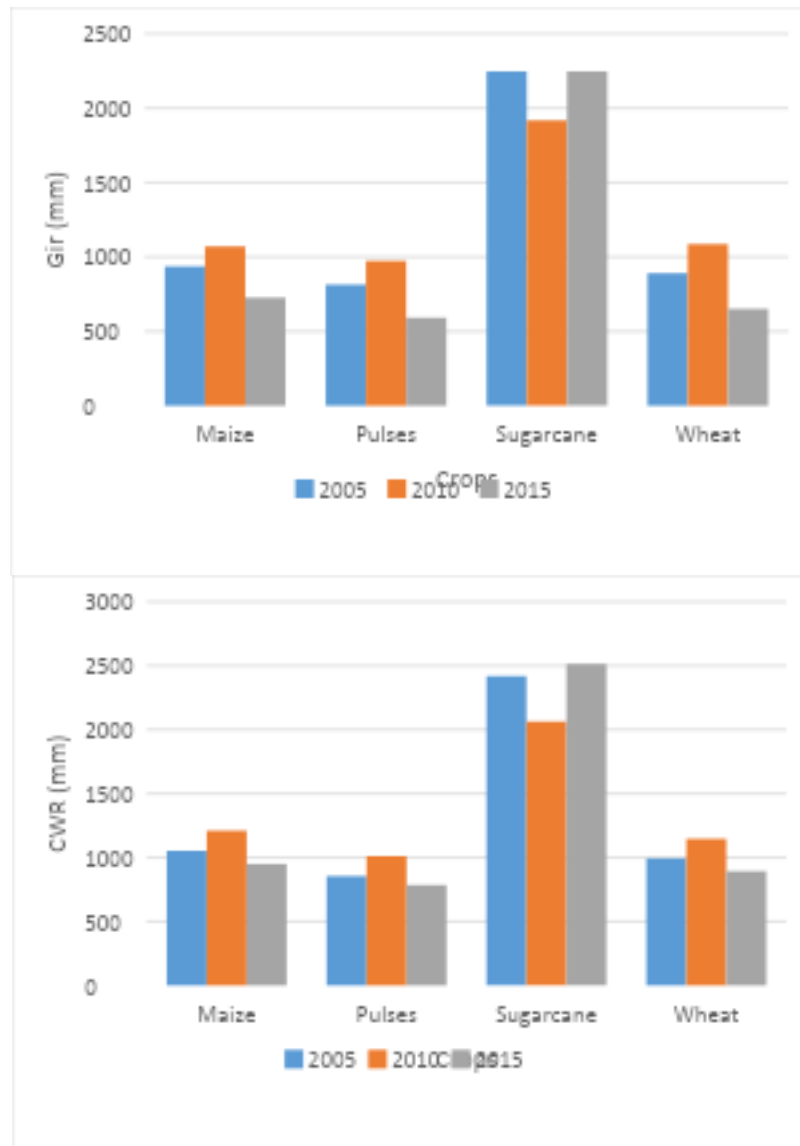
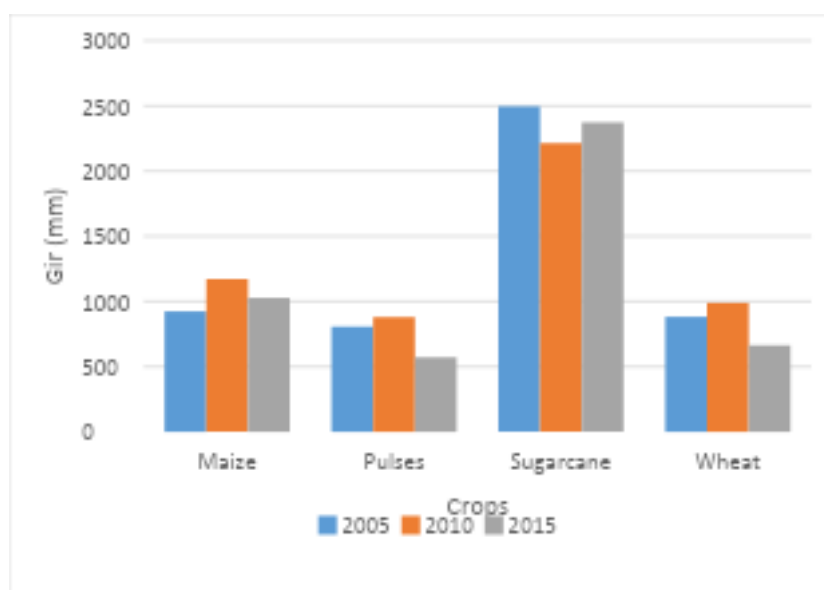


Fig. 4: Irrigation water requirement in Aligarh



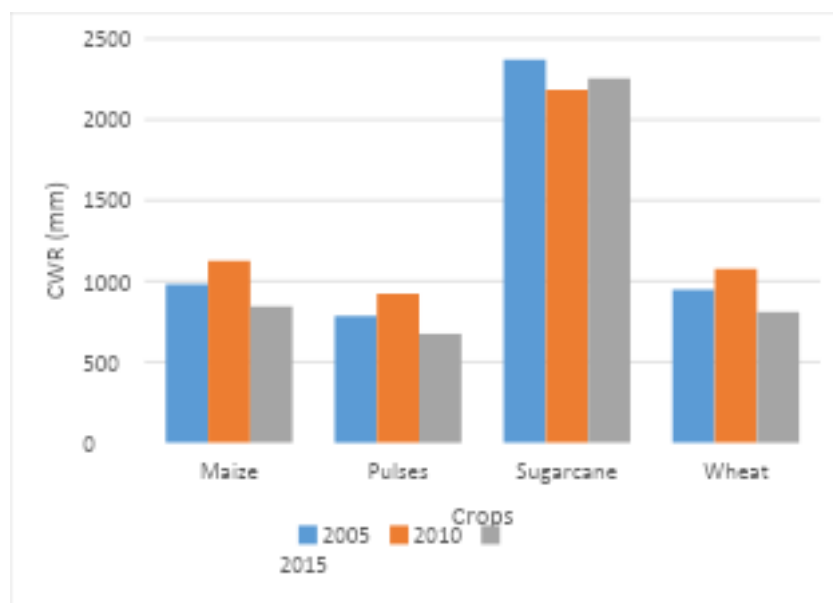


Fig. 5: Irrigation water requirement in Meerut

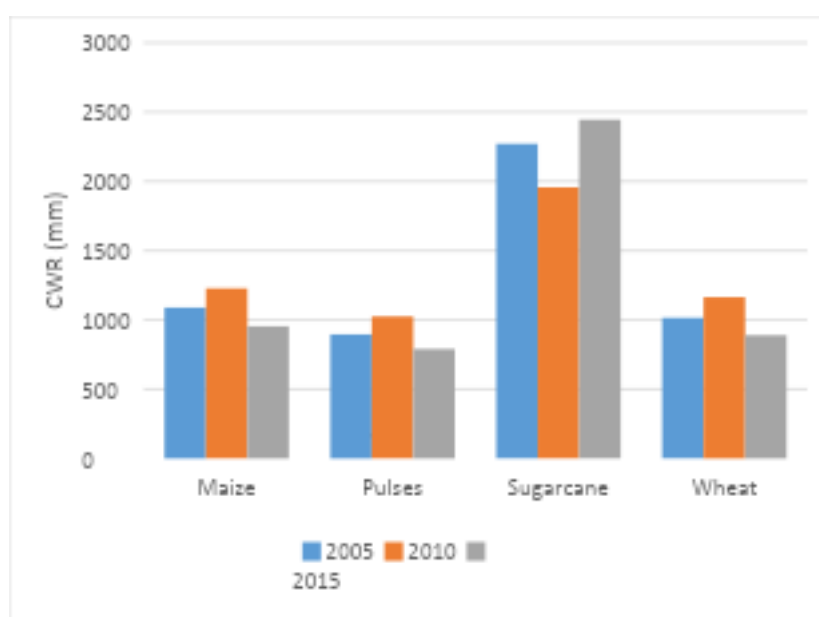
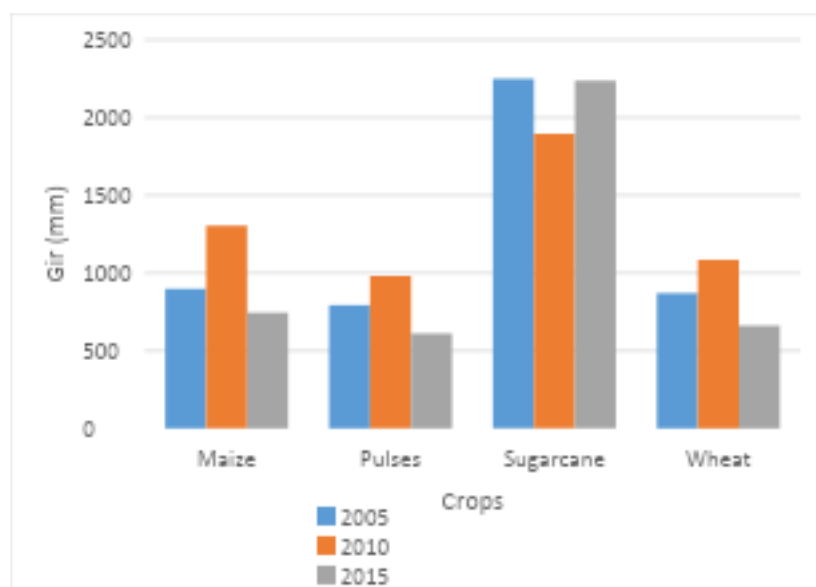


Fig. 6: Irrigation water requirement in Bulandsahar

	Aligarh			Meerut			Bulandsahar		
Crop yield (kg)	2005	2010	2015	2005	2010	2015	2005	2010	2015
Maize	49710.023	50909.9036	44880.0084	6430.3632	5677.4912	3163.932	95399.9788	112982.816	88573.6238
Pulses	6989.9616	7249.9764	5319.4176	2711.4116	2976.6932	2641.158	3378.7674	3893.2448	3040.2216
Sugarcane	50509.9629	45699.9675	32910.0462	1635431.5228	1570298.2106	1813482.4018	377667.3894	364569.7032	392235.4161
Wheat	938089.555	1054141.1882	975218.9888	810669.1395	940476.717	846349.6608	746851.7084	891343.344	855300.3856

Table 5: Yielding of crops after irrigation practices

## CONCLUSION

The variations observed in different climatic parameters clearly shows the change in climate from 2005-2015. Some of the parameters change their behaviour drastically over this time period. The determination of irrigation water requirement (CWR and Gir) using CROPWAT model depends totally on the observed climatic parameters. Therefore, climate change has a noticeable impact over the need for irrigation water of crops, which further affects the production of crops. At some points of time, there is no significant effect of CWR and Gir on crop yield as different methods and techniques are applied in those regions to fulfil that need on time. It is required to analyse these climatic parameters for prediction of water requirement in irrigation of various crops, which will further help in the management and production of these crops.

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# ASSESSMENT OF DROUGHT RISK AND ADAPTATION STRATEGIES TO CLIMATE CHANGE IN TUNCELI: SPI AND RDI ANALYSIS

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## **ABSTRACT**

*Increasing temperatures due to global warming and climate change have adverse effects on water resources. The impacts of climate change worldwide lead to floods, storms, erratic rainfall, land degradation, pollution, natural disasters, and fog issues. Climate change is a global issue affecting the frequency and intensity of natural disasters in many regions worldwide. Tunceli, known as a city rich in natural resources and environmentally friendly until a decade ago, has experienced reduced precipitation in winters with heavy snowfall. This situation has brought climate change to the forefront as a significant issue in the region. Therefore, effective strategies for adapting to climate change are needed. To identify these strategies, drought indices such as the Reconnaissance Drought Index (RDI) and the Standardized Precipitation Index (SPI) can be used to assess drought conditions. Reduced precipitation also affects existing water resources. According to scientists, the most significant impact of climate change is the disruption of the water cycle and deterioration of water quality. The volume of global water resources remains constant due to the water cycle. However, due to climate change, water resources are decreasing, and their quality is deteriorating. Examining climate change requires knowledge of past data such as temperature, rainfall, and evaporation. This article aims to detail the effects of climate change on the city and the protective responsibilities of relevant institutions. It examines the effects of climate change on a small city and outlines an environmentally friendly model that can guide towards a sustainable future. Ultimately, the impact of actions on environmental systems and infrastructure will be reduced, and the service life of existing design and assessment practices will increase. SPI and RDI calculations for Tunceli province contribute to identifying necessary strategies for adapting to climate change. The results of these calculations can help the region become more resilient to climate change and take significant steps towards a sustainable future.*

**Keywords:** Climate change, Drought, SPI, RDI.

# INVESTIGATION OF THE CLIMATE CHANGE AND METEOROLOGICAL DROUGHT IN COASTLINE OF EASTERN BLACK SEA REGION

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## ABSTRACT

*In this study, Mann Kendall, Spearman rho and Innovative Sen Method were used to determine the monthly and annual trends of temperature, precipitation, humidity and pressure parameters of four meteorological observation stations located in Giresun, Trabzon, Rize and Hopa. In addition, Standard Precipitation Index, Percentage of Normal Index and De Martonne Aridity Index were used for meteorological drought analysis of these four stations.*

*As a result of the analysis, an increasing trend in temperature values was determined. Irregularities in precipitation, humidity and pressure are observed on monthly basis. An increasing trend is observed in annual total precipitation values at Giresun and Hopa stations, however, a decreasing trend is observed at other stations. There was a decreasing trend in average humidity values and an increasing trend in maximum humidity values. These results and meteorological drought analysis results prove these irregularities. Sea surface temperature data of the ERA5 of Copernicus satellites and actual measurements were compared and the relationship between them was examined. When the data were compared, a high correlation was found in Giresun and Hopa. Also sea surface temperatures are examined, an increasing trend is observed in both data sets.*

**Key Words:** *Climate, Black Sea, Trend*

## INTRODUCTION

The climate term describes the atmospheric characteristics of a particular region. Climate is the average of parameters such as temperature, precipitation, wind, pressure, humidity, sunshine duration, cloudiness, evaporation and etc. in a region that do not change for many years. Extreme values and features, as well as average values and features constitute the range of the climate [14].

Climate change refers to the change in average characteristics. Observable change in average conditions takes many years. Relatively more important changes occur in extreme events and conditions. The increase in extreme events and conditions, their frequency and severity, are the most important determining results of climate change [14]. Climate change and global warming are one of the biggest problems that concern the whole world in the 21st century. IPCC's 6th Assessment Report revealed that the average temperature of world in 2022 is 1.15 °C warmer than the average temperature value of the 1850-1900 period is taken as a reference. In the same report, the last eight years were the warmest eight years since records date back to 1850 [9]. At the same time, negative events such as floods, heat waves and drought continue to occur increasingly in many parts of the world and situations such as food crises, loss of life and migration are encountered [16].

Turkey is also affected by the crisis. According to the annual climate assessment report that prepared by the Turkish State Meteorological Service, average temperature of Turkey in 2022 is 14.5°C, it is 0.6°C warmer than the average of 1991-2020 (13.9°C). The hottest year was 2010 is 15.5°C. 2022 was the seventh warmest year is 14.5°C. In the

same report, it is seen that the warmest years occurred in the last 20 years [15]. When annual precipitation values are examined, irregularities in precipitation regimes are observed. Disasters and extreme events occurring increasingly.

Eastern Black Sea Region is familiar with the heavy precipitations and floods. In different climate scenarios, different results are emerged especially in precipitation parameter. While the precipitation amount increases in some models, decreases in other models [6].

## DATA and METHODS

### Data

Precipitation, temperature, humidity and pressure data of four meteorological stations (Giresun, Trabzon Bölge, Rize and Hopa) of Turkish State Meteorology Service in 1991-2022 (32 years) period used to examine the change in coastal area of the Eastern Black Sea Region. To detect trends, Mann-Kendall, Spearman rho tests and the Innovative Sen Method were used for all parameters. In these analyses, the confidence interval was used as 95%.

Table 1: Features of selected stations

Station ID	Station Name	Latitude	Longitude	Elevation (m)	Data Period
17042	Hopa	41.4065	41.433	33	1991-2022
17034	Giresun	40.9227	38.3878	38	1991-2022
17040	Rize	41.04	40.5013	3	1991-2022
17037	Trabzon Bölge	40.9985	39.7649	25	1991-2022



Figure 2: Locations of selected stations

### Trend Analysis

#### Mann- Kendall Testi

The non-parametric Mann-Kendall test is a test used in trend analysis of climate data showing monotonic trends. The main reasons why it is preferred are that it is not affected by data deficiencies, errors or distributions. It is frequently preferred in hydrometeorological, meteorological and climatological data analysis. The test is applied to a data set  $x_i$  sorted up to  $i=1, \dots, n-1$  and a data set  $x_j$  sorted up to  $j=i+1, \dots, n$ . In the test,  $x_i$  is used as the reference data point and  $x_j$  data is processed for comparison with the formula (1) below.

$$\text{sgn}(x_i - x_j) = \begin{cases} 1 & \text{Eğer } (x_i - x_j) > 0 \\ 0 & \text{Eğer } (x_i - x_j) = 0 \\ -1 & \text{Eğer } (x_i - x_j) < 0 \end{cases} \quad (1)$$

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sgn}(x_i - x_j) \quad (2)$$

The variance of the test statistic  $S$ , which has a normal distribution and mean zero, is calculated with equation (3).

$$\text{Var}(S) = \frac{n(n-1)(2n+5)}{18} \quad (3)$$

Whether the Mann-Kendall test that the variance is determined is significant or not is determined by calculating the standard normal variable  $z$  with the equation below and comparing it with the critical  $z$  value.

$$z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & \text{Eğer } S > 0 \\ 0 & \text{Eğer } S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} & \text{Eğer } S < 0 \end{cases} \quad (4)$$

If  $\alpha$  significance level  $|z|$  If  $\leq z_{\alpha/2}$ , the  $H_0$  hypothesis is accepted, otherwise it is rejected. If the calculated  $S$  value is positive, it indicates the existence of an increasing trend, and if it is negative, it indicates the existence of a decreasing trend.

### Spearman rho Test

It is a simple test to investigate the existence of a trend and is based on rank statistics, is used to determine whether there is a significant correlation between two observation series. The rank statistic  $R(x_i)$  is determined by ordering the observations from smallest to largest or largest to smallest, and the test value ( $r_s$ ) is calculated with equation number 5. The critical  $z$  value is calculated with equation number 6 [7].

$$r_s = 1 - \frac{6(\sum_{i=1}^n (R(x_i) - i)^2)}{(n^3 - n)} \quad (5)$$

$$z = r_s \sqrt{n - 1} \quad (6)$$

### Innovative Sen Method

The Innovative Sen Method shows the analysis results in linear graphic form. It differs in that it gives results even if the data does not follow a normal distribution, the data length is short, and the data has internal dependency [12]. The analysis stages of this method are as follows.

The data set is divided into two equal parts and then sorted separately from smallest to largest. Then, the first piece ( $X_i$ ) is placed on the cartesian coordinate system, with the second piece ( $X_j$ ) on the Y-axis. A 1:1 (45°) line is drawn on the graph. If the data is above the line, there is no trend; if it is in the triangle below the line, there is a decreasing trend; if it is in the triangle above the line, there is an increasing trend. In addition, the time series of data can be divided into three categories: “low”, “medium” and “high”. Thus, it provides information about the direction of the data's trend as well as its severity [1].

### Meteorological Drought

Meteorological drought is defined as precipitation amount is significantly below normal values over a long period of time. Standard Precipitation Index (SPI), Percentage of Normal Index (PNI), De Martonne Aridity Index were used in meteorological drought analysis [16].

#### Standard Precipitation Index

Standard Precipitation Index (SPI) is essentially obtained by dividing the difference of precipitation from the average within a specified time period by the standard deviation. Index values are classified between -2.0 and 2.0, where 2.0 is the limit value of exceptionally wet and -2.0 is the limit value of extraordinary drought [16].

$$SPI = (x_i - x_o)/a \quad (7)$$

#### Percentage of Normal Index

The Percentage of Normal Index is the simplest of the drought indices and is essentially obtained as a percentage by dividing the amount of precipitation by the average of the precipitation over a specified period of time. Index values are classified between 65% and 85%, where 65% is the limit value of severe drought and 85% is the limit value of normal and above humidity [16].

$$PNI = \left( \frac{P_i}{P_o} \right) * 100 \quad (8)$$

#### De Martonne Aridity Index (DMI)

De Martonne Aridity Index (DMI) is calculated by dividing the total annual precipitation by the annual average temperature by adding 10. The +10 value added to the temperature values in this formula is a coefficient used to make

the negative temperature value in some places positive. Index values are classified between 5 and 60, where 5 is the limit value for drought and 60 is the limit value for very humid [16].

$$I_{DM} = P/(T + 10) \quad (9)$$

### Comparison of Sea Temperature

Actual sea temperature measurement of Giresun, Trabzon Bölge, Rize and Hopa stations and sea surface temperature observations of Copernicus satellites (ERA5 [0.25°x0.25°] data set) were used. Nearest grid points to the stations' coordinates selected from satellite observations. Pearson Correlation Coefficient were used to determine the relationship between two data set. Pearson Correlation Coefficient is a method that measure of the degree of linear correlation between two variables with the formula;

$$r_{xy} = \frac{\text{cov}(X,Y)}{\sigma_x \cdot \sigma_y} \quad (10)$$

The value  $r_{XY} = +1$  reflects a perfect positive correlation, the value  $r_{XY} = 0$  indicates that no correlation and the value  $r_{XY} = -1$  reflects a perfect negative correlation between data.

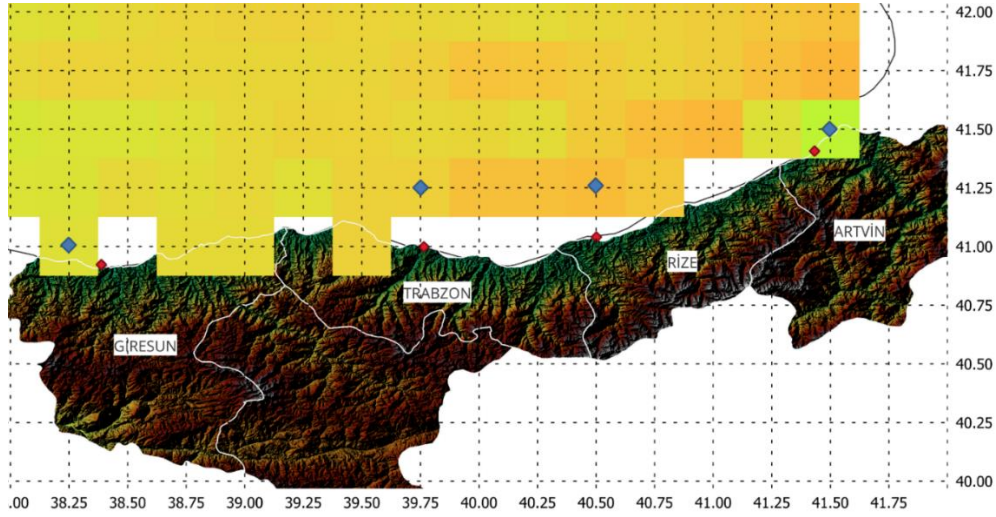


Figure 3: Selected grid points (blue objects)

Station ID	Station Name	Latitude	Longitude	Latitude of Grid Point	Longitude of Grid Point
17042	Hopa	41.4065	41.433	41.5	41.5
17034	Giresun	40.9227	38.3878	41	38.25
17040	Rize	41.04	40.5013	41.25	40.5
17037	Trabzon Bölge	40.9985	39.7649	41.25	39.75

Figure 4: Coordinates of selected stations and grid points

## RESULTS

### Pressure

Table 2: Results of trend tests for average pressure ( up-left = Trabzon Bölge, up-right = Rize, down-left = Giresun, down-right =Hopa)

	Mann Kendall			Spearman rho			Mann Kendall			Spearman rho			
	z	r	Trend	z	r	Trend		z	r	Trend	z	r	Trend
Jan.	-1.83	-0.23	-	-1.98	-0.36	-	Jan.	-0.88	-0.11	-	-1.01	-0.18	-
Feb.	-0.57	-0.07	-	-0.50	-0.09	-	Feb.	0.21	0.03	-	0.27	0.05	-
Mar.	-0.11	-0.02	-	-0.23	-0.04	-	Mar.	0.49	0.06	-	0.64	0.11	-
Apr.	2.22	0.28	Inc.	2.23	0.40	Inc.	Apr.	3.72	0.47	Inc.	3.53	0.63	Inc.
May.	-0.06	-0.01	-	-0.06	-0.01	-	May.	1.15	0.15	-	1.16	0.21	-
Jun.	-1.46	-0.19	-	-1.55	-0.28	-	Jun.	0.36	0.05	-	0.48	0.09	-
Jul.	-0.05	-0.01	-	0.03	0.00	-	Jul.	1.72	0.22	-	1.73	0.31	-
Aug.	-0.96	-0.12	-	-0.92	-0.17	-	Aug.	0.70	0.09	-	0.95	0.17	-
Sep.	-0.70	-0.09	-	-0.82	-0.15	-	Sep.	1.06	0.13	-	0.88	0.16	-
Oct.	0.91	0.12	-	1.04	0.19	-	Oct.	1.70	0.21	-	1.64	0.29	-
Nov.	0.78	0.10	-	0.99	0.18	-	Nov.	2.28	0.29	Inc.	2.25	0.40	Inc.
Dec.	0.62	0.08	-	0.62	0.11	-	Dec.	1.65	0.21	-	1.64	0.29	-
Yea.	-0.47	-0.06	-	-0.16	-0.03	-	Yea.	2.49	0.31	Inc.	2.63	0.47	Inc.
	Mann Kendall			Spearman rho			Mann Kendall			Spearman rho			
	z	r	Trend	z	r	Trend		z	r	Trend	z	r	Trend
Jan.	-1.56	-0.20	-	-1.54	-0.28	-	Jan.	-2.37	-0.30	Dec.	-2.54	-0.46	Dec.
Feb.	-0.45	-0.06	-	-0.51	-0.09	-	Feb.	-1.02	-0.13	-	-1.19	-0.21	-
Mar.	-0.05	-0.01	-	0.03	0.00	-	Mar.	-1.02	-0.13	-	-1.15	-0.21	-
Apr.	2.14	0.27	Inc.	2.19	0.39	Inc.	Apr.	0.76	0.10	-	0.80	0.14	-
May.	-0.13	-0.02	-	-0.13	-0.02	-	May.	-1.15	-0.15	-	-1.25	-0.22	-
Jun.	-1.22	-0.15	-	-1.30	-0.23	-	Jun.	-1.56	-0.20	-	-1.54	-0.28	-
Jul.	0.86	0.11	-	0.86	0.15	-	Jul.	-0.71	-0.09	-	-0.60	-0.11	-
Aug.	-0.76	-0.10	-	-0.62	-0.11	-	Aug.	-1.85	-0.23	-	-1.97	-0.35	Dec.
Sep.	0.39	0.05	-	0.34	0.06	-	Sep.	-2.00	-0.25	Dec.	-2.17	-0.39	Dec.
Oct.	1.05	0.13	-	1.17	0.21	-	Oct.	-0.32	-0.04	-	-0.21	-0.04	-
Nov.	1.14	0.14	-	1.30	0.23	-	Nov.	0.65	0.08	-	0.62	0.11	-
Dec.	0.70	0.09	-	0.64	0.12	-	Dec.	-0.19	-0.03	-	-0.28	-0.05	-
Yea.	0.55	0.07	-	0.68	0.12	-	Yea.	-2.02	-0.26	Dec.	-2.16	-0.39	Dec.

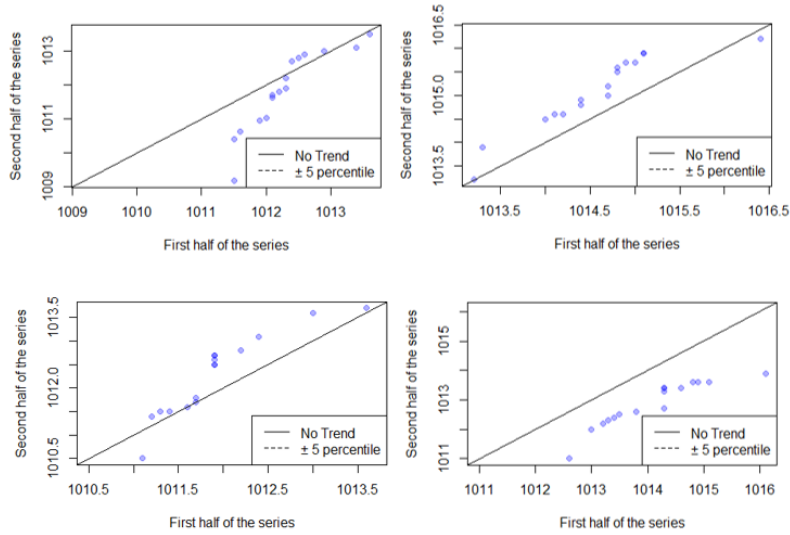


Figure 5: Results of Innovative Sen Method for average pressure by annual ( up-left = Trabzon Bölge, up-right = Rize, down-left = Giresun, down-right =Hopa)

## Relative Humidity

Table 3: Results of trend tests for maximum relative humidity( up-left = Trabzon Bölge, up-right = Rize, down-left = Giresun, down-right =Hopa)

	Mann Kendall			Spearman rho				Mann Kendall			Spearman rho		
	z	r	Trend	z	r	Trend		z	r	Trend	z	r	Trend
Jan.	-0.86	-0.11	-	-0.8	-0.14	-	Jan.	2.61	0.33	Inc.	2.73	0.49	Inc.
Feb.	1.77	0.22	-	1.79	0.32	-	Feb.	4.72	0.59	Inc.	4.19	0.75	Inc.
Mar.	1.51	0.19	-	1.39	0.25	-	Mar.	3.94	0.49	Inc.	3.78	0.68	Inc.
Apr.	0.78	0.1	-	0.95	0.17	-	Apr.	3.63	0.45	Inc.	3.56	0.64	Inc.
May	0.91	0.12	-	1.03	0.19	-	May	3.54	0.44	Inc.	3.6	0.65	Inc.
Jun.	1.15	0.15	-	1.33	0.24	-	Jun.	2.79	0.35	Inc.	2.82	0.51	Inc.
Jul.	-2.06	-0.26	Dec.	-1.8	-0.32	-	Jul.	1.61	0.2	-	1.84	0.33	-
Aug.	-1.33	-0.17	-	-1.22	-0.22	-	Aug.	1.67	0.21	-	1.9	0.34	-
Sep.	0.39	0.05	-	0.51	0.09	-	Sep.	1.49	0.19	-	1.87	0.34	-
Oct.	2.13	0.27	Inc.	2.17	0.39	Inc.	Oct.	3	0.38	Inc.	3.14	0.56	Inc.
Nov.	0.21	0.03	-	0.2	0.04	-	Nov.	2.76	0.35	Inc.	2.77	0.5	Inc.
Dec.	0.55	0.07	-	0.5	0.09	-	Dec.	4.15	0.52	Inc.	3.86	0.69	Inc.
Yea.	1.09	0.14	-	1.53	0.27	-	Yea.	3.68	0.46	Inc.	3.63	0.65	Inc.

	Mann Kendall			Spearman rho				Mann Kendall			Spearman rho		
	z	r	Trend	z	r	Trend		z	r	Trend	z	r	Trend
Jan.	-1.91	-0.24	-	-2.05	-0.37	Dec.	Jan.	0.29	0.04	-	0.41	0.07	-
Feb.	-1.05	-0.13	-	-1.12	-0.2	-	Feb.	1.52	0.19	-	1.76	0.32	-
Mar.	0.03	0.01	-	0.15	0.03	-	Mar.	1.61	0.2	-	2.03	0.36	Inc.
Apr.	-2.13	-0.27	Dec.	-2.14	-0.38	Dec.	Apr.	2.69	0.34	Inc.	2.88	0.52	Inc.
May	-2.14	-0.27	Dec.	-2.13	-0.38	Dec.	May	2.48	0.31	Inc.	2.3	0.41	Inc.
Jun.	-2.5	-0.31	Dec.	-2.46	-0.44	Dec.	Jun.	1.7	0.21	-	1.59	0.29	-
Jul.	-4.93	-0.62	Dec.	-4.45	-0.8	Dec.	Jul.	1.36	0.17	-	1.38	0.25	-
Aug.	-3.31	-0.41	Dec.	-3.03	-0.54	Dec.	Aug.	1.18	0.15	-	0.93	0.17	-
Sep.	-3.13	-0.39	Dec.	-2.93	-0.53	Dec.	Sep.	1.44	0.18	-	1.41	0.25	-
Oct.	-1.04	-0.13	-	-0.92	-0.17	-	Oct.	2.56	0.32	Inc.	2.48	0.45	Inc.
Nov.	-1.36	-0.17	-	-1.42	-0.25	-	Nov.	1.54	0.19	-	1.63	0.29	-
Dec.	-1.15	-0.15	-	-1.18	-0.21	-	Dec.	1.7	0.21	-	1.46	0.26	-
Yea.	-2.19	-0.27	Dec.	-2.29	-0.41	Dec.	Yea.	1.91	0.24	-	2.04	0.37	Inc.

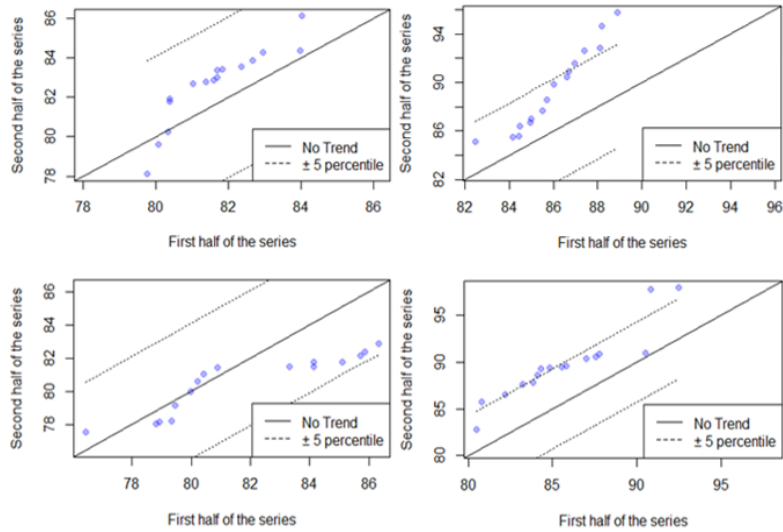


Figure 6: Results of Innovative Sen Method for maximum relative humidity by annual ( up-left = Trabzon Bölge, up-right = Rize, down-left = Giresun, down-right =Hopa)

## Precipitation

Table 4: Results of trend tests for precipitation ( up-left = Trabzon Bölge, up-right = Rize, down-left = Giresun, down-right =Hopa)

	Mann Kendall			Spearman rho				Mann Kendall			Spearman rho		
	z	r	Trend	z	r	Trend		z	r	Trend	z	r	Trend
Jan.	1.31	0.17	-	1.35	0.24	-	Jan.	0.9	0.1	-	1	0.18	-
Feb.	-2.77	-0.35	Dec.	-2.8	-0.5	Dec.	Feb.	-1.7	-0.21	-	-1.54	-0.28	-
Mar.	1.39	0.18	-	1.29	0.23	-	Mar.	1.46	0.18	-	1.33	0.24	-
Apr.	-0.99	-0.13	-	-0.98	-0.18	-	Apr.	0.36	0.05	-	0.37	0.07	-
May	0.65	0.08	-	0.8	0.14	-	May	0.67	0.08	-	0.6	0.11	-
Jun.	0.11	0.02	-	0.14	0.03	-	Jun.	-1.25	-0.16	-	-1.36	-0.24	-
Jul.	0.42	0.05	-	0.5	0.09	-	Jul.	0.5	0.06	-	0.54	0.1	-
Aug.	-0.18	-0.02	-	-0.14	-0.03	-	Aug.	1.22	0.15	-	1.34	0.24	-
Sep.	0.34	0.04	-	0.42	0.07	-	Sep.	1.51	0.19	-	1.3	0.23	-
Oct.	-1.51	-0.19	-	-1.63	-0.29	-	Oct.	-0.28	-0.04	-	-0.2	-0.04	-
Nov.	-1.02	-0.13	-	-1.02	-0.18	-	Nov.	-0.6	-0.08	-	-0.5	-0.09	-
Dec.	0.05	0.01	-	0.13	0.02	-	Dec.	-1.6	-0.2	-	-1.58	-0.28	-
Yea.	-1.02	-0.13	-	-0.99	-0.18	-	Yea.	0.2	0.02	-	0.14	0.03	-

	Mann Kendall			Spearman rho				Mann Kendall			Spearman rho		
	z	r	Trend	z	r	Trend		z	r	Trend	z	r	Trend
Jan.	2.38	0.3	Inc.	2.36	0.42	Inc.	Jan.	0.5	0.06	-	0.46	0.08	-
Feb.	-1.65	-0.21	-	-1.52	-0.27	-	Feb.	-1.28	-0.16	-	-1.34	-0.24	-
Mar.	2.45	0.31	Inc.	2.43	0.44	Inc.	Mar.	2.03	0.25	Inc.	2.02	0.36	Inc.
Apr.	-2.42	-0.3	Dec.	-2.52	-0.45	Dec.	Apr.	1.61	0.2	-	1.54	0.28	-
May	0.96	0.12	-	0.95	0.17	-	May	0.37	0.05	-	0.23	0.04	-
Jun.	0.26	0.34	-	0.58	0.1	-	Jun.	-0.24	-0.03	-	-0.11	-0.02	-
Jul.	1.54	0.19	-	1.7	0.3	-	Jul.	0.96	0.12	-	0.97	0.18	-
Aug.	-0.99	-0.13	-	-1.07	-0.19	-	Aug.	0	0	-	0.06	0.01	-
Sep.	0.83	0.1	-	0.73	0.13	-	Sep.	1.96	0.25	Inc.	1.94	0.35	-
Oct.	-0.29	-0.04	-	-0.33	-0.06	-	Oct.	1.02	0.13	-	1.06	0.19	-
Nov.	-0.05	-0.01	-	-0.02	0	-	Nov.	-0.21	-0.03	-	-0.34	-0.06	-
Dec.	1.1	0.14	-	1.12	0.2	-	Dec.	0.75	0.09	-	0.79	0.14	-
Yea.	2.25	0.28	Inc.	2.07	0.37	Inc.	Yea.	2.08	0.26	Inc.	2.14	0.38	Inc.

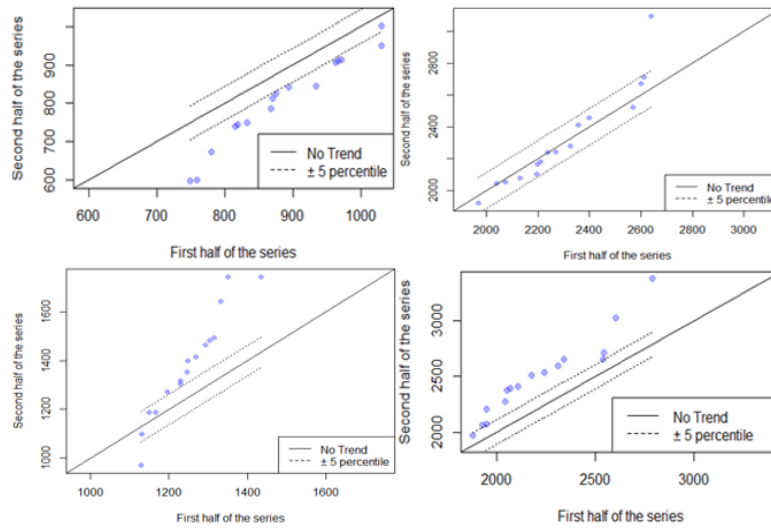


Figure 7: Results of Innovative Sen Method for precipitation by annual ( up-left = Trabzon Bölge, up-right = Rize, down-left = Giresun, down-right =Hopa)

## Temperature

Table 5: Results of trend tests for average of maximum temperature ( up-left = Trabzon Bölge, up-right = Rize, down-left = Giresun, down-right =Hopa)

	Mann Kendall			Spearman rho				Mann Kendall			Spearman rho		
	z	r	Trend	z	r	Trend		z	r	Trend	z	r	Trend
Jan.	1.78	0.22	-	1.97	0.35	Inc.	Jan.	2.11	0.27	Inc.	2.22	0.4	Inc.
Feb.	2.55	0.32	Inc.	2.63	0.47	Inc.	Feb.	3.2	0.4	Inc.	3.13	0.56	Inc.
Mar.	0.5	0.07	-	0.52	0.09	-	Mar.	1.72	0.22	-	1.78	0.32	-
Apr.	0.47	0.06	-	0.52	0.09	-	Apr.	1.1	0.14	-	1.26	0.23	-
May	1.77	0.22	-	1.77	0.32	-	May	2.03	0.26	Inc.	2.12	0.38	Inc.
Jun.	1.9	0.24	-	1.88	0.34	-	Jun.	3.69	0.47	Inc.	3.61	0.65	Inc.
Jul.	0.67	0.09	-	0.62	0.11	-	Jul.	3.12	0.39	Inc.	3.01	0.54	Inc.
Aug.	1.22	0.16	-	1.49	0.27	-	Aug.	3.59	0.45	Inc.	3.49	0.63	Inc.
Sep.	1.66	0.21	-	1.7	0.3	-	Sep.	3.26	0.41	Inc.	3	0.54	Inc.
Oct.	0	0	-	0	0	-	Oct.	0.67	0.09	-	0.62	0.11	-
Nov.	1.98	0.25	Inc.	2.02	0.36	Inc.	Nov.	2.68	0.34	Inc.	2.6	0.47	Inc.
Dec.	1.71	0.22	-	1.8	0.32	-	Dec.	2.01	0.25	Inc.	2.19	0.39	Inc.
Yea.	2.69	0.34	Inc.	2.75	0.49	Inc.	Yea.	4.25	0.53	Inc.	4	0.72	Inc.

	Mann Kendall			Spearman rho				Mann Kendall			Spearman rho		
	z	r	Trend	z	r	Trend		z	r	Trend	z	r	Trend
Jan.	2.34	0.29	Inc.	2.4	0.43	Inc.	Jan.	1.36	0.17	-	1.51	0.27	-
Feb.	3.42	0.43	Inc.	3.4	0.61	Inc.	Feb.	2.26	0.28	Inc.	2.20	0.40	Inc.
Mar.	1.35	0.17	-	1.45	0.26	-	Mar.	0.49	0.06	-	0.56	0.10	-
Apr.	1.56	0.2	-	1.68	0.3	-	Apr.	-0.32	-0.04	-	-0.24	-0.04	-
May	2.99	0.37	Inc.	3.2	0.58	Inc.	May	1.02	0.13	-	1.00	0.18	-
Jun.	4.82	0.61	Inc.	4.44	0.8	Inc.	Jun.	1.30	0.16	-	1.40	0.25	-
Jul.	3.78	0.47	Inc.	3.66	0.66	Inc.	Jul.	0.13	0.02	-	0.09	0.02	-
Aug.	3.48	0.44	Inc.	3.49	0.63	Inc.	Aug.	1.71	0.22	-	1.68	0.30	-
Sep.	3.43	0.43	Inc.	3.21	0.58	Inc.	Sep.	1.09	0.14	-	1.15	0.21	-
Oct.	0.58	0.08	-	0.52	0.09	-	Oct.	-0.52	-0.07	-	-0.56	-0.10	-
Nov.	3	0.38	Inc.	3.04	0.55	Inc.	Nov.	1.17	0.15	-	1.26	0.23	-
Dec.	2.13	0.27	Inc.	2.3	0.41	Inc.	Dec.	1.72	0.22	-	1.84	0.33	-
Yea.	4.61	0.58	Inc.	4.43	0.79	Inc.	Yea.	1.90	0.24	-	2.24	0.40	Inc.

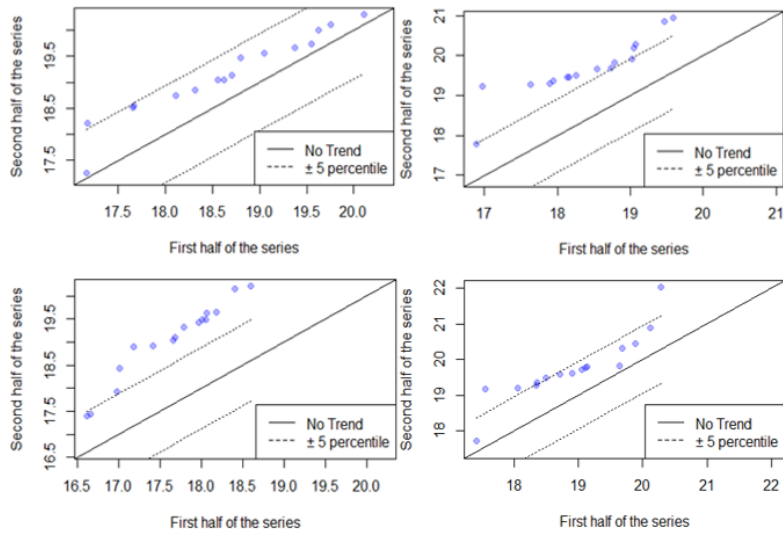


Figure 8: Results of Innovative Sen Method for average of maximum temperature by annual ( up-left = Trabzon Bölge, up-right = Rize, down-left = Giresun, down-right =Hopa)

## Meteorological Drought Analyzes

### Standardized Precipitation Index – SPI

Table 6: Results of the SPI analysis(Number of years)

	Trabzon	Rize	Giresun	Hopa
Extremely Dry	2	-	-	-
Dry	15	19	18	17
Wet	15	12	12	14
Extremely Wet	-	1	2	1

### Percent of Normal Index – PNI

Table 7: Results of the PNI analysis(Number of years)

	Trabzon	Rize	Giresun	Hopa
Drought	-	-	-	-
Light Drought	2	-	1	-
Normal	28	31	28	30
Humid	2	1	3	2

### De Martonne Aridity Index

Table 8: Results of the DMI analysis (Number of years)

	Trabzon	Rize	Giresun	Hopa
Dry				
Sub Wet	8			
Wet	24		29	
Very Wet		32	3	32

## Comparison of Sea Temperatures

Table 9: Correlation coefficient between actual measurement and satellite observation

	Giresun	Trabzon	Rize	Hopa
Jan.	0.538	0.492	0.167	0.412
Feb.	0.731	0.339	0.363	0.732
Mar.	0.726	0.552	0.466	0.711
Apr.	0.670	0.668	0.646	0.605
May	0.355	0.716	0.374	0.351
June	0.563	0.753	0.724	0.642
July	0.550	0.304	0.164	0.318
Aug.	0.603	0.393	0.103	0.411
Sep.	0.619	-0.004	-0.002	0.250
Oct.	0.533	0.292	0.285	0.388
Nov.	0.394	0.127	0.175	0.184
Dec.	0.303	0.219	0.403	0.529
Ann.	0.633	-0.064	0.101	0.352

## CONCLUSION

According to the Mann Kendall and Spearman rho trend tests, increasing trends were determined in Giresun station for average and average of the maximum temperature values in almost all months and annual values. According to the Innovative Sen Method, a medium and high increasing trend was observed in february, may, june, november and annual values. For average and maximum relative humidity, decreasing trend was determined in almost all months and annual values by Mann Kendall and Spearman rho trend tests and Sen Method. There is an increasing trend in pressure parameter for april in Giresun. As a result of trend analysis, an increasing trend was observed in Giresun station precipitation values in january, march and annual results, and a decreasing trend was observed in april by Mann Kendall and Spearman rho tests. According to the Innovative Sen Method, a low increasing trend was observed in the january, march and july charts, and a low and medium decreasing trend was observed in the february and april charts.

According to the Mann Kendall and Spearman rho trend tests, an increasing trend was determined in Trabzon Bölge station for average temperature values in almost all months and annual values. For average of the maximum temperature, and increasing trend was determined in february, november and annual values. According to the Innovative Sen Method, a medium and high increasing trend was observed in january, february, september and annual values. For average relative humidity, decreasing trend was determined in almost all months and annual values, despite increasing trend was observed in maximum relative humidity in october by Mann Kendall and Spearman rho trend tests. By Sen Method, there is increasing trend in february, march, october and annual values. There is an increasing trend in pressure parameter for april in Trabzon. As a result of trend analyzes, a decreasing trend was observed in precipitation values in february and a decreasing trend was observed in april by Mann Kendall and Spearman rho tests. According to the Sen Method, low, medium decreasing trend was observed in the february, october and annual charts.

As a result of trend analyzes, increasing trends were determined in Rize station for average and average of the maximum temperature values in almost all months and annual values. According to the Innovative Sen Method, medium and high degree of increasing trends in the almost all months and annual charts. As a result of trend analysis, no trend was observed in Rize station precipitation values according to Mann Kendall and Spearman  $\rho$  tests. According to the Innovative Sen Method, it was observed that there was a low trend in the January chart, a medium increasing trend in the September and August charts, and a moderate decreasing trend in the February, June and December charts. For average relative humidity, no trend was observed, despite increasing trend was observed in maximum relative humidity in almost all months and annual values by Mann Kendall and Spearman rho trend tests and Sen Method. Increasing trends were determined in pressure parameter for april, november and annual values by all tests.

According to the Mann Kendall and Spearman rho trend tests, an increasing trend was determined in Hopa for average and average maximum temperature values in february and annual values. According to the Innovative Sen Method, a medium increasing trend was observed in february and annual charts. For average relative humidity, decreasing trend was determined in almost all months and annual values, despite increasing trend was observed in maximum relative humidity in march, april, may, october and annual values by Mann Kendall and Spearman rho trend tests and Sen Method. There is a decreasing trend in pressure parameter for january, august, september and annual values in Hopa. As a result of trend analyzes, an increasing trend was observed in precipitation values in march, september and annual values by Mann Kendall and Spearman rho tests. According to the Sen Method, low and medium increasing trend was observed in the september and annual charts.

According to the Standardize Precipitation Index, 12 years were wet, 18 years were dry and 2 years (2009, 2016) were extremely wet in Giresun. In Trabzon, 15 years were wet and 15 years were dry. The years 2012 and 2013 were extremely dry. Rize has 12 wet and 19 dry years. 2016 was extremely wet in Rize. In Hopa, 14 years of wet and 17 years of drought, 2016 was extremely wet year for Hopa.

According to the Percent of Normal Index, 1 year in Giresun and 2 years in Trabzon were light drought. 1 year in Rize, 2 years in Hopa, 2 years in Trabzon and 3 years in Giresun were humid. According to the results of the De Martonne Aridity Index, Rize and Hopa were very wet in all years. Giresun has 3 very wet years and 29 wet years, 8 years were sub wet and 24 years were wet in Trabzon.

The comparison result of the sea temperature data shows that Giresun has the highest correlation coefficients, Rize has the lowest. There are significant irregularities for each station by monthly basin. Giresun has 6 high and 3 low correlations, Hopa has 4 high and 6 low correlations. 3 high and 8 low correlations were determined for Trabzon, there are 2 high and 9 low correlations for Rize. Comparison of the sea temperature data shows that the satellite observations are not suitable enough for coastal areas of Eastern Black Sea Region because there are deficiencies of the satellite observations at coastal areas and significant differences between the sea temperature data due to the high number of the cloudy, rainy days and phase of the sea currents.

In briefly, average and maximum temperatures are increasing for all stations in monthly and yearly basin. In light of these results, it is obvious that climate change has caused changes in these provinces. Although the average relative

humidity values decreasing due to increase in temperature, the maximum relative humidity values increase. When results of precipitation were examined, Hopa and Giresun have increasing trend in annual amount. There is no significant trend observed in Trabzon and Rize. Also there are increasing and decreasing values in all stations by monthly basin. The results show that there are crucial irregularities in precipitation regimes. Trend tests and drought analyzes clearly show these irregularities. These irregularities are important for the problems that climate change may cause on a micro scale. It is essential to use higher resolution models and data from other stations for regional analyzes in the future to understand climate change and meteorological drought.

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# CLIMATE CHANGE PROJECTIONS OVER TÜRKİYE AND EFFECTS ON WATER RESOURCES: EXAMPLE OF EUPHRATES TIGRIS RIVERCOURSE

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## ABSTRACT

*In the last century, the effects of climate change caused by the increasing greenhouse effect as a result of human activities have started to be felt intensely in our lives. Assessing the potential impacts of climate change on environmental and natural systems is crucial for adaptation to and mitigation of climate change. Therefore, estimating how the climate will change regarding different scenarios should be examined and coping strategies should be put forward in the light of these expectations. The aim of this paper is to present the global scale climate change and its reflections over Türkiye in particular. In this context, climate scenarios and climate models on which future climate projections are based were examined. The spatial and temporal changes of global mean temperatures and precipitation within the Representative Concentration Pathway scenarios of global modeling studies will be presented. Future climate projections for Türkiye produced for medium and high emission scenarios using regional climate models will be evaluated. Moreover, to discuss the potential consequences of climate change over the waters of Euphrates and Tigris Rivers, investigations on various regional climate models in terms of temperature and precipitation will be presented.*

**Keywords:** Climate Projections, SSP Scenarios, RCP Scenarios, Regional Climate Models, Türkiye Euphrates, Tigris

## INTRODUCTION

Climate has a significant impact on life on Earth as well as human activity. Climate variables like temperature and precipitation determine the flora in a given area, and summer and winter temperatures, as well as the likelihood of flooding, determine the design and location of houses. A late frost or a severe hailstorm can ruin entire crops. Therefore humankind have always had to cope with climate and its consequences. Earth's climate has never remained constant and the global mean temperature has varied within the range of 10°C. Within this 10°C temperature range, ice ages have occurred in the world and temperate climatic conditions have been realized between these ice ages. Therefore, the 1.1°C increase in global average temperatures in the last century compared to the pre-industrial revolution indicates an extremely rapid climate change. These increases over the last century may seem insignificant to people other than climate scientists, but changes in the central parts of the continents (where agriculture is dense) are typically twice the global average change, while changes at higher latitudes are 3 to 4 times the global mean (with large impacts on tundra, permafrost, boreal forests and sea ice). Furthermore, small changes in global mean surface temperature correspond to large changes in climate patterns that affect human activities and ecosystems (Schneider et al., 2014).

Changing the composition of the atmosphere through human impacts changes the global climate by increasing the atmospheric greenhouse effect. The exponential increase in the concentration of CO<sub>2</sub>, one of the most potent greenhouse gases in the atmosphere, from 280 ppm in the 1800s before the industrial revolution to around 424 ppm in 2024, as well as increases in the emissions of other greenhouse gases and the consequent warming trend of the world climate have led many atmospheric scientists to investigate the response of the global climate to future increases. The IPCC 5th and 6th Review Reports, in which global climate studies are compiled, reveal that air temperature has increased more over land than over oceans, that the last four decades have been much warmer than on record, and that the 2000s were the warmest years on record, based on analyses of independent data sets. Hence, to better understand and make predictions on climate, several different climate emission scenarios were developed by scientists and policymakers. These scenarios are based on different assumptions about how human activities, such as the burning of fossil fuels, will affect the concentration of greenhouse gases in the atmosphere.

To help understand the potential impacts of different levels of greenhouse gas emissions on climate, the IPCC has developed a set of scenarios known as Representative Concentration Pathways (RCPs). The RCPs are based on four different pathways for future emissions, ranging from relatively low to relatively high emission levels. Each RCP is characterized by a specific greenhouse gas concentration in the atmosphere, measured in parts per million (ppm) of CO<sub>2</sub> equivalent (CO<sub>2</sub>e) (van Vuuren et al., 2011). Surely, these climate scenarios are not enough to understand the changes in regional climates of various locations on earth. Therefore many climate models have been developed to simulate climate projections due to natural climate forcings, land use changes, changes in anthropogenic emissions of greenhouse gases and aerosols, and to understand the response of the climate system to these forcings. Global and

regional models are the tools we use to improve our knowledge of the most important features of the climate system and the causes of climate change.

Correspondingly, the aim of this article is to present the global tendencies in climate change and its impacts over Türkiye and Euphrates-Tigris Rivers in particular. First, the climate scenarios on which future climate projections are based will be presented, then the expectations of climate change globally under different scenarios and the effects of climate change based on studies conducted in Türkiye will be discussed especially on Euphrates-Tigris region.

## **PROJECTIONS OVER TÜRKİYE**

Studies show that the Mediterranean basin, including Türkiye, is one of the climate change hotspots where the effects of global warming are seen as a result of changes in greenhouse gas concentrations in the atmosphere (Diffenbaugh & Giorgi, 2012). CMIP5, CMIP6, HighResMIP and CORDEX simulations all project that temperatures in the Mediterranean basin will increase between 3.5°C and 8.75°C for the RCP8.5 scenario by the end of the century. Largely independent of models and emission scenarios, summer warming is projected to be up to 40-50% higher than global annual warming. The projected warming over Türkiye, the Balkans, the Iberian Peninsula and North Africa can reach twice the global average locally, and the increase in summer temperatures increases the amplitude of the annual temperature oscillation (Lionello & Scarascia, 2018; Almazroui et al., 2020). Climate models predict a decrease in precipitation in all seasons and an expansion of the Mediterranean climate northwards and eastwards, with affected regions becoming more arid with increasing drought (Alessandri et al., 2015; Rajczak & Schär, 2017; Lionello & Scarascia, 2018; Spinoni et al., 2020). As a result of the decrease in precipitation, the decrease in soil moisture and thus the inability to cool the surface through evaporation will lead to a faster increase in temperatures in the region.

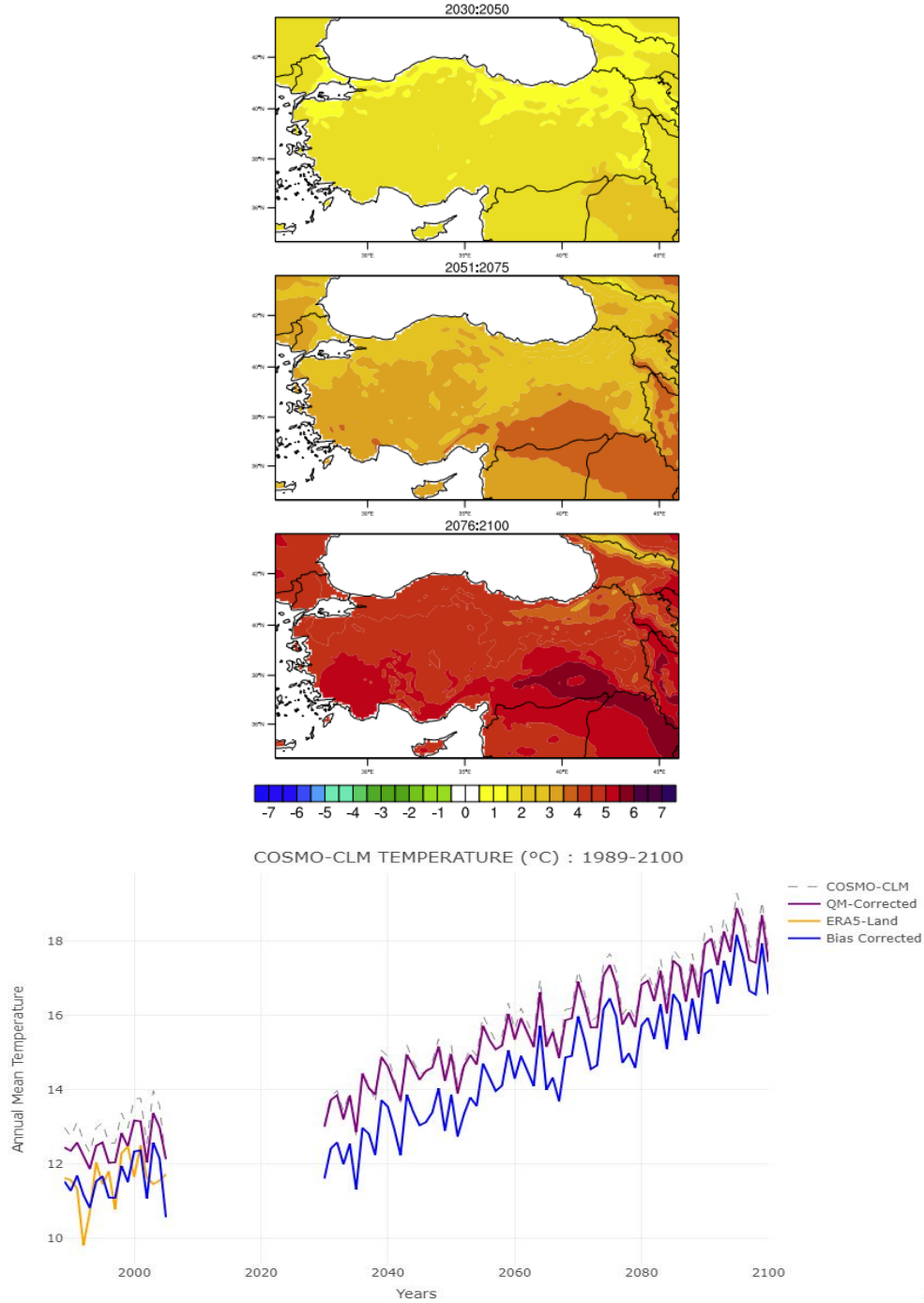


Figure 1. Mean Temperature Change over Türkiye regarding RCP8.5

Determining global climate projections at a higher resolution in a region with highly variable topography, coastal zones and vegetation cover such as Türkiye's geography is important in determining strategies for adaptation studies and measures to be taken. Climate change can have significant impacts on sectors such as agriculture, water resources, health and tourism. In order to provide information with better resolution, global climate model outputs are transferred to limited areas by using dynamic downscaling method with regional climate models. Many modeling studies have been conducted to investigate climate variability in Türkiye. Ünal et al. (2001); Önel and Semazzi (2009); Ünal et al. (2010); Bozkurt and Şen (2011); Önel (2012); Önel and Ünal (2014), Önel et al. (2014), MGM (2015) and SYGM (2016) are examples of climate modeling studies involving Türkiye. However, in recent years, regional climate simulations at 3 km resolution have started to be carried out over Türkiye in order to conduct impact studies at local scale (Yürük, 2017; Ünal & Yürük, 2017; Yürük & Ünal, 2016; Yürük et al., 2022). A major source of uncertainty in regional climate model simulations stems from the parameterization of sub-grid scale convection. As the scales that allow convection are approached with increasing model resolution, it is possible to turn off convection parameterization. Simulations at very high resolutions are particularly capable of better representing the statistics associated with extreme weather events (e.g. extreme precipitation).

## EUPHRATES AND TIGRIS RIVER CASE

The Euphrates and Tigris River Basin (ETR), being less developed and minimally influenced by human activities, clearly shows the impacts of climate change, beyond natural climate fluctuations. Research indicates a rise in drought frequency and duration in this region. To combat droughts, irrigation and dam construction have increased, affecting the water and energy balance and leading to higher evaporation rates. Additionally, reduced rainfall and changes in snowmelt patterns disrupt the water cycle. Growing concerns over water resources emphasize the need for ongoing climate research in the ETR. Several studies have analyzed the effects of various climate scenarios on the region, focusing on aspects like water balance and the accuracy of climate and hydrological models. As a continuation of this research, this study aims to project the climate of the ETR throughout the 21st century using data from the Coordinated Regional Climate Downscaling Experiment (CORDEX).

Results presented consist of annual zonal means for 2-meter temperature given in Celcius (°C) and annual zonal sums for daily total precipitation in millimeters per day (mm/day) within the ETB. Basin boundaries are highlighted in bolder black lines, national borders are in light grey, and the water bodies are masked for visualizations. The annual zonal mean temperature for the reference period within the ETB for ERA5 is 18.8°C, where the annual zonal mean of daily total precipitation is 1 mm/day (Table 1 and Table 2). Accordingly, lower temperatures and higher precipitation values are seen in the areas with higher elevations. Temperature values increase over the watercourse towards the Shatt al-Arab River, and the maximum temperature means of the basin are located near the Persian Gulf. Annual zonal sums for daily total precipitation are layered concerning the elevation.

Table 1 - Annual zonal mean of daily temperature at 2 meters (Celcius)

ERA5	ETB – 2-meter Temperature (Celcius)					
	Ref. 1986-2005	DJF	MAM	JJA	SON	Annual
	Min	-8.4	1.5	14.8	4.9	3.4
	Max	14.3	26.7	38.8	28	26.9
	<b>Mean</b>	<b>6.5</b>	<b>17.7</b>	<b>30.6</b>	<b>20.2</b>	<b>18.8</b>

Table 2 - Annual zonal mean of daily total precipitation (mm/day)

ERA5	ETB – Daily Precipitation (mm/day)					
	Ref. 1986-2005	DJF	MAM	JJA	SON	Annual
	Min	0.3	0.2	<0.2	0.2	0.2
	Max	8.4	5.7	3.5	3.3	4.1
	<b>Mean</b>	<b>1.9</b>	<b>1.4</b>	<b>0.1</b>	<b>0.7</b>	<b>1</b>

Figure 2 – ERA5, Reference period, annual zonal mean of a) daily temperature (Celcius) b) daily Total Precipitation (mm/day)

The results for CORDEX Africa's future scenarios are analyzed through the ensemble data generated by nine equally weighted regional models. To obtain the highest number of regional models with continuous data, RCP2.6 and RCP8.5 scenarios were adopted. Due to having developed an ensemble, rows of the panel plots represent seasons, while columns represent the early (2021-2040), mid-term (2051-2070), and late (2081-2099) future results regarding the 21<sup>st</sup> century. The reference period belongs to the ensemble results between 1986 and 2005. The results consist of the difference in the annual zonal mean 2-meter temperature given in Celcius (°C) and the difference in annual zonal sums for mean daily total precipitation in millimeters per day (mm/day) within the ETB. It should also be noted that the values of the future scenarios account for the bias-corrected values.

According to the RCP2.6 projections, temperatures rise globally during the early and mid stages of the 21st century and tend to decrease after peaking around the 2050s. Parallel to the global trend in RCP2.6, the annual zonal mean temperature over the basin shows an increase of 1.3°C during the early period and 1.5°C for the middle of the century. The annual mean follows the decrease expected in RCP2.6 during the late future period, decreasing by 0.1°C up from 1.5°C, resulting in an overall increase of 1.4°C by the end of the century compared to the reference period (Table 3).

*Table 3 - Changes in annual zonal mean daily surface temperature at 2 meters regarding RCP2.6 (Celcius)*

<b>Change in Temperature (RCP2.6) - Future minus Reference (Δ°C)</b>					
	<b>DJF</b>	<b>MAM</b>	<b>JJA</b>	<b>SON</b>	<b>Annual</b>
<i>Reference</i>					
<b>Mean</b>	<b>6.3</b>	<b>17.6</b>	<b>30.6</b>	<b>20.2</b>	<b>18.8</b>
<i>2021-2040</i>					
<b>ΔMean</b>	<b>1.2</b>	<b>1.4</b>	<b>1.6</b>	<b>1.4</b>	<b>1.3</b>
<i>2051-2070</i>					
<b>ΔMean</b>	<b>1.6</b>	<b>1.6</b>	<b>1.6</b>	<b>1.5</b>	<b>1.5</b>
<i>2071-2099</i>					
<b>ΔMean</b>	<b>1.5</b>	<b>1.6</b>	<b>1.5</b>	<b>1.4</b>	<b>1.4</b>

Overall, the results show that the minimum temperatures are expected to increase more than maximums, leading the gradient between minimums and maximums to decrease. Mountainous areas are also likely to receive increases, especially during the mid and late century's DJF. Increases projected for the mid-century remain in the late century over the mountainous areas during DJF and MAM.

Being the worst-case scenario, RCP8.5 projects a continuous rise in temperatures throughout the century. Accordingly, ETB's mean temperatures see a zonal increase of 1.5°C, 3.5°C, and 5.7°C during early, mid, and late periods consecutively (Table 4). However, similar to RCP2.6's results, the minimum temperatures are expected to increase more than the maximums, weakening the gradient between minimums and maximums. This is likely to cause an increase in relative humidity and evapotranspiration.

*Table 4 - Changes in annual zonal mean daily surface temperature at 2 meters regarding RCP8.5 (Celcius)*

<b>Change in Temperature (RCP8.5) - Future minus Reference (Δ°C)</b>					
	<b>DJF</b>	<b>MAM</b>	<b>JJA</b>	<b>SON</b>	<b>Annual</b>
<i>Reference</i>					
<b>Mean</b>	<b>6.3</b>	<b>17.6</b>	<b>30.6</b>	<b>20.2</b>	<b>18.8</b>
<i>2021-2040</i>					
<b>ΔMean</b>	<b>1.2</b>	<b>1.5</b>	<b>1.9</b>	<b>1.5</b>	<b>1.5</b>
<i>2051-2070</i>					
<b>ΔMean</b>	<b>3.2</b>	<b>3.4</b>	<b>4.2</b>	<b>3.4</b>	<b>3.5</b>

2071-2099

$\Delta$ Mean

4.8

5.9

6.8

5.5

5.7

Considering the annual zonal daily total precipitation mean of the ETB (1mm/day) and RCP2.6 being the best-case scenario, the decrease in mountainous areas is striking during DJF and MAM. Mainly during MAMs throughout the century, the northern parts of the ETB receive a decline in precipitation greater than 0.5mm/day (Table 5). The decline in precipitation spreads over every season, especially during the early stages of the 21st century. The ensemble also shows a decline over the same region during the early and late periods.

Table 5. Annual and Seasonal Changes in Precipitation RCP2.6

		Seasonal Changes in Precipitation (RCP2.6) - Future minus Reference ( $\Delta$ mm/day)				
		DJF	MAM	JJA	SON	Annual
Reference	Min	0.1	0.1	0	0.1	0.1
	Max	11.1	8.4	2	5.3	6.1
	Mean	1.7	1.4	0.2	0.8	1
2021-2040						
	$\Delta$ Min	0	-0.1	0	0	0
	$\Delta$ Max	0.3	-1	-0.1	1	-0.1
	$\Delta$ Mean	0.1	-0.1	-0.1	0.2	0
2051-2070						
	$\Delta$ Min	-0.1	0	0	0	0
	$\Delta$ Max	-0.6	0.3	0.2	-0.1	-0.2
	$\Delta$ Mean	0	0.1	0	0	0.1
2071-2099						
	$\Delta$ Min	0	0	0	0	0
	$\Delta$ Max	-0.2	-0.6	0	0.4	-0.1
	$\Delta$ Mean	0	0	-0.1	0.2	0.1

RCP8.5 scenario delivers more extreme results. The mountainous arch reaching the northern to eastern boundaries of the basin hosts significant changes except the JJA season. For the DJF, changes mentioned in RCP2.6 increase their impact. The decline in precipitation over the Taurus and Munzur Mountains extends its coverage to the ranges of Kavuşşahap, Buzul, and İkiyaka. Western Taurus Mountains see a similar decline in precipitations exceeding 0.5mm/day. When the annual zonal total precipitation means for ETB are investigated, besides the local changes ranging between 0.5mm/day declines to 0.5mm/day increases, the ETB is likely to see no changes in precipitation until the 2070s. The mean difference in the annual zonal total precipitation increases by 0.1mm/day at the beginning of the late century.

Table 6. Annual and Seasonal Changes in Precipitation regarding RCP8.5

		Seasonal Changes in Precipitation (RCP8.5) - Future minus Reference ( $\Delta$ mm/day)				
		DJF	MAM	JJA	SON	Annual
Reference	Min	0.1	0.1	0	0.1	0.1
	Max	11.1	8.4	2	5.3	6.1
	Mean	1.7	1.4	0.2	0.8	1
2021-2040						
	$\Delta$ Min	0	0	0	0	0
	$\Delta$ Max	-0.7	-0.9	-0.1	0.9	-0.1
	$\Delta$ Mean	0	0	-0.1	0.2	0
2051-2070						
	$\Delta$ Min	0	0	0	0	0
	$\Delta$ Max	-1.2	-1.8	-0.2	1	-0.4
	$\Delta$ Mean	-0.1	-0.2	-0.1	0.2	0
2071-2099						
	$\Delta$ Min	0	-0.1	0	0	0
	$\Delta$ Max	0.3	-2.4	-0.4	1.8	0
	$\Delta$ Mean	0.1	-0.3	-0.1	0.4	0.1

The early century of the ETB brings a decrease of 0.1mm/day and an increase of 0.2mm/day for JJA and SON consecutively. The mid-century seasons see a decline for the DJF with 0.1mm/day, the MAM with 0.2mm/day, and the JJA with 0.1mm/day, while during the SON, zonal means increase by 0.2mm/day (Table 6). In the late century, the mean precipitation of the ETB increases by 0.1mm/day during DJF. MAM and JJA, on the other hand, host 0.3mm/day and 0.1mm/day decreases, but SON sees a spiking 0.4mm/day increase primarily because of the increase presented over the southern ranges of the Zagros Mountains.

## CONCLUSIONS

Türkiye is located in the Mediterranean basin, which is defined as the most vulnerable to climate change. Regional modeling studies have determined that average temperatures will increase until the end of the century according to the RCP4.5 and RCP8.5 scenarios, and by the end of the century, temperature increases will be in the range of 2°C to 6°C depending on the scenarios. Simulations show that temperatures rise particularly in summer than in winter, with stronger temperature increases in the South Aegean coast, Mediterranean and South East Anatolia regions. The increase in daytime and nighttime temperatures will increase both the frequency and duration of heat waves in Türkiye. Considering the increase in atmospheric humidity, sensible temperatures will be higher. Accordingly, increases in energy use for cooling purposes should be expected in the summer months.

Both optimistic and pessimistic scenarios foresee a decrease in total annual precipitation in Türkiye. RCP8.5 indicates that Türkiye will be exposed to a stronger drought towards the end of the century compared to the medium scenario. Reduced snowpack in the Eastern Anatolia region could lead to significant reductions in river flows in spring and summer, when melting occurs today. This will cause economic losses in Türkiye's agriculture and energy sectors. Increased evapotranspiration, especially due to the increase in temperatures, will increase the need for irrigation in the agricultural sector.

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# CLIMATE CHANGE AND WINTER DROUGHT

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*Winter drought in Pakistan and combating climate change were discussed at this paper. Winter Drought in Pakistan: Pakistan is a country where 84% of water flow originates from monsoon rains in the summer. In the winter, western disturbances bring only 5-6% of the precipitation. However, this amount is crucial as winter is the season for growing wheat, a staple food crop. Various global simulation models and adjustments were applied. Different models provide varying results depending on parameters and data quality. However, one common point among all models is that climate change prediction. Pakistan will face both drought and flood risks in the future. Impacts of Climate Change: Climate change affects not only food security but also hygiene, drinking water, health, and the physical resilience of children. Climate change has become one of the most pressing issues in Pakistan. However, Pakistan is not among the countries causing climate change; it contributes only 0.03% of total carbon emissions. Despite this, it is among the top 10 countries most affected in terms of loss of life. Climate Change and Responsibility: According to United Nations data, the highest per capita carbon emissions come from small, wealthy Middle Eastern countries. However, in terms of total pollution, the United States, China, and India are the largest emitters. Pakistan is not responsible for the climate change problem but must cope with its consequences. Agricultural Impacts and Groundwater Usage: Winter drought has two major impacts on wheat production. Groundwater Usage: Insufficient water leads to increased use of already declining groundwater reserves. Heat Waves: High temperatures result in smaller wheat grains, causing significant losses in production. Proposed Solutions and Scientific Studies: Innovative approaches, such as developing new crop varieties and altering cropping patterns, are needed to combat climate change. Additionally, investment in education and scientific research is essential for the advancement of climate change science. Climate change is not yet a fully developed scientific field and contains many uncertainties. Therefore, support for educational institutions to run models and understand local impacts is critical. The Importance of Dams and Financial Challenges: Dams in Pakistan were initially built to store summer flows. However, due to climate change, dams are needed to provide protection during dry years. Securing financing is key to constructing these dams. International financial support is crucial for ensuring dam safety and sustainable development. As a conclusion; the international community provides various funds and initiatives to combat climate change. However, these supports should be directed towards education and climate change science. Universities should serve as a focal point for climate change science.*

**Keywords:** Winter drought, flood risk.

# PURIFICATION OF INDUSTRIAL WATER BY PLANTS FOR IRRIGATION PURPOSES

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## **ABSTRACT**

*The study was planned to determine the potential uses of naturally growing aquatic plants for industrial water purification. Different aquatic plants which have capability to decrease water pollution by absorbing nutrients were utilized in this study. The capability of plants were investigated by measuring chemical oxygen demand (COD), biochemical oxygen demand (BOD), electrical conductivity (EC), total dissolved solids (TDS) and pH of the medium on weekly basis. Some naturally growing aquatic plants were collected and subjected to industrial water at different concentration (50 and 100%) in plastic pots with three replicates. Then after 30 days the morphological, and biochemical parameters of plants was calculated to observe the effect on plants. The experiment was conducted in completely randomized design. It has been observed that morphologically and biochemical attributes were adversely affected. However, the COD, BOD, TDS and pH were gradually decreased with increasing time as compared to control. The data was collected and analyzed statistically by using statistics 8.1 program.*

**Keywords:** Industrial water, pollution, nutrients

# USE OF STRAW WATER HOLDER IN AGRICULTURE

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## **ABSTRACT**

*Water and water resources, which are the source of life for all living things, are decreasing and disappearing day by day in our country as well as in the world. Our country is among the countries that will be affected by drought and global warming. In Turkey, 72% of water resources are used in agriculture, 18% for domestic use (drinking and utility purposes) and 10% in industry. Due to global warming and drought, the use, consumption and savings of water are extremely important.*

*In agricultural production, we can prevent water loss in the soil by irrigation, and thus we can get more efficiency from production by getting maximum benefit from irrigation. For this purpose, straw water retainers and straw water retainer compounds can be used to ensure water conservation in the soil in agricultural production. These compounds retain water hundreds of times their weight and turn it into gel form. Straw water retainers and their compounds slowly return the retained water to the production environment, that is, to the soil. Therefore, they help preserve water in the soil in hot and arid climates.*

*In this study, the general characteristics of straw water retainers, their benefits in preserving soil water and their use in agriculture will be explained.*

**Key words:** *Irrigation, mulch, , soil humidity, water management.*

## **INTRODUCTION**

Climate change due to global warming also negatively affects agricultural ecosystems. The most important of these effects is drought. Lack of sufficient water at the effective root depth during the plant growing period negatively affects the quality and quantity of the product. Most soils of arid and semi-arid regions are defined by low water retention capacity [1].

The use of various water retaining products is becoming widespread in order to get maximum benefit from irrigation and to get more efficiency from production by reducing the loss of water given to the soil in agricultural production. These products can be an ideal product for plant production in hot and arid climates, where irrigation opportunities are limited and fresh water resources are insufficient, thanks to their ability to release the water they hold into the environment little by little. The main purpose of their use in production is to increase the water retention capacity of the soil [2, 3, 4]. Thanks to these products, the permeability of the soil surface increases and more rainwater is retained in the soil.

In this study, the general characteristics of straw water retainers, their benefits in preserving soil water and the importance of their use in agriculture, especially in crop production, will be emphasized.

## **WHAT IS A STRAW WATER TRAP?**

In order for the soil to retain water, the amount of organic matter in the soil should be increased by adding worm castings, animal manure and green manure to the soil in agricultural production. The higher the amount of organic matter, the higher the water holding capacity of the soil.

Straw water retainers are an easy-to-use soil additive that can retain water and nutrients. These products, which are also used as soil regulators and plant improvers, absorb rain and irrigation water and preserve 200-300 times their volume of water in the plant root zone. It acts as a constantly available water reservoir in plant roots, making the water the plant needs available for consumption.

Straw water retainers increase the water retention capacity of sandy, silty, clayey and humus soil environments. Water-retaining compounds contain different amounts of Carbon (C), Hydrogen (H), Oxygen (O), and Potassium (K). It allows the irrigation period to be reduced by approximately 50%. It limits water and nutrient loss due to washing. It increases water retention capacity and reduces the loss of nutrients and trace elements in water. It provides resistance to drought and water stress in the plant [5, 6, 7].

When straw water retainers are added to the soil, plant roots turn directly towards the water-activated water retaining granules to get the water they need. It is fed by the suction force from the product in the form of a water tank. Additionally, it provides additional nutrition thanks to the straw it contains. It also easily absorbs water-soluble fertilizer and ensures its slow release into the soil. Since there will be no free water as a result of water retention, there is absolutely no decay. It takes approximately 3 years for the water retaining product to be broken down by microorganisms in the soil [1].

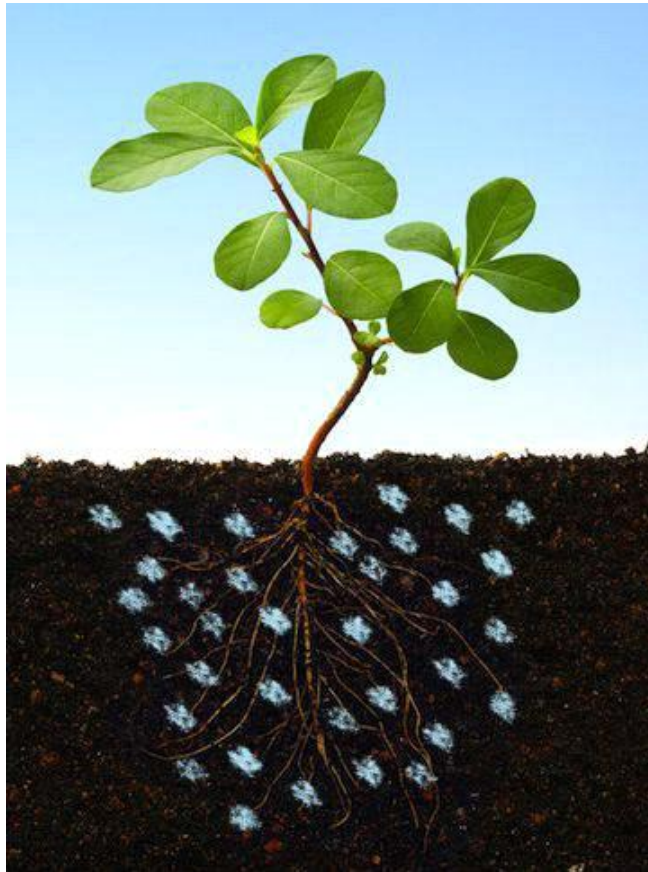
## **APPLICATION OF STRAW WATER TRAPS**

Straw water traps can be used for all kinds of plants in cultivation areas such as fields, vineyards, gardens, lawns, nurseries and ornamental plants.

**In potted plants;** A water trap with 15-20 grams of straw can be used in large pots. In small pots, using 5-10 gr is sufficient. During soil change or repotting in the pots, we place some soil at the bottom of the new pot, place a water trap with straw on it, and add some water on top to ensure water retention. We place our rooted and soil-covered plant in our pot and fill the margins with soil. We can end the application process by giving life water to our plant.

In pots with planted plants, we open the soil until we see the plant roots, spread the straw water retaining material to reach the root area of the plant, and add some water on top. Thus, we ensure water retention. After watering, the plants in the pot will not need water for a long time, as the straw water trap will hold hundreds of times its own volume of water.

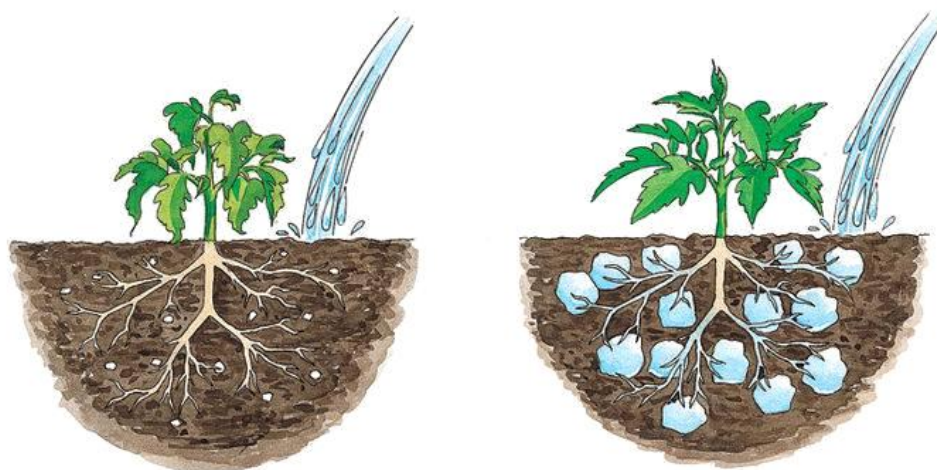
**In saplings;** Straw water retainer is applied dry or diluted to the pit where planting will be done. Then the sapling is placed in the hole and covered.



**Figure 1.** Use of straw water catchers in planting saplings [8]

**In the trees;** The straw water catcher is compatible with all types of trees and shrubs. Application for trees and shrubs can be done wet or dry. When applying on planted trees, the soil at the base of the tree is opened by 20-40 cm and a circular water pool is created at the base of the plant by hoeing. The plant is allowed to absorb water from this created water pool. Then, the straw water trap in powder granule form is manually sprinkled in accordance with the tree form. Some irrigation is also done to ensure that the product reaches a gel consistency. The gel-like product acts as a water reservoir for tree roots by holding water and preventing water from escaping deeper and evaporating. The opened irrigation pool is covered with soil and a water tank is created in the plant root area. After this process, the plant can be watered in later periods.

**In seedlings;** Straw water trap is used for transferring seedlings from the greenhouse to open areas and for bare root dipping to prevent the roots from losing water and drying out during transportation to long distances. For a good result, it is important that the product has a consistency that will completely adhere to the roots.



**Figure 2.** Use of straw water traps in planting seedlings[8]

**In the grass;** In order for the plants that will improve the ventilation and water circulation in the soil to create an optimum long-lasting and greener more lush landscape area, ventilation channels are opened by applying a lawn aeration machine to the grass areas. Straw water traps in powder granular form are poured into the opened ventilation channels. A water tank for plants is created at the bottom of the ventilation channels. Plant roots head towards the water tanks created at the bottom of the channels. In this way, plants can create a lush and greener landscape that is more resistant to long irrigation periods.

**In grains;** In mechanized agriculture, it can be easily applied to the fertilizer hopper of the seeder before planting, in combination with fertilizer. Here, care should be taken to ensure that the seeder chamber is not damp.

## USAGE DOSES ACCORDING TO FRUIT AND VEGETABLE TYPES

**Table 1.** Usage doses required for some fruit types

Strawberry	1-1.5 kg/da
Apple	100-120 g/ tree
Melon	1.5 kg/da
Watermelon	1.5 kg/da
Cherry	12-150 g/ tree
Nectarines	90-120 g/ tree
Peach	90-120 g/ tree
Pear	90-129 g/ tree

**Table 2.** Required dosages for some types of vegetables

Tomatoes	1.5 kg/da
Pumpkin	1.5 kg/da
Bean	1.2-1.5 kg/da
Spinach	1-1.5 kg/da
Cabbage	1.2-1.5 kg/da
Cauliflower	1.2 kg/da
Lettuce	1-1.2 kg/da
Parsley	1.5 kg/da
Potatoes	1.2-1.5 kg/da

Leek	1.2 kg/da
Cucumber	1.5 kg/da
Garlic	1.5 kg/da
Onion	1-1.5 kg/da
Pepper	1.2-1.5 kg/da

## HOW MUCH WATER IS SAVED?

Depending on soil, climate and environmental conditions, up to 50% water savings can be achieved. Considering the problem of irrigation and clean water supply, it can economically reduce electricity, labor and water loss by more than half.

## BENEFITS OF STRAW WATER TRAPS IN AGRICULTURAL USE

- \* Increases the water retention capacity of the soil
- \* Provides economic benefit in reducing irrigation costs
- \* Prevents water loss caused by infiltration and evaporation in the soil
- \* Reduces the density of the soil after being placed in the soil
- \* Increases air and water circulation in the soil
- \* It allows the irrigation period to be reduced by approximately 50%.
- \* Limits water and nutrient loss due to washing due to irrigation.
- \* Increases water retention capacity and reduces the loss of nutrients and trace elements in water.
- \* Provides resistance to drought and water stress in the plant
- \* Reduces costs by contributing to product efficiency
- \* It increases plant development by ensuring the absorption of water and nutrients in the root area so that the plant can receive nutrients at optimum levels.
- \* Increases germination and sprouting rates by providing the necessary moisture to the seed
- \* It improves the physical properties of tight impermeable soils by increasing the aeration capacity of the soil.
- \* Prevents fertilizer losses due to excessive irrigation and rainfall
- \* Works in combination with many soluble fertilizers and soils
- \* Protects the environment against drought and pollution of groundwater
- \* Prevents water stress of plants caused by drought
- \* It prevents the roots from drying out and keeps them moist when transferring the seedlings from the greenhouse to open areas and long distances.

## CONCLUSIONS

In agricultural production, the water requirements of plants vary according to years and development periods. It is necessary for plants to have water and nutrients in the environment as they complete their developmental stages. Straw water retainers act as a water tank and provide the water that plants need. This helps plants get rid of water stress and reduces wilting and drying rates. It will also reduce water usage, time and money as it will reduce the frequency of irrigation and fertilization. It will also contribute to the protection of clean water resources.

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## SHORT BIOGRAPHY

Funda DÖKMEN graduated from Uludağ University, Faculty of Agriculture, Department of Horticulture. She completed her master's degree on greenhouse cultivation at the same Faculty. She was a scholarship researcher at the College of Agriculture at the University of London for one year. She completed her PhD on irrigation at Trakya University Tekirdağ Faculty of Agriculture, Department of Agricultural Structures and Irrigation.

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# INFLUENCE OF CLIMATE CHANGE CONDITIONS ON PHYTOMASS PRODUCTION OF PERENIAL GRASS IN ARID ECOSYSTEMS OF TUNUSIA

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## **ABSTRACT**

*Climate change was characterized by important modifications in rainfall and temperature. The characteristic of the functioning of Mediterranean ecosystems, especially those of arid zones, is the diversity of plant behavior in relation to the environmental factor's variability. The study of this variability is the key for understanding how plant communities respond to climate change and to environmental factors. This study aimed to examine the phytomass production of two important forages species in pastoral ecosystems of Tunisia: *Stipagrostis ciliata* (Desf.) De Winter and *Cenchrus ciliaris* L. We compared the performance of different populations of them. Biomass accumulation showed a very significant population effect ( $P < 0.001$ ). Population from Sidi Toui and Bou Hedma were the most efficient in terms of rainfall use efficiency. The least productive populations were Tozeur and Raas Jedir. Biomass accumulation of *S. ciliata* populations showed significant differences ( $F = 2.986$ ;  $P = 0.053$ ). Population Bou Hedma and Sfax, those were the most productive. *S. ciliata* populations from Matmata and Gabes kept the same range in phytomass productivity. This variability emphasizes the importance of variability in intraspecific phytomass production in these perennial grass species. This variability also proved the importance of the precipitation effect on the production of phytomass. Differences between the two species differed significantly, *Cenchrus ciliaris* was the most productive. Within protected areas (National parks of Bouhedma and Sidi Toui) this species is still vigorous. Considering its high adaptability to bioclimatic constraints and its high pastoral value *Cenchrus ciliaris* may be considered as important grazed forage to small ruminant nutrition.*

**Key Words:** *Perennial grass – precipitation – phytomass -arid zone*

# MONITORING AND MANAGEMENT OF GROUNDWATER IN PAKISTAN FOR SUSTAINABILITY OF AGRICULTURE AND RURAL LIVELIHOOD

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## Abstract

Groundwater management is a complex and crucial resource in developing countries like Pakistan, where it contributes 40–50% to irrigation water requirements, 100% to drinking water, and nearly 90% to industrial water needs. The Punjab Irrigation Department (PID) has installed 3000 observation wells in canal-irrigated areas, and groundwater levels and quality are monitored twice a year. However, this monitoring often fails to accurately demarcate fresh, saline, and critically depleted zones over the year and on a long-term basis due to changing climate conditions. Traditional tools and methods are used for monitoring aquifer potential, which does not capture recharge and extraction events due to global climatic changes. Human and instrument errors are also encountered. The intensity, frequency, and duration of hydroclimatic disasters like floods and droughts have changed, necessitating continuous and more scientific monitoring. A research study on improving groundwater management to enhance agriculture and farming livelihoods in Punjab, Pakistan, was conducted at pilot sites in the province along with the other two provinces. Under this research, automatic data loggers have been installed in the pilot study sites in the Lower Bari Doab Canal (LBDC) area to keep a continuous record of groundwater levels and quality. Community groups were involved and sensitized about changing trends in the level and quality of groundwater by imparting necessary onsite training and awareness. The sustainability of groundwater for irrigation and domestic/industrial use depends on achieving or moving towards salt balance in groundwater and irrigation systems. For soil health and crop productivity, salt balance in groundwater and in the root zone is important. There is a need when groundwater is polluted; it cannot be recovered, and even if it is difficult to manage the highly depleted aquifers once they are polluted.

**Keywords:** *Groundwater, Monitoring, Data-Loggers, LBDC, Monitoring network, Observation-well, Punjab, Pakistan*

## Introduction

Water is essential for life on earth but according to **USGS**, 96.5 percent of earth's water is oceans and 2.5 percent freshwater and the other 0.9 percent saline. Around 99 percent of all fresh water is available in underground aquifers (**UNEP, 2002**), and more than a quarter of the world's population draws water from these underground aquifers. Currently, Pakistan country is 4<sup>th</sup> largest user of groundwater in the world after India, USA & China (**Margat, J., and J. Van der Gun. 2013, M.T. Bhatti., et al. 2017**). About 60 percent of groundwater withdrawn worldwide is used for agriculture; the rest is almost equally divided between the domestic and industrial. In many nations, more than half of the groundwater withdrawn is for domestic water supplies and globally it provides 25 percent to 40 percent of the World's drinking water (**J. van der Gun. 2004**). Groundwater in Pakistan underpins the food security and livelihood of a multitude of small rural communities. Pakistan's population of over 200 million relies heavily on water because it relies heavily on agriculture which makes a significant contribution (~21 percent) to gross domestic production (**Government of Pakistan, 2014**). Presently, the cropping intensity in the Indus Basin of Pakistan has increased from 68 percent during 1947 to around 150 percent to meet the food requirement of increased population which has resulted

overexploitation of groundwater to meet more than 50 percent water demand for irrigation. In Pakistan, irrigated agriculture contributes about 90 percent of food production. In Punjab province of Pakistan groundwater is contributing about 40-50 percent in irrigation water requirements in addition to about 100 percent drinking water and nearly 90 percent industrial water needs.

Proper monitoring plays a vital role in the assessment of potential and sustainable use of any natural water resource especially under the globally changing climatic conditions. Groundwater is a hidden common pool natural resource and its management is fraught with many and more complex challenges as compared with surface water resources. Accurate monitoring of groundwater levels, quality and abstraction rates has remained a major constraint in developing countries like Pakistan. Directorate Land of Reclamation (DLR) of Punjab Irrigation Department (PID) were installed about 3000 observation wells in canal irrigated areas of the province since year 2003. Development of private tubewells and the emergence of groundwater markets are related physical, economic and social factors which are complex and interlinked (PIES, 2001). Groundwater level in the Punjab Province is being monitored from the observation well twice in a year during pre and post monsoon. Similarly, groundwater quality from about 2500 irrigation tube wells is being observed twice in a year.

Similarly, groundwater quality from about 2500 irrigation tube wells is being observed twice in a year. There are issues and challenges in this monitoring which in cumbers the proper demarcation of fresh, saline and critically depleted zones over the year and on long term basis under the changing climate. Community is not involved; and traditional tools and methods are being used for monitoring of aquifer potential in the province. This monitoring does not capture the events of recharge and extraction taking place during a year due to global climatic changes and human and instrument errors are apprehended. Under current scenario; intensity, frequency and duration of hydro climatic disasters like floods and droughts have changed which demand for continuous and more scientific monitoring. In Punjab province, a model project in the sense of team building, grass root level approach and innovative ideas/tools implemented in the LBDC command area. Different interventions were implemented at two pilot sites of LBDC in collaboration with partnerships, farming community and other stakeholders to address the complexity of achieving effective and fair groundwater management.

**Aim and Purpose of this study:** The aim of this study is to (i) build the skills, knowledge and confidence of researchers, farmers, farming communities, relevant government and non-government agencies, and provide tools and processes to improve groundwater planning and management (iii) to enhance capacity and institutional arrangements for post project adoption of tools for agricultural sustainability and to enhance livelihoods of farming families in Pakistan.

## **Methodology**

**Study Area:** The study was implemented in three provinces of Pakistan viz Punjab, Sindh and Baluchistan which was completed in 2021. In Punjab Province, study was conducted in the Lower Bari Doab Canal (LBDC) command area including districts Kasur, Okara, Sahiwal and Khanewal. The cultivable command area (CCA) of LBDC is about 1.7 million acres (0.747 m ha). LBDC originates from the left bank of River Ravi at Balloki Barrage located in South west of Lahore at a distance of about 65 km. Balloki Barrage was constructed in year 1911. Surface water and groundwater are two major irrigation water sources in the LBDC command area. The Irrigation system of LBDC consisted of Fall Structure (20 Nos), Head Regulators (55 )

## **Groundwater Challenges**

- Lack of holistic groundwater management policy framework
- Groundwater use much beyond the sustainable limits

- Multiple groundwater uses.
- Complexities in defining groundwater entitlements and enforcement.
- General lack of awareness among the stakeholders.
- Deterioration of groundwater quality
- Saline groundwater intrusion in the fresh areas
- Increasing cost of groundwater pumping with decline in water table.

Groundwater plays the major role to meet the irrigation demands in upper and lower area. There are some similarities and differences in terms of groundwater management aspects in upper and lower LBDC command area. The upper and lower areas provide diverse hydrogeological and socio-economic conditions for agricultural activities and food production. Following main activities and mile stones have achieved under the project. Given the complex interactions of physical and socio-economic factors and the variability of these factors across the case study areas, it is important to have a clear understanding of the scientific and socio-economic impacts of the local groundwater management problem.

For this reason, the research this was conducted in two selected distributaries as a pilot sites i.e 1-R at district Okara and 11-L at district Sahiwal for groundwater use impact assessment along the head, middle and tail of the selected distributaries and also at the upper and lower area of the LBDC area. The purpose of the selecting pilot sites for groundwater monitoring in this project was to collect data through automatically data loggers, and manual groundwater sounder instrument to evaluate changes in groundwater levels due to variations in precipitation and groundwater pumping. To enhance the impacts of this study, it was considered the groundwater monitoring through different instruments and methods, awareness raising campaign and providing training among farmer communities and other stakeholders about groundwater dynamics and encourage for observing and managing their groundwater cooperatively. For this reason, the activities were designed for hydrological data collection by researchers, farmers and stakeholder forum participation. In view of this, a sound methodology for data collection and its implementation in the study area was considered. Different department, Institutions, NGOs and progressive farmers were involved to conduct a participatory rural appraisal (PRA) in the area to increase the data quality and knowledge base from the beginning.

**Field Interventions:** Different interventions/experimentations were applied in the selected sites along the LBDC command area to achieve the goals and objectives of the study. A multi-disciplinary approaches involved selection of site area, field observations, farmers interviews, literature review and analysis of Geographical Information System (GIS) data for spatial and temporal groundwater situation, assessment of groundwater plumage activities and climatic conditions for their influence on fluctuation of groundwater level, water quality, local hydrology, groundwater monitoring through installation of piezometers and data loggers (Baro, Diver & CTD), ApnaPani software, handing-over groundwater monitoring instruments, trainings for groundwater monitoring, financial and livelihood of the stakeholders in the area. The underlying approaches adopted in the project were systemic, people-centered and holistic.

**Participatory Rural Appraisal:** PRA is a set of approaches, methods and behaviors that help people share reflections on their social and physical environment. PRA emphasizes co-learning, both through learning alongside local communities, and by involving project stakeholders from a variety of backgrounds. PRA is an intensive, systematic but semi-structured progressive learning experience, compressed in time, and carried out in a community by a multi-disciplinary team. The PRA activity fit into a larger systems-framing that we are calling an on-going process of co-inquiry that moves research beyond individual projects led by research academics into a process of inquiry that draws on, and enhances, the skills of multiple co-inquirers. A major feature apparent from the PRAs is the diversity across the sites. Access to groundwater varies depending on position in the distributary, and the use of groundwater also varies widely. Some villages are prosperous, others are clearly impoverished and struggling. In some areas agriculture

is thriving, and young people are interested in working the land, and improving outcomes. In other villages agriculture is declining, and young men are moving away for work, sometimes internationally. The usefulness of the Farmer Organizations is also highly variable across the potential sites. A clear theme common to all villages is the potential for improved water use. PRAs were conducted at the head middle and tail of the right and left of fourteen distributaries of the Lower Bari Doab Canal (LBDC) located in districts Okara and Sahiwal. PRAs were undertaken with men and women within the same locations. The interviews involved economists and sociologists from academia, hydro-engineers from PID and PCRWR, PIDA and NGOs representatives meeting in the selected villages to discuss groundwater and related issues with the men. The details from the pairs of discussions are included, partly to show the areas of overlap and disparity, and to capture as much detail as possible.

**Installation of piezometers and Data Loggers:** After field visits, it was observed that most of existing observation wells had been choked and there are no observation wells at the suitable sites along the distributaries. Four new groundwater observation wells were installed in the head and tail of the pilot distributaries of the study area. The locations were selected in consultation with field team with due consideration to access and security. The observation wells typically consisted of a bore-hole 25– 30 m deep in which a section of blind pipe and slotted pipe were and slotted pipe were installed (2 feet dia). Automatic recording instruments with a pressure transducer (Schlumberger Baro logger, TD Diver and CTD-Diver), herein referred to as instruments, were suspended in each groundwater observation well. The instruments (Diver & CTD) measure depth to water table, temperature and conductivity. Each data logger was suspended at a measured depth from the surface using steel cable. Instruments were secured within a lockable iron box enclosure. For data accuracy of automatic data loggers, depth to water table from observation wells were measured through manual water level sounder (solinst Brand) by a field team after each month since 2018. Data collected from data loggers, manually measured from observation wells in June 2010 were spatially interpolated using the kriging method in Arc GIS, graph from Micro Soft Excel. Further, the approach used micro based case studies (comprising upper & lower area) to analyses and assess the current situation and identify strategies to enhance economic, social and environmental outcomes of groundwater monitoring activities. Community groups have been involved and sensitized about changing trends of level and quality of groundwater by imparting necessary onsite trainings and awareness. Different instruments and methods were applied for groundwater monitoring in the area. All these instruments are economical viable and benefit for both farmers and environment because these instruments help for sustainable use of surface and groundwater for irrigation. Monitoring of groundwater level fluctuations work as a parameter to proxy for the volume of water in the aquifer.

**Monitoring of Groundwater levels -Ground trothing:** Monitoring of groundwater from observation wells are the main source of information regarding the hydrologic stresses on the aquifer system (Alley and Taylor, 2001). In LBDC command area, there were about 31765 of tube wells in district Okara and Sahiwal in 2001 which have been reached about 57144 of tube wells in 2019. The development of farmer's tube wells increased due to the extraction of groundwater to meet crop water requirement. Depth to water table in the LBDC area has decreased as a result of unconscious and excessive pumpage of groundwater for irrigation which resulted negative effects including a decrease of groundwater levels figure 4 and increase of groundwater pumping cost (AS Qureshi, 2020). **The purpose of this study** is to evaluate spatial and temporal changes in the depth to water table of groundwater in the study area. In LBDC command area, 194 numbers of Observation wells were installed which were started to install since 2003 and completed in 2006. Observation wells are approximately evenly distributed in the study area. The parameter depth to water table has been used which is useful when assessing water logging in canal command area. Depth to Water table also used to measure more groundwater extraction and recharge in an aquifer. Spatial and temporal maps of the study area was prepared for depth to water table using appropriate interpolation method with the data from active observation

wells in the LBDC command area which also helps to detect risk-prone areas for groundwater abstraction. About 40 to 50 % agriculture water requirement is met from groundwater due to which groundwater levels are continuously falling down. Groundwater level in district Okara and Sahiwal is declining continuously due to high pumpage by farmers for irrigation purpose.

#### **1-R/ LBDC District Okara**

To show the groundwater flocculation in the area, the data period ranges between 2008 and 2018 from the selected observation well in the area 1-R distributary of LBDC district Okara was observed and hydrograph was plotted. It has been observed that depth to water table in that area was 16 feet in 2008 and after ten years, depth to water table declined due to more pumpage and reached up to 22 feet in 2018.

**11-L/ LBDC District Sahiwal:** To show the groundwater flocculation in the area, the data period ranges between 2008 and 2018 from the selected observation well in the area 11-L distributary of LBDC District Sahiwal was observed and hydrograph was plotted. It has been observed that depth to water table in that area was 39 feet in 2008 and after ten years, depth to water table declined due to more pumpage and reached up to 43 feet in 2018.

A stakeholder's forum in LBDC command area was framed under the ACIAR project LWR-036/2015 to share the understanding of sustainable groundwater use for agriculture and the need for improved management through a participatory and integrated systems approach, The stakeholder's forum meeting was conducted at Chak No. 7/11-L Lahorianwala tehsil Chicha Watni, district Sahiwal. Five small groups including experts from different departments and local farmers were constituted to discuss about the following agenda and types of interventions which will be feasible for the study

- Identification of assets/resources.
- Identification of issues related to groundwater management and possible solutions.
- Presentation of each group and discussion on priority, resources and needs.
- Prioritization of interventions by stakeholders.
- Development of future action plan.

Stakeholder meetings were held in the office of Deputy Director, Agriculture (Extension), Okara and District Sahiwal for groundwater management and to enhance the farmers capacity building. Stakeholders including Water Management and Agriculture (Extension) of Agriculture Department, representatives for Agriculture University Faisalabad and Okara Campus, representative of DLR and IRI of PID and Farmers of the distributary 1-R and 11-L attended the stakeholder meeting. All Participants/stakeholders contributed in the discussion on groundwater issues and following management options were suggested:

- i. Applying water saving techniques and methods
- ii. changing cropping patterns
- iii. Soil quality/ salinity improvement.
- iv. lesser use of low delta crops
- v. Use of green manuring

**Distribution of field kits:** Distribution of EC meters to the Farmers for groundwater quality monitoring and knowledge sharing about need of groundwater monitoring (level & quality) to enhance crop productivity and to reduce more groundwater extraction and its pumping cost.

**Innovative mobile/Web applications:** Apna Pani (the Mobile application) and Apna Farm Decision support system (DSS) has been developed to assist agricultural and irrigation for the official and farmers in the field. Farmers and officials were trained about different mobile applications like Apna Pani and Apna Farm. Apna Pani to be used to record spatial reading of groundwater depth and quality in the area. The 'Apna Farm is to be used to find the monthly crop water requirement. These mobile applications are used to assess the monthly crop water requirements, deficits in surface water supplies, groundwater quality to make decision on sustainable crop production. The database has climate and weather information sources from the Pakistan meteorological department and World Weather On-line. The

database also includes the evapotranspiration algorithm of the Food and Agriculture Organization (FAO) to enable crop water re-equipment's to be estimated (Allen et al, 1988). The mobile app send data to the server using an internet connection (either broadband or mobile data). In case of unavailability of internet connection. The data will be stored offline and will be transferred once the mobile device is in the range of internet. The “Apna Pani” has three major components: Register a well record, report a well reading and check a well reading. Apna Farm which is the backbone of the farm management and displays information about land on the map. The Apna Farm app can be used via Mobile App and Web App. The Mobile version of Apna Farm shows information which include Weather, Soil Type, Soil Fertility, Groundwater depth and Profitability. The Web version of Apna Farm shows some additional information which includes crop water requirements estimation, groundwater data (from mobile to web), soil data, and crop profitability data. Map annotations and custom reports.

**Observation well Information (located at IRI Lahore):** The temporal variation of EC and depth of groundwater at specific location at Lahore city. The value of EC at this site is not salty (EC is between 0.8 – 2.5 mS/cm) which show that water is not bad for irrigation and agriculture process (Syed et al., 2021). The Apna Pani mobile application has the capability to determine the groundwater depth. It would be helpful to identify the hotspots where groundwater extraction areas are resulting in significant water level declines. Crop Water requirements are completely dependent on climatic conditions and Crop evapotranspiration depends on soil moisture availability and climatic conditions. The current and future weather data is very important for successful crop production. It helps in real-time decision-making in relation to irrigation scheduling, sowing dated, plant protection measures, fertilizers application and time of crop harvesting.

**Estimation of Crop Water Requirements:** The Web based DSS will produce monthly water requirement's for the crops of interest. Crop water requirement is the total requirements of water from sowing to maturity of a Crop. Irrigation schedules have an important role for successful crop production especially in water scarce areas. The same crop may have different water requirements in different areas due to climate difference. The crop water requirement of same crop at same location may also vary from year to year due to difference in climatic conditions. The Apna Pani mobile application can determine the crop water requirement of each crop based on the site-specific climatic conditions. The trend in the outcome of Apna Pani and Apna Farm was validated by using the International Water Management Institute (IWMI) recommended crop water re-equipment's (Ullah et al., 2001). The results showed a close association between the crop water reequipment results from the mobile app and the IWMI data. The crop water reequipment for two different crops, wheat and maize, at two different locations are present below. The crop water reequipment for both crops planted at Sahiwal as calculated using the mobile app was compared with IWMI data and the error percentage varied from 1 to 18 %.

**Awareness Raising among Farmers and other Stakeholders:** One of the objectives of project study was to create awareness among farmers and other stakeholders in the LBDC canal command area and its adjacent distributaries, about groundwater issues and to share understanding of sustainable groundwater use for agriculture and the need for improved management through a participatory and integrated systems approach.

The field visits, field workshops and stakeholders meeting were organized in the LBDC area to create awareness among the farmers and other stakeholders regarding groundwater value, groundwater monitoring and its management options. Team demonstrated to the stakeholders about monitoring of groundwater level & quality through EC/TDS Meters, and water level sounder/indicator and digital data loggers installed at the pilot sites. Farmers were also provided on site demonstrations about monitoring of groundwater level and quality and Electrical Resistivity Survey (ERS) test. The use of scientific instruments will be help for installation of tube well at proper place, water requirement for crop types as per soil types and water quality etc.

Overall, the approach mentioned above helped us to understand and explore the full range of issues in groundwater uses, monitoring and management in the LBDC command area. Specifically, we identified promising interventions (direct as well as indirect) that can contribute to sustainable groundwater management. The project also helped to synthesize lessons from Australian experience on creating sustainable groundwater management regimes and assisting policy makers, NGO, and Provincial government agencies and other stakeholders associated with groundwater management.

Groundwater Management Cell of IRI, Irrigation Department arranged one field workshop in LBDC command area at Nai Wala Canal Rest House, Chak No.143/9-L, district Sahiwal on Saturday, November 25, 2017. Workshop was conducted under ACIAR Project LWR-036 titled “Improving Groundwater Management to Enhance Agriculture and Farming Livelihoods in Pakistan. Participants from the following Departments, Institutions, NGO, FOs and local farmers attended the workshop.

Irrigation Department.

- Irrigation Research Institute (IRI)
- Farmers Organizations (FOs)
- Farmers of 11-L, 9-L and 10-L/LBDC distributaries
- PIDA
- Agriculture Extension Department.
- On Farm Water Management.
- University of Agriculture Faisalabad.
- Individual experts
- Local Drillers

Workshop was to build the skills, knowledge and confidence of researchers, farmers, farming communities and relevant government and non-government agencies, and provide tools and processes to improve groundwater planning and management for enhancing agricultural sustainability in Pakistan. Field visits are conducted for the monitoring of daily gauges and discharge data of all the rivers, main canals, branch canals, feeders, distributaries, minors and sub minors for ensuring proper management of the Irrigation System and equitable distribution of canal water. Farmers said that surface water is not sufficient that’s why we have to pump more groundwater for crops. Farmers also said that there is proper need of awareness regarding groundwater management, types of water saving techniques and economic benefits by applying drips, sprinklers and other water saving instruments/techniques. Our forefathers needed less water for crop because at that time cropping intensity was 67%. Now it has increased from 67% to 150% to meet the food requirements of increasing population. According to IRSA report, water shortage is 35% in the country in year 2017. Numbers of tubewells have been increased from ten thousand to about one million in Punjab for last 70 years. He requested the farmers to use High Efficiency Irrigation System (drip system, Sprinkler, bed furrow, tunnel farming. etc). Agriculture Department is supporting farmers in installation of HEIS at subsidized rates. To share understanding of sustainable groundwater, use for agriculture and the need for improved management through a participatory and integrated systems approach a Stakeholder’s forum was conducted in LBDC command area at Chak No. 7/11-L Lorianwala tehsil Chicha Watni, district Sahiwal on 15th April, 2019. In stakeholder’s forum, representatives for Water Management and Agriculture (Extension) of Agriculture Department, Agriculture University Faisalabad and Okara Campus, DLR and IRI of PID and Farmers of the distributary 1-R and 11-L attended the meeting to achieve the ACIAR Project LWR-036/2015 titled “Improving Groundwater Management to Enhance Agriculture and Farming Livelihoods in Pakistan. Through an interactive webinar the three integrated components- Apna Pani (meaning “our water”) and Apna Farms were demonstrated with Pakistani farmer Sharaz Akhtar farmer from the village Chak No. 7/11-L Lorianwala tehsil Chicha Watni and also shared his experience of using the Apps. In order to increase farmer’s capacity and use of Apna Pani (meaning “our water”) and Apna Farms apps for groundwater management, two training days at farmer’s field were held at farmer’s field in district Chicha Watni, Punjab Pakistan for the introduction of technologies.

**Training and Capacity Building:** Farmers were also provided on site demonstration about monitoring of groundwater level sounder/indicator, TDS meter and pH meter and quality and Electrical Resistivity Survey (ERS) test before installation of tubewells. Representatives from DLR and GWMC of IRI team briefed the farmers about application and role of.

At the end, participants thanked the organizers to arrange an excellent field workshop and requested for arranging such events in future as well.

**Lessons learnt and Conclusions. :** It has been observed that depth to water table at Chak No. 7/1-R along 1-R distributary of LBDC district Okara was 19 feet in 2018 and at Chak 15/1-R was 30 feet. To meet water requirement for crops and due to more pumpage, the depth to water table reached up to 22 feet at 7/1-R and was 34 feet at 15/1-R after two years. Similarly, depth to water table at Chak No. 7/11-L along 11-L distributary of LBDC district Sahiwal was 49 feet and at Chak 22/11-L was 50 feet in 2018 while after year, the depth to water table reached up to 52 feet at 7/11-L and was 53.5 feet at 22/11-L due to over exploitation of groundwater to meet crops water requirement. A variety of participatory learning techniques are used under the ACIAR project. These techniques include participatory rural appraisal (PRA) consisting small group discussions, plenary discussion/presentation, practical (field) activities, field walk/field observations, stakeholder's forum development, field trials and field tours.

The project study revealed that awareness raising and capacity building among the farmers regarding surface and groundwater use in agriculture and domestic use, demonstration regarding groundwater monitoring instruments, EC&TDS meter, Apna Pani and Apna Farms software etc are to be required at top priorities for proper groundwater monitoring and management at local level. Under the ACIAR LWR-036, transfer of technologies including groundwater modeling, data loggers, Apna Pani and Apna Farm has been the prevalent practice for developing and spreading technological innovations from scientists to farmers. In this research study, it has been the researcher's task to identify, analyze and solve farmers' technical problems and the extension workers' task to transfer the results as messages to the farmers. The majority of participants of training program are adults, both women and men farmers in order to facilitate this capacity building activity. Farmers Training (FT) aims to ensure continued farmers' participation and a sustainable implementation of this project. Farmers' capacity has been enhanced through the development of new skills, the design, implementation, operation and maintenance of water management system and promoting the community capacity for joint management and raising the income for improving livelihood through farm diversification. It may have to be shared with other people as part of the process.

### **Recommendations for Future**

After discussion among the participants, it was concluded that for proper groundwater monitoring and management at local level, following recommendations for future have been suggested at top priorities:-

- Awareness among the farmers and public about surface and groundwater use in agriculture and domestic use, Punjab Water Policy and Punjab Water Act 2018, monitoring, management and governance.
- Awareness raising program/seminars/workshops on extent of groundwater depletion, water saving techniques/cropping pattern to increase crop-water productivity.
- Apply water saving techniques (sprinkler & drip) and methods.
- Applying ApnaPani and Apna Farm.
- Changing cropping patterns by adopting agro-climatic water productivity-based cropping.
- Soil quality/ salinity improvement and low delta crops use.
- Demonstration/Training to the farmers and other water users about use of groundwater monitoring scientific instruments like water level sounders, Ph, EC&TDS meters, and ApnaPani software etc,
- A biannual meeting (Rabi and kharif seasons) of stakeholder forum along with local farmers should be arranged to share cost analysis water saving techniques and to plan the new strategies.
- Interventions/technologies/methodologies for groundwater management should be implemented through subsidies, reward etc.
- Continuous monitoring should be taken/recorded.

- Facilitation of Soil & Water testing: Government Departments as well as private partnerships like FFC provide mobile facilities for water and soil testing in the areas and provide training to the farmers for collection of soil and water samples for testing.
- Construction of water storage/Rainwater Harvesting
- Run the groundwater Model and Management scenarios in other areas of the Punjab.
- Capacity building of farmers and researchers should be developed.

Note:

Authors declare no conflict of interest.

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# CAUSES AND EFFECTS OF CLIMATE CHANGE ON HUMAN HEALTH, AGRICULTURE, FOOD SECURITY- A CASE STUDY IN PAKISTAN

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## ABSTRACT

Climate changes have directly effect on human health which include respiratory and heart diseases, pest-related diseases like Lyme disease and food-related diseases and it also increases overall poor mental health. The indirect effects such as under-nutrition brought on by crop failures or a lack of access to safe drinking water.as climate change poses a wide range of risks to population health. The effect of climate change on agriculture can result in lower crop yields and nutritional quality due to drought, heat and flooding as well as increases in pest and plant diseases. The effects are unevenly distributed across the world and are caused by changes in temperature, precipitation and atmospheric carbon dioxide levels due to global climate change. In the year 2019, millions of people already suffered from food insecurity. Due to climate change and predicted decline in global crop production of 2-6% by decade. It has been predicted in 2019 that food prices will rise by 80% by 2050 which will likely lead to food insecurity, disproportionately affecting poorer communities. A study results predicts that estimates that the severity of heatwave and drought impacts on crop production tripled over the last 50 years in Europe from losses of 2.2-7.3% during 1964-2015.

Direct impacts from changing weather patterns are caused by rising temperatures heat waves and changes in rainfall (including droughts and floods). There are also direct impacts from increased atmospheric CO<sub>2</sub> levels: Higher crop yields due to CO<sub>2</sub> fertilization but also reduced nutrition value of crops due to lower levels of micronutrient. There will be climate driven changes in pests, plant diseases and weeds which can result in lower yields as well as other indirect impacts from changed conditions include agricultural land loss from sea level rise. There will also be less irrigation water availability due to melting glaciers. There will also be impacts on erosion and soil fertility and also effects on growing periods, food safety and losses (caused by fungi, leading to mycotoxins and bacteria that increase with climate warming and additional financial burdens. Climate change also creates water scarcity including disturbances of terrestrial precipitation, evaporation and soil moisture or worsened and have substantial effects in agriculture.

**Acknowledgment:** Contribution made by the Turkish authors for this review article is highly acknowledged and appreciable.

**Keywords:** Climate, Temperature, Rain, Health, Agriculture, Food, Pakistan.

# REVIEW OF BRINE TREATMENT IN REVERSE OSMOSIS DESALINATION PLANTS UTILIZING MEMBRANE TECHNOLOGIES

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## ABSTRACT

Concentrate management refers to the challenge of effectively handling and disposing of the byproduct generated during reverse osmosis process. The concentrate management problem arises from the need to properly handle and dispose of this concentrated waste stream. It often causes environmental and economic concerns, as the concentrate may contain high levels of pollutants, contaminants, or valuable resources that need to be managed appropriately. This research seeks to evaluate various handling approaches for the high-salinity byproduct stream rejected by the reverse osmosis membranes. Proper concentrate disposal is necessary both to protect the environment and to prolong membrane life. Some options that could be analyzed include the conventional, and membrane-based methods. Conventional methods involve the disposal of brine through physical or chemical processes. While, membrane-based methods involve the use of specialized membranes to separate and treat brine, allowing for water recovery and reducing the volume of waste. Comparing factors such as cost, footprint, regulatory compliance and sustainability metrics may help identify superior alternatives.

Parameters such as recovery rate, salt rejection, energy usage, and concentrate volume/composition may be monitored to gauge each technique's performance. Life cycle assessment can evaluate sustainability, while economic modeling assesses total cost of ownership. Statistical analyses may identify correlations between influential factors and process efficiency/effectiveness.

The conclusions drawn could offer valuable guidance to RO operators seeking the most cost-effective and eco-friendly concentrate management process. Such insights will be instrumental as desalination grows in importance to water security worldwide, especially in arid coastal regions. With careful experimental design and insightful analysis, this research promises to advance the scientific understanding and practical application of membrane technology.

**Keywords:** Concentrate Management, Reverse Osmosis, Waste Disposal, Membrane-based Methods, Sustainability Metrics.

# **NATURE – CLIMATE – HUMAN – RESULT**

## **A Case Study on Lake Eğirdir**

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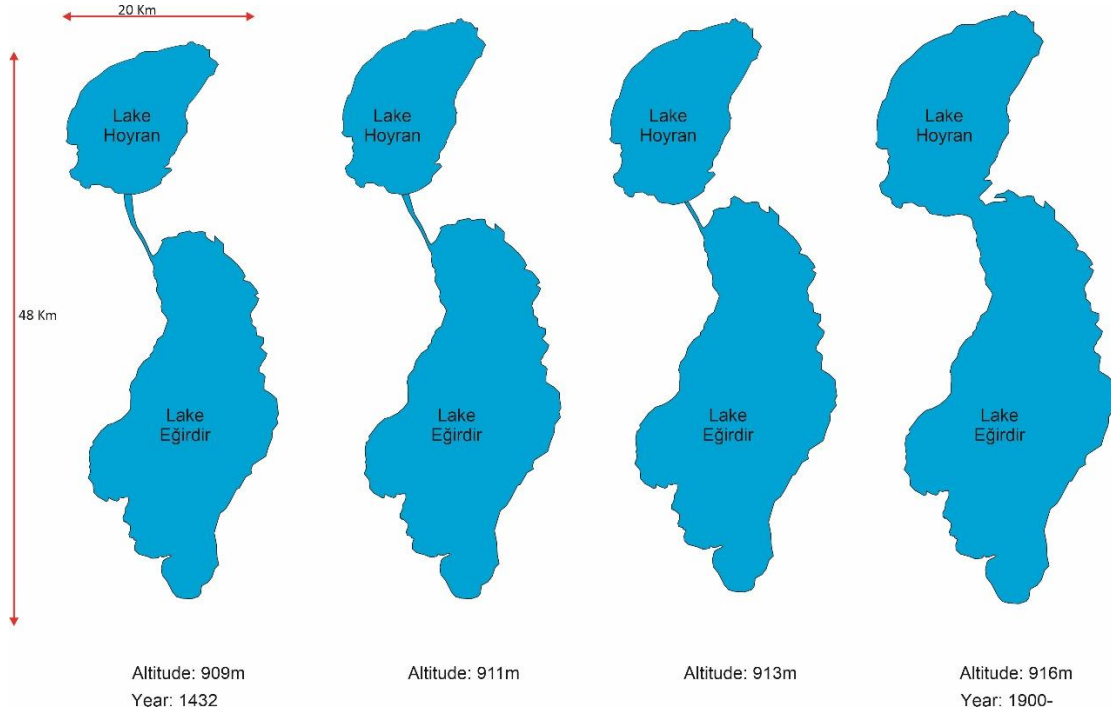
### **Introduction**

In this paper, the natural, climatic and construction-induced changes in Lake Eğirdir, located in the Lakes Region, will be introduced. Eğirdir lake is located in the center of the Lakes Region of Türkiye. There is Beyşehir in the east, Kovada in the south, and Burdur lake in the west. The surface areas of Eğirdir and Beyşehir lakes are close to each other. These two freshwater lakes give life to their surroundings. Lake Kovada is smaller than these two lakes, is fed by Lake Eğirdir and is a national park. The water of Burdur Lake contains arsenic, so it is not suitable for drinking and irrigation. In this paper, the changes in Lake Eğirdir over 500 years and their consequences will be discussed.

### **Change in Nature**

Eğirdir Lake is 917 m above sea level and has a surface area of 479 km<sup>2</sup>. The average depth of the lake is 14 m and the deepest point is approximately 16.5 m. The lake was formed as a result of a landslide formation and its water is sweet. Lake Eğirdir is fed by bottom waters and water from the surrounding streams. The most important of these are Gelendost Stream coming from Gelendost, Değirmen Stream coming down from Hoyran Plain, Akçay coming from Yalvaç and Pupa Stream coming from Uluborlu. The fact that bottom water resources are rich and the water coming from the bottom does not carry soil is shown as an important benefit for the longevity of the lake.

In the 1430s, there were two lakes in the region named Hoyran and Eğirdir. XVI. As a result of earthquakes and climate changes in the 16th century, the water levels of the lakes rose and the two lakes merged in 1614. During this changes, some villages located on the lakeside were moved to higher places (for example, Maziye Village was moved to Yenice Village). As a result of the rise in water levels, the bridges and connection roads connecting the two sides in the region called the Hoyran Strait were submerged. In Figure-1, from 1432 to XXI. century the natural change in Lake Eğirdir is shown depending on the height above sea level [1].



**Figure-1:** Change in the nature of Lake Eğirdir (Source DSI-Bathymetric map)

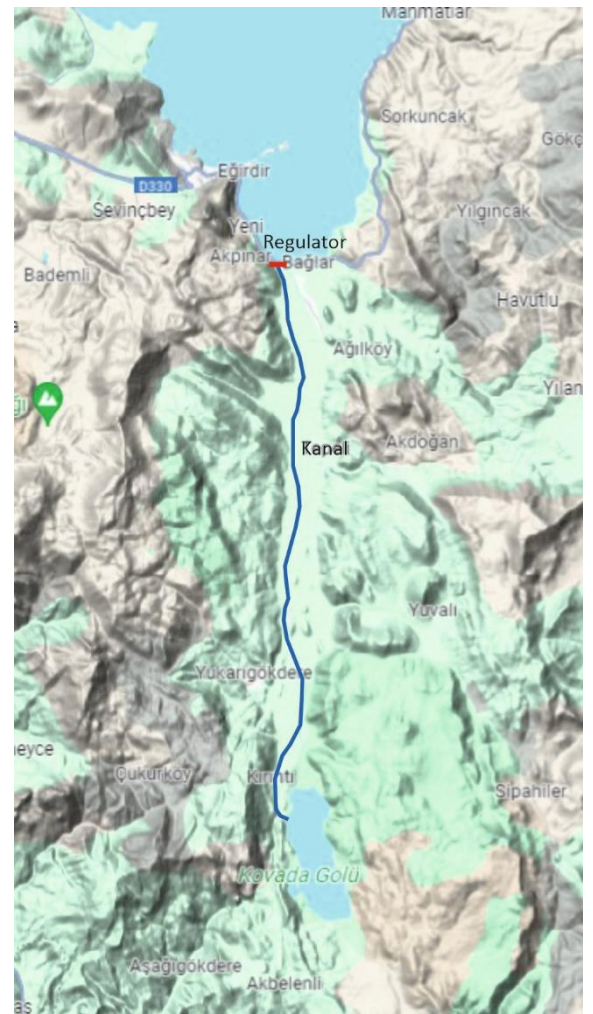
## Changes People Make

Among the changes made by human to benefit from the water of Lake Eğirdir, we can list the reclamation of Boğazova, the irrigation of Atabey Plain, the canals opened for Gelendos Plain and the ponds built on streams.

### Drying of Boğazova

The water of Lake Eğirdir is not still. The water of the lake first flows from its southern end to Kovada Lake, 22 km south of it, then to Karacaören Lake, and from there to the Mediterranean via the Aksu River. Boğazova, located between Lake Eğirdir and Lake Kovada, was drained and turned into productive agricultural land between 1952-55 as part of the fight against malaria. Boğazova's north-south length is approximately 20 km and its east-west width is approximately 2-2.5 km. Within the scope of these works, water level regulator were placed at Köprübaşı in the south of the lake and a concrete channel was built to reduce water loss. This regulator is used to adjust the water level of the lake. The orchards in Boğazova are irrigated with water taken from the canal.

A certain part of the water going towards Kovada Lake feeds the Kovada-I and Kovada-II hydroelectric power plants. The installed powers of these power plants are 8.25 MW and 51.2 MW, respectively. In other words, Kovada-I power plant is capable of meeting the electrical energy



needs of 6,500 houses and Kovada-II power plant is capable of meeting the electrical energy needs of 40,000 houses.

## Irrigation of Atabey Plain

Work on Atabey Plain Irrigation was started in 1967 and

80% of the project was completed and put into use in 1974. Atabey plain is 20 km in east-west direction and 8 km in north-south direction. The average altitude of the plain is around 995-1100 m.

The water was first raised to an altitude of 44.50 meters with the pump station with an installed power of 4200 KW, which was established on the

Bedre side of Lake Eğirdir to irrigate the Atabey plain. Then, it is delivered to the irrigation area through a 4,231 m long tunnel, 104,996 m of main channel and 447,985 m of canals (concrete-lined open canals and flumes). Figure-3 shows the Atabey plain and its irrigation system.

Atabey irrigation is in accordance with the technology of the period in which it was planned and carried out, but it is an outdated practice. It is written in DSI documents that 32% of the water provided from Eğirdir Lake is used for irrigation and the irrigation efficiency is 37%. Work on the renewal of Atabey irrigation has been initiated.

The pumps installed in Bedre not only irrigate the Atabey Plain, but also provide drinking water to Isparta. The pumps in Bedre pump 13 million m<sup>3</sup> of water per year for drinking water and 160 million m<sup>3</sup> for agricultural irrigation. It is estimated that approximately 70% (112 million m<sup>3</sup>) of water pumped for agricultural irrigation is wasted. Meanwhile, different solutions are being worked on to meet Isparta's drinking water needs.

**Figure-2: Boğazova irrigation**



**Figure-3: Atabey irrigation system**

## Gelendost Plain Irrigation

Open channels connected to the lake are opened for irrigation of the Gelendost plain. It cannot be said that there is any engineering work regarding the opening of the channels. It can be said that water is wasted because the channels are open and not protected with concrete.



Figure-4 shows the channels opened for irrigation of Gelendost Plain.

## Ponds

Approximately 9 ponds were built on the relatively small streams that feed Lake Eğirdir. These ponds, built for easy access to water for people engaged in agriculture, have, in a sense, caused a decrease in the water input of the lake.

Figure-4: Gelendost Plain irrigation channels

## Earnings

- Draining Boğazova and turning it into productive agricultural land provided an important source of income for the people of the region. Today, the most beautiful apples of Turkey are grown in this plain, which is approximately 50 km<sup>2</sup>. Annual production is approximately 250,000 tons. By drying the swamp, the malaria problem was also solved.
- In the Atabey Plain, where only dry farming was possible until 1975, fruit, especially Gala, Granny Smith, Fuji, Braeburn and Cripps Pink (Pink Lady®) types of apples are now produced. Annual production is approximately 732,000 tons. It has created an important source of income for the Atabey district and surrounding towns located in the Atabey Plain.
- With the irrigation of Gelendost Plain, fruit production has become widespread in this plain. The amount of apples collected from this plain reaches 400,000 tons.
- A total of 1,230,530 tons of apples were collected in 2023 from the agricultural lands fed by the water of Lake Eğirdir. This amount is  $\frac{1}{4}$  of the total Turkish apple production. Apart from apples, cherry and apricot production around the lake also constitute an important source of income. Considering these results, it can be said that taking water from Eğirdir Lake for irrigation purposes provides a significant gain to the region [2].

## Losses

- The main purpose of Atabey and Boğazova irrigation carried out by DSI is to provide irrigated agriculture opportunities, thus supporting the people living in the region. For this reason, the fee charged for the use of water is very low. Since the price of water is charged according to the surface area of the land used, there is no limit on the amount of water used by farmers. For this

reason, the amount of water used in irrigation is much higher than the amount that should be used. This situation causes salinization of the soil.

- The efficiency of the system established to irrigate the Atabey Plain is very low. 70% of the water supplied to the plain is lost due to evaporation in open channels and water losses in broken channels.
- It cannot be said that the water given to Boğazova is used efficiently.
- Since the water supplied to Gelendost Plain is given through open and irregular channels, the numerical value of water yield is unknown.

## Conclusion

- As a result, the irrigation systems established to develop the surroundings of Lake Eğirdir have caused wild irrigation and the water level of the lake is gradually decreasing. In the autumn of 2023, the water level of the lake is approximately 3 m lower than it should be. Some values regarding the changes in the lake are given below:
- The lowest operating water level of the lake was determined by DSI as 914.72 m. The measurement made in September 2020 showed that the water level was 914.70 m.
- It is calculated that there has been a decrease of 55 Km<sup>2</sup> in the surface area of the lake from 1969 to 2020.
- 1/3 of Lake Eğirdir's water is lost by irrigation and 1/3 by evaporation. Therefore, 2/3 of new water resources are required every year. It is observed that global warming also causes a decrease in the amount of water in the Lake. Decreasing precipitation reduces water input, and increasing ambient temperature increases evaporation.
- Lake Eğirdir, Turkey's second or third largest fresh water source, is in danger of extinction as a result of wild irrigation.

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# ASSESSING ENVIRONMENTAL IMPACTS OF IRRIGATION PROJECTS ON SOIL AND WATER RESOURCES IN RESERVOIR AREAS: A WAVELET MODEL APPROACH

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## Abstract

The increasing impacts of climate change, combined with the rapid depletion of water and soil resources in terms of both quantity and quality, pose significant challenges to sustaining ecosystems and agricultural productivity. These challenges jeopardize access to safe food and threaten the sustainability of life by hindering the ability to meet nutritional needs and provide raw materials for industry. To address these pressing issues, it is critical to optimize agricultural practices to achieve maximum and high-quality yields per unit area. This requires the efficient utilization of soil and water resources while understanding and mitigating their environmental impacts. The growing demand for agricultural irrigation has led to the development of basin-scale irrigation projects, which aim to ensure water availability in the right location, at the right time, and in the appropriate quantity and quality. However, the adverse effects of climate change, coupled with other environmental impacts in irrigation project areas, highlight the need for proactive risk assessment and management. For stakeholders, awareness of these risks is vital to ensure the long-term sustainability of agricultural and water resource systems. Artificial intelligence (AI) has emerged as a powerful decision support tool for addressing these challenges. AI-driven models, supported by data science, can analyze complex datasets to improve agricultural management strategies and enable informed decision-making. By leveraging AI, stakeholders can better understand and anticipate risks related to soil and water resource depletion, pollution, and other environmental concerns. Moreover, AI applications have the potential to deliver additional benefits in other agricultural impact categories, such as mitigating climate change, reducing terrestrial acidification, addressing toxicity burdens, and enhancing the health of terrestrial and freshwater ecosystems. Wavelet models offer advanced capabilities to process and analyze non-linear and non-stationary data, making them well-suited for evaluating the complex interactions between irrigation practices and environmental factors. By integrating AI-driven insights into agricultural management, this approach contributes to the sustainable use of natural resources and supports resilient food production systems.

**Keywords:** Climate impacts, sustainability, ecosystem resilience, artificial intelligence.

# THE ROLE OF DISRUPTIVE TECHNOLOGIES FOR DRIVING A SUSTAINABLE ENVIRONMENT

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## *Abstract*

As the urbanization and fast-improving quality of life raises the energy consumption, over 72% of carbon emissions come from cities. With the current petrol-powered cars on the road, there are large amounts of CO<sub>2</sub> emissions, which pollute the atmosphere resulting in what is called global warming. At the same time, the advent in technology has brought up emerging technologies like Radio Frequency Identification (RFID), wireless sensor networks, and Internet of Things (IOT), which found their way in tracking everything particularly in supply chain and manufacturing. In this paper, the research focuses on the state-of-the-art technologies used to reduce Greenhouse Gases (GHG) emissions in traffic congested areas. It is based on developing a prototype of a wireless sensor module based on RFID technology to mitigate the CO<sub>2</sub> footprint in the environment interfaced to an access control toll payment system in parking lots.

**Keywords:** Energy Consumption, RFID , GHG

# EDUCATION FOR AWARENESS ON CLIMATE CHANGE AND WATER RESOURCES MANAGEMENT AROUND THE MEDITERRANEAN BASIN: TUNISIA AS AN EXAMPLE

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**Abstract:** While the Mediterranean basin is considered the hotspot of all interconnected climate risks, scientists continue to emphasize the crucial importance of education in making a meaningful contribution to climate action in the region, especially as the sector is capable of influencing perceptions, strengthening awareness, and shaping behavior towards eco-responsibility and sustainability. In this context, given that water scarcity has become a constraint on development and a source of social tensions, promoting education as a lever for responsible water management is particularly judicious in Tunisia. Paradoxically, despite Tunisia's potential in terms of human capital and its strategic orientation placing education at the heart of its development policies, including long-term ecological issues, the seriousness of the water situation is increasingly pronounced. Even more worryingly, scientific projections reveal a high risk of an absolute water shortage in the event of inaction. Thus, this metadata paper, in seeking to explore possible pathways through which education can stimulate transformative change towards sustainability in Tunisia, identifies adaptation financing as a barrier that prevents education from playing its key role in the governance of water resources.

**Keywords:** Climate change, water scarcity, education.

## INTRODUCTION

While natural and human systems can adapt to change to some extent through existing knowledge and technology, in the water sector, information, education, and training materials, as well as knowledgeable capacity builders and experts, can help facilitate these processes (Cosgrove & Loucks, 2015). Given that education plays a key role on the path to human development and societal transformations (Macintyre et al.2018), it should be used as an efficient tool to improve environmental protection awareness of all people dealing with environmental, social, and economic issues of sustainable water management (Sarkar et al.2007). This is particularly evident in Tunisia, where it is suggested that all links between

education, research, society, and politics be co-created (Mader et al. 2015, p.288) which is reaffirmed by Besbes et al. (2019, p.177) emphasizing that “achieving a higher level of the overall efficiency of water systems requires the empowerment of the whole society, which implies a massive appropriation of knowledge. It implies first an expertise with user education, and learning water management by children through school education. But there is also access to the whole of society to general knowledge”. However, the assessment of the developmental situation in Tunisia reveals the persistence of major or to a lesser extent, significant challenges despite slight improvements, particularly for SDGs 4 [Ensuring equitable, inclusive, and quality education and lifelong learning opportunities for all], 6 [Guarantee access for all to sustainably managed water supply and sanitation services], 13 [Take urgent action to fight climate change and its impacts] (Sachs et al. 2023), even it is found that climate threats continue to increase in Tunisia (IPCC, 2022), and in particular a water scarcity crisis (de Waal et al. 2023). In this sense, the country is placed, according to simulations, in a serious situation of water stress in the future (Besbes & Chahed, 2023; World Bank, 2021).

While the fight against climate change depends on behavioral change and support for climate-friendly policies, little is known about how to achieve these results and, in particular, the crucial role of education (Dechezleprêtre et al., 2022). Further, although the role of education in addressing the challenges of climate change is increasingly recognized, the education sector remains underutilized as a strategic resource to tackle climate change issues (Mochizuki & Bryan, 2015). This is particularly true in Tunisia, where the current education system appears to hinder a successful water transition (World Bank [forthcoming])<sup>1</sup>. Thus, this research paper attempts to explore how education can contribute to the fight against climate change and better governance of water resources, and what are the reasons that prevent it from playing this critical role in Tunisia.

The paper is structured as follows: the first section will be dedicated to the conceptual framework by highlighting the reality of climate change and its close links with knowledge management and education. The second section presents the case study and focuses on Tunisia's specific climatic profile and the reality of the Tunisian education sector from an environmental perspective. The last section is devoted to an analysis of the current situation in Tunisia with a holistic understanding of what could prevent education from playing an important role on the path to climate action and

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<sup>1</sup> Cited in the World Bank (2023).

sustainable water management and a discussion of the literature review. Finally, the conclusion summarizes the main observations and outlines certain perspectives for future research.

## **1. CONCEPTUAL FRAMEWORK**

### **1.1. CLIMATE CHANGE IS A REALITY**

Being among the nine planetary boundaries [PB] (Rockström et al. 2009) and the three limits with the risk of irreversibility, identified with the biosphere integrity as “core” PBs for the earth system [ES] (Steffen et al. 2015), climate change is no longer merely a trend but a stark reality. It has become the most pressing issue for the survival of humanity (Nylund et al. 2021). The calls for urgent and even immediate action to avoid the catastrophic and irreversible effects of climate change have never been stronger than they are now. It is evident that rapid, deep, and, in most cases, immediate reductions in greenhouse gas emissions across all sectors are inevitable for mitigation efforts. Additionally, the evidence of observed negative impacts and associated losses and damage, projected risks, levels, and trends in vulnerability and adaptation limits demonstrates that global action for climate-resilient development is more urgent than previously assessed in the IPCC Fifth Assessment Report (AR5) (IPCC, 2023 a, p. 20; p. 24).

### **1.2. CLIMATE CHANGE AS A SUSTAINABLE AND KNOWLEDGEABLE GOAL**

The fight against climate change requires a profound transformation towards sustainability while filling a significant knowledge gap along this path (Sachs et al., 2019). In this perspective and in the era where the only certainty is uncertainty (Nonaka, 2007), knowledge is the most important strategic resource (Drucker, p. 38, 1993) to achieve sustainable development (Denner & Diaz, 2013) particularly in the fight against climate change (Shi et al., 2015), especially since climate change is one of the most emblematic anthropogenic effects according to the IPCC reports, to such an extent that it has become a major concern for all scientists (Picard, 2012) and a critical global problem that reinforces the uncertainties and complexity (Debref, 2017). In this regard, it is evident that there is a need for both fundamental scientific knowledge on climate change and context-specific knowledge on impacts, vulnerabilities, and adaptation alternatives (Biesbroek, 2010). Based on the fact that climate change can be a game changer for academic research, promoting science through linking knowledge production and societal action is considered a transition towards more sustainable development paths (Campos et al. 2016). Research on climate change has tended to rely on a multidisciplinary approach (Ugaglia & Peres, 2017). It is in this context that education is of critical importance.

### **1.3. EDUCATION AS A GAME CHANGER**

Education can facilitate awareness, increase risk perception, influence behavior, and increase public awareness

to accelerate efforts to combat climate change at multiple levels of governance (IPCC, 2023b, p. 107). Education is at the heart of information and awareness efforts on climate change efforts in its two dimensions of mitigation and adaptation (Leal Filho & Hemstock, 2019, p. 13). According to the theory of action, education undoubtedly offers one of the best opportunities to accelerate action against global warming by ensuring the required readiness to address the reality of climate change and unsustainability (Miller & Charlesworth, 2019, p. 19; p. 27). Drawing on organizational learning theory, Dieleman (2013) finds that education and training build climate change resilience by stimulating eco-cultural innovations. Likewise, based on the theory of planned behavior (TPB), Goldman et al. (2020) emphasize that education is critical to change behavior and achieve effective, sustained climate action. Drawing on social learning theory, Carangan (2023) concludes that education and awareness are the most important elements in terms of knowledge and behavior regarding climate change issues. Considered the foundation for achieving sustainable development (Sarkar et al., 2007), education can equip current and future generations of students with relevant scientific knowledge, necessary skills, and values to act as change agents for effective policy-making, problem-solving, and promoting sustainable business futures in the context of climate change (Emblen-Perry, 2019, p. 550). Additionally, transformative learning theory (TLT) provides insights into the transformational process of higher education that underpins the journey toward sustainability, including critical issues such as climate change (Leal Filho et al. 2018). In this context, focusing on education is highly recommended.

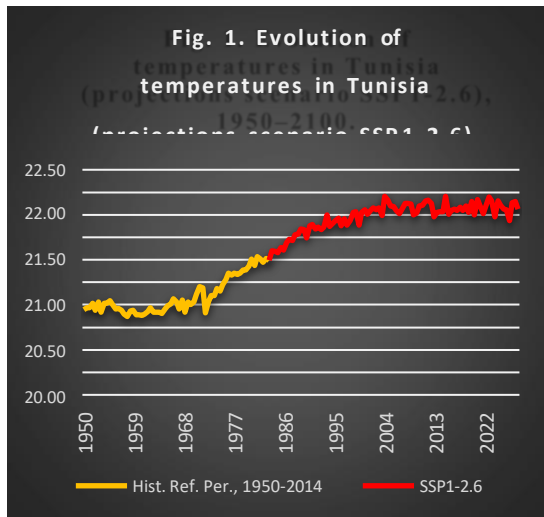
## **2. CONTEXT OF THE STUDY**

### **2.1. THE SPECIFIC CLIMATE CASE OF THE MEDITERRANEAN BASIN COUNTRIES: THE EXAMPLE OF TUNISIA**

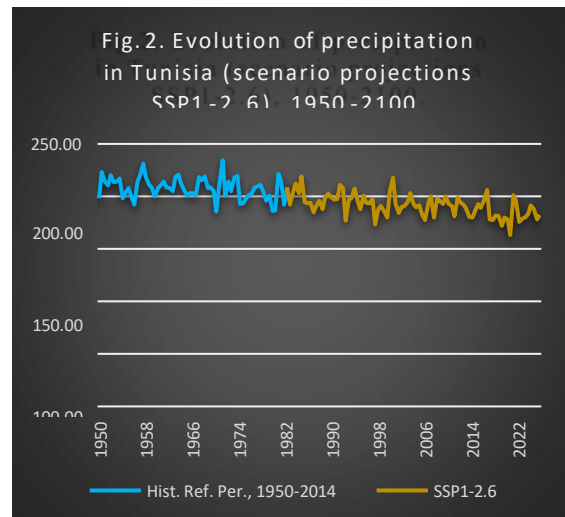
All countries in the Mediterranean basin are considered hotspots for highly interconnected climate risks due to their particular combination of multiple strong climate hazards and high vulnerability (IPCC, 2022, p. 2235, p. 2236), reflected by the accelerated rise in sea level, the increase in average temperatures, drought and the extension of heatwaves, and the scarcity of water, much more than in any other region of the world (PNUE, PAM, and Plan Bleu, 2020). Five Mediterranean countries, Egypt, Algeria, Morocco, Lebanon, and Tunisia, bring all these characteristics of climate change together, with a rate of temperature increase on average of 0.4 degrees Celsius per decade since the 1980s, which is almost double the global average (Greenpeace, 2022); in particular, Tunisia remains plagued by a serious problem of water scarcity, greatly threatening its water security by exacerbating the water stress (FHS, 2023; World Bank, 2021).

Tunisia is considered highly vulnerable to climate change and is expected to experience adverse impacts from

increased temperatures, drought, reduced precipitation, and rising sea levels (World Bank, 2021). As illustrated in Figure No. 1, Tunisia is expected to face a considerable rise in average temperatures even under the most optimistic scenario SSP1-2.6 by 2100, reaching no less than 1°C. As shown in Figure No. 2, the situation is also well pronounced regarding the increased decline in precipitation under the same optimistic scenario SSP1-2.6; by 2100, hydraulic projections show significant drops in precipitation of 9% (Besbes & Chahed, 2023).



Source: World Bank CKP.

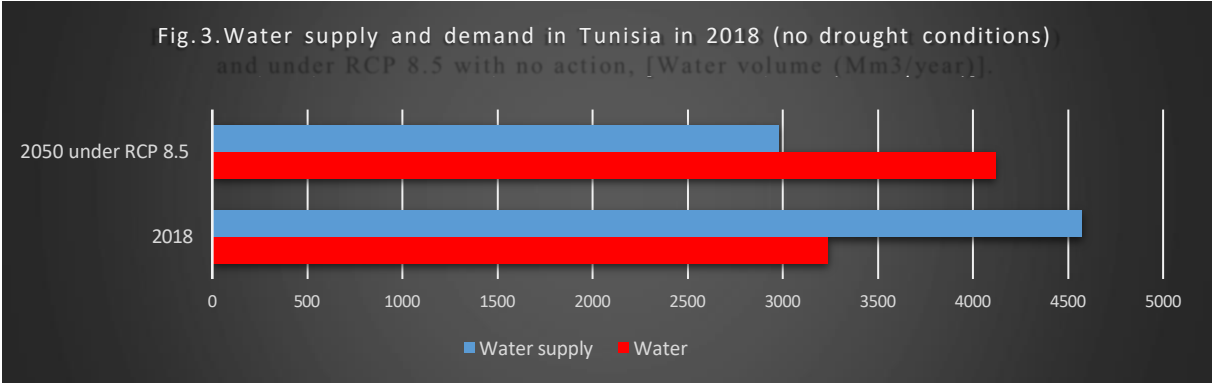


Source: World Bank CKP.

Tunisia is a country with a high water footprint (PNUE, PAM, and Plan Bleu, 2020). The situation is very critical; the total water footprint of Tunisian consumption is higher than the world average by more than 50%, and agricultural production dominates the total water footprint relating to consumption, contributing to more than 90% of the national water footprint (Chouchane et al., 2013). While Tunisian agriculture is strongly linked to rainfall and climatic hazards, it remains a water-intensive sector overexploiting hydraulic resources (World Bank, 2021), using 80% of national blue water resources for irrigation, which is approximately equivalent to the maximum water allocation (Besbes & Chahed, 2023), coupled with the rise in water consumption in the services sector. As illustrated in Figure 5, this leads to unprecedented pressure on internal water resources and consequently colossal water stress, reaching 96.31% in 2020. This is how the diagnosis of the current water situation in Tunisia paints a gloomy picture: on the one hand, the country is clearly below the critical threshold of absolute water shortage set at 500 m<sup>3</sup> per inhabitant [per year] (de Waal et al., 2023), and on the other hand, the projections by 2050 reveal in

<sup>2</sup> Shared Socioeconomic Pathways.

the RCP 8.5 scenario a serious drop in supply against an increase in demand for water (World Bank, 2023); see Figure No. 3.

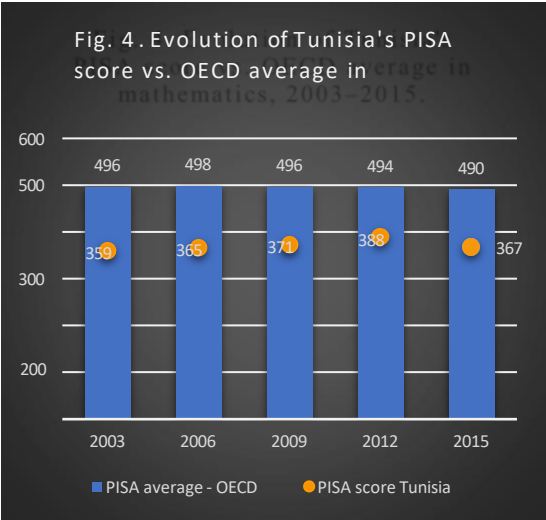


Source: World Bank (2023).

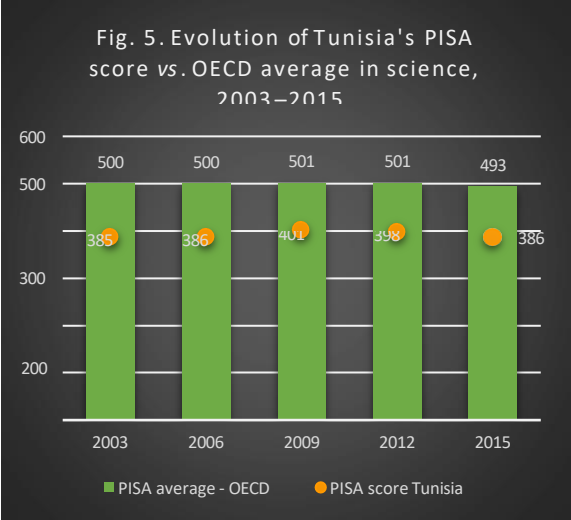
### 2.3.ASSESSMENT OF EDUCATION IN TUNISIA FROM AN ENVIRONMENTAL PERSPECTIVE

#### a. Performance of Tunisia students in PISA assessments<sup>3</sup>

At the heart of the worrying situation of education in the country, another important observation emerges of the mediocre scores of Tunisian students in international PISA exams in the fields of mathematics and sciences. In this context, the PISA assessments reveal that the educational level of Tunisian students is below the OECD average, as well as a deterioration in country scores over time [see Figures No. 4 and 5].



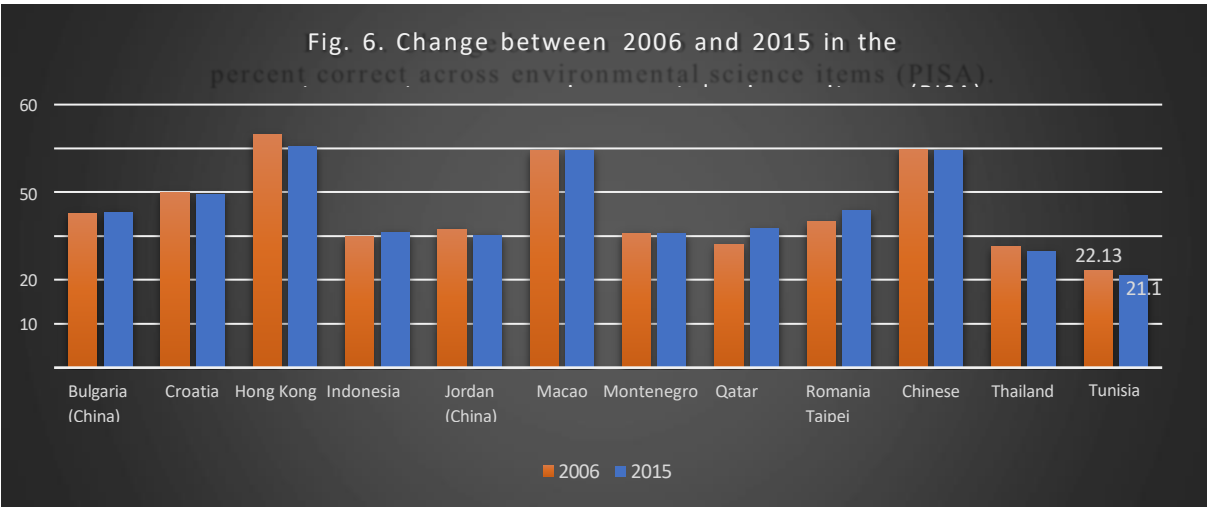
Source: OECD (2022).



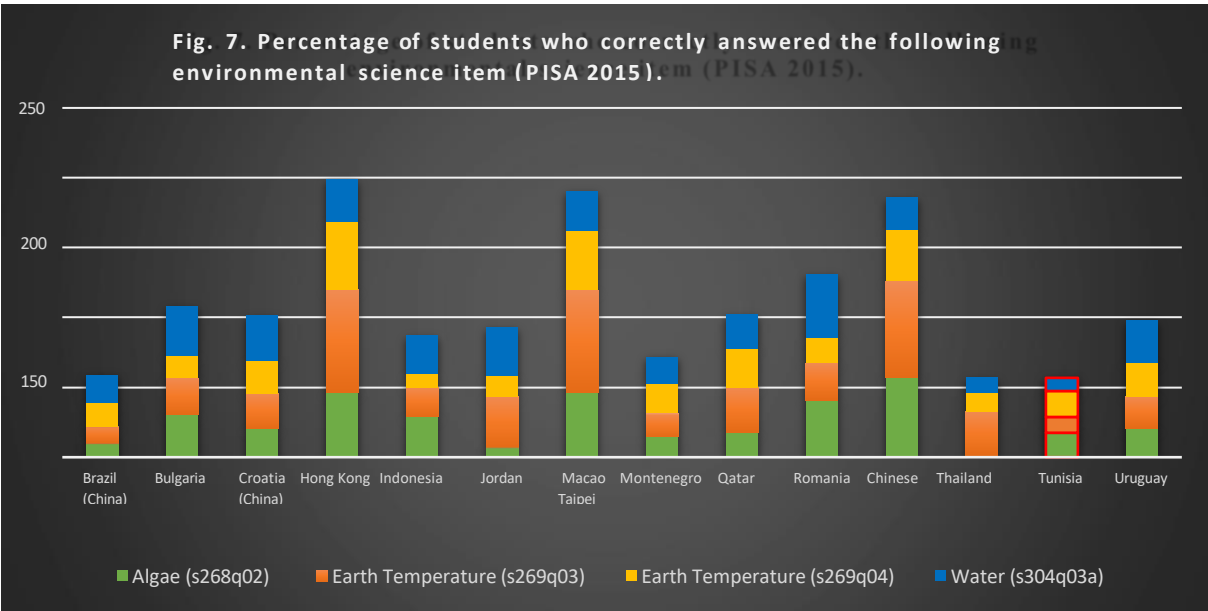
Source: OECD (2022).

<sup>3</sup> Program for International Student Assessment, launched by the OECD in 1999, is a three-year assessment that measures students' knowledge and skills in three main areas: reading, scientific knowledge, and mathematics. The last Tunisian participation in the PISA exams was in 2015 (GPE, Ministry of education and UNICEF, 2022).

What is even more worrying when interpreting the PISA results is twofold: first, Tunisia was the country with the lowest correct answer rates on environmental exams in the 2006 and 2015 PISA assessments compared to various countries; this is also coupled with a decline in the score of Tunisian students compared to the same evaluations in 2006 [see Figure No. 6]. Second, and most surprising, is that among all environmental exams, the lowest correct answer rate of Tunisian students was in the field of water with 9.4%; also, the same rate was the lowest among all the countries in the sample studied [see Figure No. 7].



Source: OECD (2022).



Source: OECD (2022).

b. Assessment of the role of education in the path of climate change and sustainable water management in Tunisia.

The process of sustainable climate action as well as responsible management of hydraulic resources seems hampered, among other things, by the educational situation in Tunisia. In this sense, despite the indisputable role of education on the path to climate resilience and sustainable management of natural resources via knowledge creation, awareness strengthening, and sustainable development skills provision (Besbes et al., 2019, p. 177; Mader et al., 2015, p. 288), the current situation in Tunisia paints a gloomy picture. Indeed, in addition to the structural failures of education in Tunisia as reflected by economic and opportunity inequalities (Boughzala et al. 2020), school dropout and completion rates (GPE, MDE & UNICEF, 2022), the quality of education and the inadequacy with the needs of the employment market (Grundke and Cassimon, 2022): education is far from playing its leading role in sustainable development as set out in target 4.7 of resolution 70/1<sup>4</sup>; this is illustrated by the PISA assessments where Tunisia's scores in environmental tests between 2006 and 2015 were the lowest compared to all the countries in the selected sample, these results are also associated with a decline in scores from 22, 13% in 2006 to 21.1% in 2015. Even more worrying, the 2015 PISA assessments reveal that among all environmental themes, water is the area in which Tunisian students obtained the lowest scores not only compared to all countries in the sample but also compared to all other environmental questions (OECD, 2022). However, it is still premature to judge the environmental skills of Tunisian students for two reasons. First: the lack of data on environmental knowledge of Tunisian students (UNESCO, 2021). Second: is that Tunisia has not participated in PISA assessments (in science and mathematics) since 2015 (GPE, Ministry of Education and UNICEF, 2022). However, the available data linked to the results of the PISA assessments: were later coupled with the persistence of interconnected climate threats which continue to increase in Tunisia (IPCC, 2022) and in particular water scarcity (Greenpeace, 2022), in this sense, Tunisia has one of the highest water footprints in the world (Chouchane et al. 2013; PNUE, PAM & Plan Bleu, 2020), and is below the critical threshold of absolute water shortage set at 500 m<sup>3</sup>/inhabitant/year (de Waal et al. 2023). In this context, the projections place Tunisia in a dangerous situation of water stress in the future (Besbes & Chahed, 2023; World Bank, 2021).

### **3. ANALYZES AND DISCUSSION OF THE LITERATURE REVIEW**

#### **3.1. ANALYZES**

In Tunisia, the assessment of the educational situation on the one hand, and the increase in climate risks, as well

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<sup>4</sup> "Transforming our world: the 2030 Agenda for Sustainable Development," Resolution 70/1, adopted by the United Nations General Assembly on September 25, 2015.

as the water crisis on the other hand, can be attributed to many reasons. *First*, the lack of awareness about the preservation of water resources is a basic foundation for better governance of these resources (Rodríguez-Clemente & Hidalgo, 2012, p. 246). *Second*, the current education system appears to favor higher-level “green” skills in renewable energy-related programs, while there is a substantial capacity gap when it comes to medium or low “green” skills, particularly at the technical and vocational education training level (World Bank, 2023). *Third*, the current education system has limited capacity to provide the skills needed to achieve a successful water transition (World Bank [forthcoming]<sup>5</sup>). However, despite the relevance of the arguments put forward, this is probably only the tip of the iceberg. Indeed, since the creation of the Ministry of the Environment and Regional Planning (MEAT) in 1991, environmental awareness and education have been privileged actions, carried out in collaboration with the other ministries concerned (education, interior, agriculture, health, etc.). In this sense, educational programs focused on environmental protection have been inserted into the programs of primary and secondary schools (Souissi, 2024). The Tunisian government has also implemented the national education strategy for sustainable development, intending to establish dedicated teaching programs to increase awareness in the educational arena and broaden the scope of access to information related to sustainable development (Ben Youssef, 2022). Also, Tunisia's updated NDC<sup>6</sup> submitted to the UNFCCC in October 2021 recognizes through its pillar “*action for climate empowerment (ACE)*” that education, training, public awareness, and public access to climate information are key areas of intervention in Tunisian climate action (MENV, 2021).

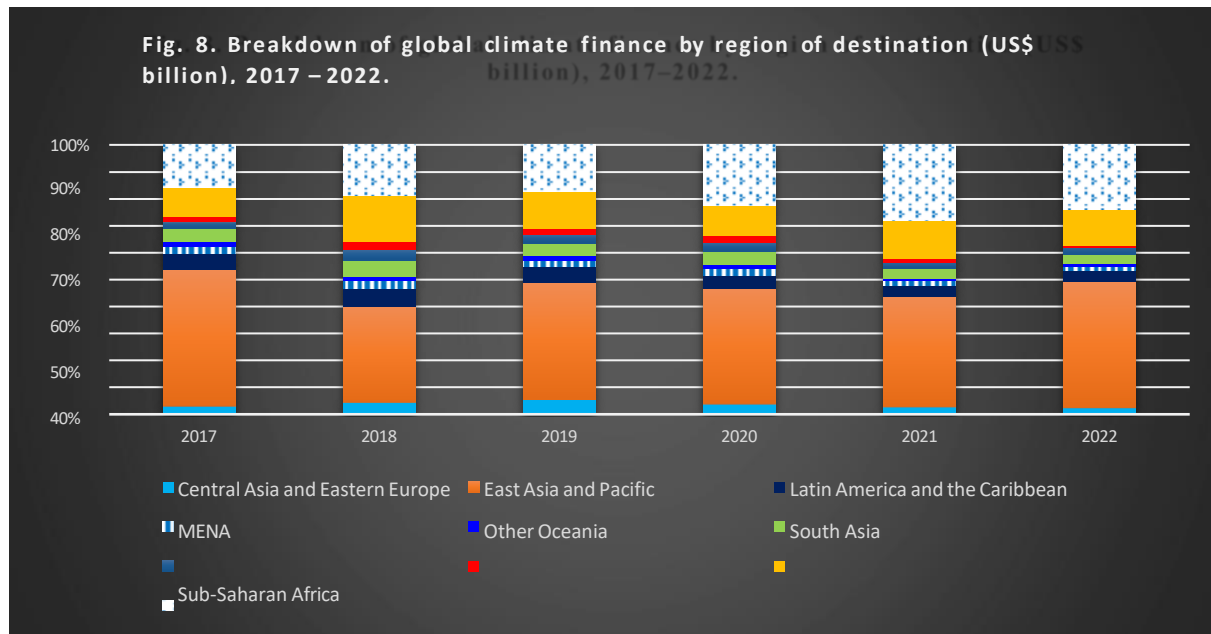
Thus, based on these analyses and findings, and according to Pauw et al. (2022) clearly state that: “*Concern exists about a possible decline in aid budgets or diversion of essential aid away from important development priorities, e.g. education or public health*”, and to the best of the authors' knowledge, it seems that the financial dimension and more particularly climate finance is lacking and hinders education from playing its role as a *climate and water changer*. Indeed, firstly, it should be noted that the share of expenditure dedicated to the Tunisian Ministry of Education in the state budget evolved at an average annual rate of 2.47% in real terms during the 2010–2020 period. However, this progression was below the rate of growth of the state budget (excluding debt service) estimated at 4.53% (GPE, Ministry of Education, and UNICEF, 2022). In the same context,

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<sup>5</sup> Cited in World Bank (2023).

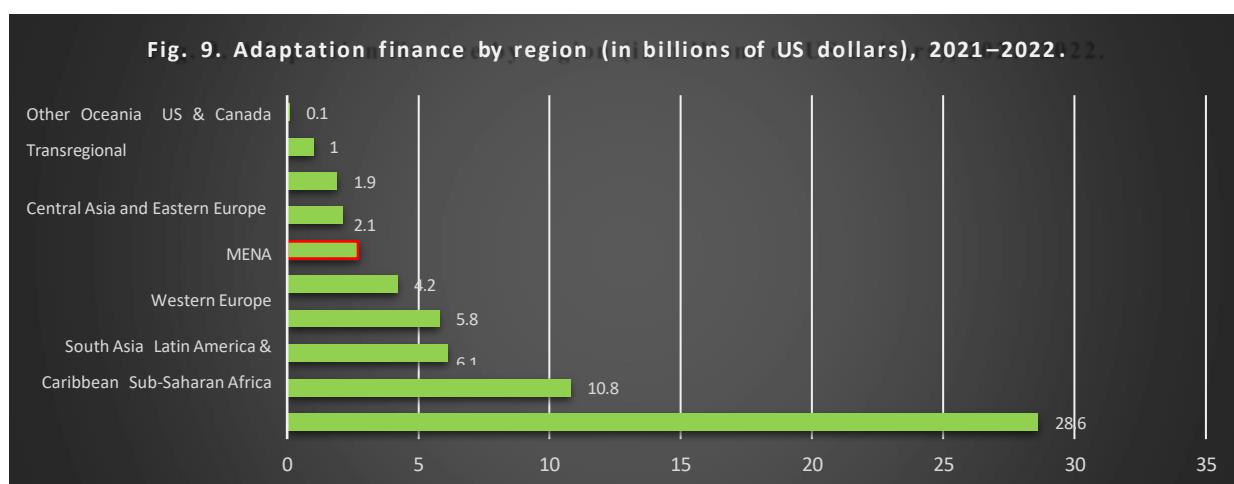
<sup>6</sup> In accordance with the fourth article of the Paris Agreement on climate change promulgated in 2015, each party shall prepare, communicate and maintain successive nationally determined contributions (NDC) that it intends to achieve.

expenditure remains on a downward trend, falling from 28% in 2008, 2009, and 2010 to 22.1% in 2022. Further, the latest assessments made by CPI (2023) on the flows of climate finance circulating throughout the world in 2021 and 2022 reveal that the MENA region (to which Tunisia belongs) is among the regions to benefit the least compared to other regions in the world with only US\$20 billion in 2022, or 1.4% of the total global climate finance flows estimated at US\$1,415 billion in the same period [see Figure No.8].



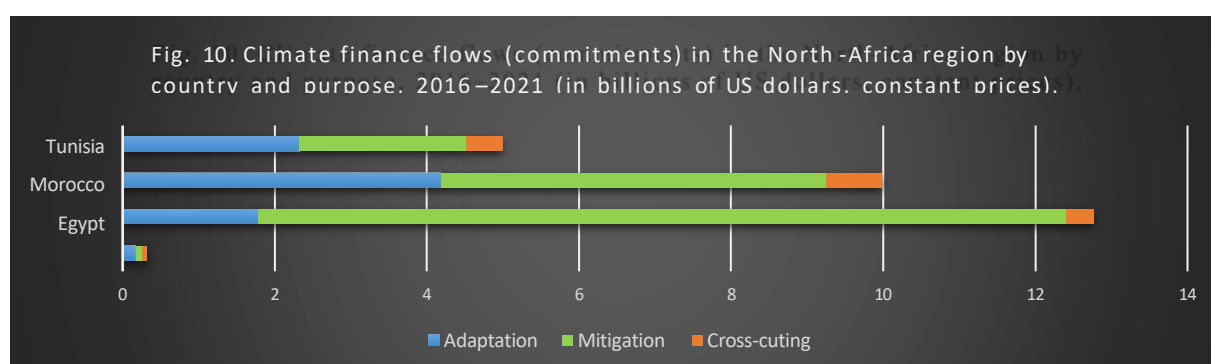
Source: Authors' calculations based on CPI data (2023).

While, according to the UNFCCC, climate action has two fundamental pillars: mitigation and adaptation. Adaptation is an important policy response, along with mitigation, and depends greatly on the adaptive capacity of an affected system, region, or community to cope with the impacts and risks of climate change (IPCC, 2001, p. 879). Adaptation is key to enhancing climate resilience and reducing vulnerability (Lienard, 2022) and remains at the forefront of any sustainable development policy agenda, particularly in developing countries (UNDP, 2004, p. 1). However, adaptation finance continues to lag and grew modestly in 2021/2022, reaching US\$ 63.3 billion [which only represents 5.5% of the amount of financing intended for mitigation estimated at US\$ 1150 billion], and once again, the MENA region's share of adaptation finance flows is among the lowest in the world, with only US\$ 2.7 billion in 2021/2022, which represents 4.25% of global flows of adaptation finance [knowing that all these flows intended for the MENA region are entirely from international sources] (CPI, 2023), [see Figure No. 9].



Source: CPI (2023).

In the same context, the situation is even more pronounced in all North African countries following the same trend in terms of climate finance architecture; in other words, the mitigation pillar monopolizes the largest share of climate financing in North Africa. Until 2020, only US\$ 1.31 billion is allocated for adaptation<sup>7</sup>, which represents 36.30% of the total climate finance flows intended for the North African region. It should be noted that the financial instrument used to grant all these climate flows is mainly debt (GCA, 2022, p. 129, p. 130). In this perspective, and except Algeria, as shown in Figure No. 20, Tunisia benefits less from climate finance flows (even in the form of commitments) compared to other countries in the region (mainly Egypt and Morocco) over the period 2016–2021. There is an imbalance in the distribution of funds across Arab countries, with 92% of flows over the period 2010–2020 going to just six countries: Egypt, Iraq, Jordan, Lebanon, Morocco, and Tunisia. Egypt and Morocco have been the most successful in costing and mobilizing climate finance to meet their needs, receiving more than 60% of the region's flows (US \$21.6 billion) over the same period (ESCWA, 2022), [see Figure No. 10].



Source: Authors' calculations based on OECD Climate-related development finance datasets (Recipient perspective).

<sup>7</sup> As disbursement (Savvidou et al.2021).

### 3. DISCUSSION OF THE LITERATURE REVIEW

While education is also a key building block of adaptive capacity, adaptation finance has not followed the same trend as that of mitigation, signaling an unfair imbalance between these two pillars of climate action (GCA, 2022, p. 10; p. 387). Likewise, donors' agreements give access to climate finance, which is far from a given (Houzir & Alaoui, 2018, p. 52). In this sense, it should be emphasized that the disbursement ratio in adaptation finance in North Africa is the lowest across the entire continent, with an average of only 15% (Savvidou et al., 2021). Taking into consideration that the implementation of the updated NDC in Tunisia will require the mobilization of significant financial resources, estimated at around US\$ 19.4 billion over the period 2021–2030, including US\$ 14.4 billion for mitigation, US\$ 4.3 billion for adaptation, and US\$ 0.7 billion for capacity-building actions (MENV, 2021, p. 9), it seems that climate finance in general and particularly adaptation finance is lacking, leaving little chance for education to fully play its role in the fight against climate change and promoting sustainable water management in Tunisia.

These results are supported by various research and studies targeting the international context and also Tunisia. Indeed, while climate finance is vital for developing countries to adapt to climate change, findings reveal that climate finance has targeted mitigation rather than adaptation (Lienard, 2022), which is underlined in the most recent assessments of climate finance flows, noting categorically that adaptation finance is still lagging (CPI, 2023). Also, by conducting new large-scale surveys of more than 40,000 respondents in 20 countries, covering the main emitters of greenhouse gases in developed and developing economies, Dechezleprêtre et al. (2022, p. 7) found that financing constitutes a major constraint to the adoption of more climate-friendly behaviors in all the countries examined. At the African level, another study carried out by Atteridge (2011) found that no foreign direct investment (FDI) was reported in education, health, or social services. Savvidou et al. (2021) later reaffirm that financial support targeting core development sectors like education or health as a deliberate component of climate adaptation spending has been negligible in Africa. At the Mediterranean level, Hamdy & Choukr-Allah (2012, p. 275) underlined that the states of the region need institutional, educational, and financial support to ensure effective action by institutions in the area of integrated water resources management (IWRM) strategies. In Morocco, Houzir & Alaoui (2018, p. 54) highlighted that climate finance intended for adaptation remains derisory, suggesting on the one hand an equitable allocation to

both adaptation and mitigation and, on the other hand, rethinking a new, more substantial financial objective for the period after 2025 because climate financing needs have been largely underestimated.

In the Tunisian context, it is found that the transition to a new development paradigm focused on green growth is hampered by underinvestment in human capital, particularly in education and health (FHS, 2023). Likewise, the increased importance of local action on climate adaptation in the context of vulnerable and developing countries is widely recognized (GCA, 2022, p. 86; UNFCCC, 2015, p. 53), as well as its close link with education (Bangay & Blum, 2010; UNFCCC, 2021, p. 17; p. 18; p. 19) and sustainable management of water resources (Ehlers et al., 2022; UNEP, 2023), it is found that financing is identified in more than 84% of cases as the main obstacle faced by Tunisian municipalities in developing a climate change adaptation strategy at the local level (Ben Youssef, 2022). Noting that in Tunisia, good governance of water resources requires an exhaustive approach through the integration of financial, economic, and normative tools, the financial implications of these profound transformations have been little addressed (Besbes et al. 2019, p. 235, p. 266), where several barriers exist to how public and private climate finance are made available and accessed (Essaber et al., 2023) Finally, the latest assessments by the World Bank (2023, p. 59) on the challenges of climate change in Tunisia firmly concluded that the country does not have a national climate financing strategy to accurately measure its climate investment needs and support the investment risk linked to financing the green transition.

## **CONCLUSION**

Despite UNESCO's urgent calls for the greening of education at COP26, 27, and 28 following the Berlin Declaration for Education for Sustainable Development (ESD) and previously the UNFCCC agreement in Rio de Janeiro in 1992 (notably in its articles 4 and 6) ratified by Tunisia later in July 1993, education in Tunisia fails to play its role as a climate and water changer. The current education system compromises a successful water transition and needs more capacity to provide the skills needed to enhance resilience to climate threats. In addition to the widely recognized and debated structural problems of Tunisian education, such as inequalities, education quality, dropout and completion rates, and inadequacy with the employment market, this paper identifies climate finance, and more particularly adaptation finance, as a major obstacle in Tunisia towards education capable of addressing climate risks and strengthening sustainability at different levels. Although education is a key adaptation solution correlated with strengthened adaptive capacity and reduced climate vulnerability, it has also not been central to climate and adaptation strategies. The international financial architecture in climate matters has favored

financing mitigation much more than adaptation, which only benefits from derisory amounts. This situation is well pronounced in the Tunisian context, which hinders education from playing its role in addressing climate issues and achieving responsible management of water resources.

Finally, this metadata paper asks the question about the role of education in improving behavior change and awareness of the challenges of climate change and the water scarcity crisis. In this perspective, while the transition to a sustainable economic model that is carbon neutral and resilient to climate change is inevitable, climate finance will play a key role in this process. However, creating the necessary environment for implementing climate finance mechanisms is problematic. It requires a high degree of knowledge, technical learning, and appropriate managerial skills because climate finance relies more on human resources, which constitute the main driver of sustainable economic growth. In this context, implementing a climate financing strategy in Tunisia is essential and should promote human capital, specifically knowledge workers.

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# WATER RESOURCES MANAGEMENT UNDER CLIMATE CHANGE

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**Abstract:** Climate change affects water resources through the decrease of rainfall and the increase in temperature and evapotranspiration. The increased usage of water by human activity is another indirect effect of climate change. In order to better understand the implications of climate change on water resources, ecosystems, human health, security, and socioeconomic aspects, a selection of studies covering five continents was made and included in this article. Worldwide scientists offered their recommendations and plans for addressing climate change, as well as the best approaches for managing water resources in the future. The primary solutions that have been identified include new technologies, better understanding, political direction, policies, and integrated management of water resources. Additionally, the majority of the reviewed publications emphasise that managing water resources must take ecosystem restoration and protection into concern. The foundation of novel, scientific approaches to addressing climate change and preparing for future climate adaption must come from nature-based solutions.

**Keywords:** Climate change; integrated water research management; water resources.

**INTRODUCTION:** The Intergovernmental Panel on Climate Change (IPCC) has been identifying human-caused climate change since the early 1990s, which has resulted in catastrophic worldwide changes (such as rising sea levels and temperatures, acidity of the oceans, etc.) [5]. The new models established at this time began to take into account the possible impacts of human activity on the climate, such as the rise in sulphate aerosols and stratospheric ozone. Furthermore, a more precise characterization of the climate system's inherent variability was created [5]. Indirect effects of climate change on inland waters and their catchments may include both positive and negative effects on precipitation, the totals, riverine runoff, snowfall and accumulation, evapotranspiration, lake levels, and reductions in connecting channel flows [8, 30].

According to the initial analysis of climate change and its effects on the availability of freshwater resources, there appears to be a rise in the frequency of drought enchantments, primarily in the summer, and it is likely that this is due to climate change. [20].

Freshwater supplies around the world are predicted to be significantly impacted by anthropogenic climate change. These effects include warmer temperatures leading to greater evapotranspiration and possibly more frequent and intense droughts with decreased snowpack and altered spring runoff timing. Higher winter temperatures in river basins where snowmelt occurs led to less snowpack accumulation and less snowmelt input to summer river flow [36]. Therefore, water supply is impacted by climate change, which also has an impact on distribution of water resources, sanitation services due to declining water quality, infrastructure damage from floods, and water scarcity as a result of decreased rainfall and increased demand.

Additionally, the frequency of floods and droughts, soil moisture, groundwater level, and groundwater recharge are all impacted by climate change in different places. Studies on the socioeconomic effects of climate change, based on assessments of future scenarios and uncertainties, the timing, scope, and nature of climate change,

ecosystems' capacity to adjust to changing conditions naturally or through managed intervention, and the effects of future population growth and economic activity on natural resources how people, businesses, policy changes, and security logically respond to adapt society [27,44]. Specifically, freshwater security pertains to the ability of water to sustain and devastate economic, social, health, and ecological components [13]. It is true that climate change affects the frequency of rainfall, increasing the precipitation.

Changes that have negative effects on rivers flow, water resource availability, agricultural output, and economic growth in a number of nations [21, 32], as well as groundwater recharge [17, 26]. Thus, global precipitation and streamflow volumes saw notable variations due to a combination of climatic change and extensive human activity [50].

It is obvious that the management strategy must adapt to the era of changing climate conditions. Population, storage, and rainfall trends should all be understood at the foundation of water management, as the storage trend changes in opposition to the gradient in rainfall. As suggested by a variety of research, some degree of climate change is unavoidable and that the focus should be on adaption techniques. Changes in lifestyle, technical advancements, modifications and enhancements to laws and policies, and the management of water resources should all be part of these efforts [14, 32]. It is necessary for national and regional long-term development strategies and appropriate development to evaluate the freshwater resource availability in the context of future national requirements, anticipated impacts of climate change, and its variability [16, 27]. There is unlikely to be a severe physical water scarcity; rather, the inability to meet multipurpose water demands (or needs) will result in a severe water crisis because of climate change [36].

Many strategies to tackle or adjust to climate change have been put forth over time. These include the incorporation of climate resilience measures into water safety plans and water resources management, which are closely linked to new technological advancements and policy recommendations (e.g., wastewater treatment, pumping efficiency, renewable sources) [22]. The new paradigms for politics, institutional practices, and national-international laws therefore were likely to be adaptive management, integrated freshwater resources management, social learning, and resilience thinking [2].

After that, a specific concept was introduced to assess the availability of freshwater resources worldwide, including surface and ground waters, that are directly related to floods, droughts, and sea level changes. This concept is known as Terrestrial Water Storage (TWS), and it can be man-made or natural. It represents for all subsurface, underground, and naturally occurring water storage found on Earth's surface, including snow, ice, soil moisture, root zones, groundwater, water held in vegetation, rivers, lakes, reservoirs, and ponds. The TWS is therefore the ability offered by lakes, rivers, groundwater, soil moisture, glaciers, canopy water storage, to balance hydrological cycle, ecological, environmental and socio-economic elements [25]. The Gravity Recovery and Climate Experiment model (GRACE) has made it possible to assess water resources, drought and flood occurrences, and most importantly, the effects of human activity on the water cycle, including groundwater depletion [37].

The following adaptation strategies have been studied: increasing water supply, decreasing demand through water conservation, or utilising infrastructure such as groundwater artificial recharge (water spread or impound on the land surface to allow infiltration and percolation to the aquifer or injecting directly into the aquifer using wells); stepping up water conservation efforts (through rainwater harvesting, ponds, lakes, canals dug, water reservoirs expanded, and installing rain water catching ducts and filtration systems on buildings); lining kilometres of unpaved canals, land-use changes, and crop conversion [36]. Increasing the capacity of water storage appears to be the most practical answer as it may boost economic and agricultural productivity, aid in the production of hydropower, and supply water to businesses and industries. Strong multitasking functions of this solution support sustainable development, poverty alleviation, and climate change adaption. Climate change adaptation must be dynamic and take into account ecological services, biodiversity, and socio-political competition in integrated development-oriented processes [18].

This paper examines the effects of climate change on agriculture, socioeconomic development, biodiversity, and ecosystem services across all continents. Specifically, we focus on the rise in evapotranspiration, annual runoff, variability in water resources, temperature, longer drought periods, and the overall number of extreme events with decreasing snowpack accumulation. Comprehensive bibliographic analysis providing support is presented in the supplementary material, divided out by subject and nation.

This overview aims to: 1) summarise how climate change affects the availability of freshwater resources globally; 2) understand the types of responses governments are taking in different countries; 3) highlight the effects of various water management solutions on fields like economy, society, and nature in order to find strategies and smarter solutions that also take the cost-benefit ratio and environmental aspects into consideration; and 4) identify and propose to Italian policy makers potential appropriate solutions already implemented in other countries to address challenges related to water resource management under climate change.

**Material and Methods:** A total of near around 270 papers were retrieved from the internet using Google and Google scholar search engines in two steps.

The initial analysis phase employed long-tail keywords that included more than one word, such as "Climate change," "Effects of climate change," and "Climate change and water resource," to focus on climate change and its evolution over time and space, examining papers from 1990 to 2022.

The second step, which involved using the keywords "Water research management" followed by "Climate change and water storage" and "Water storage," was centred on finding the most recent research on the effects of climate change and on more intelligent ways to manage water resources. It also addressed solutions to water scarcity, water multiple uses, groundwater, and water for ecosystems. Papers from 2000 to 2022 were examined in this process.

We obtained approximately 140 references for every stage, encompassing scientific papers, books, memoranda, and grey literature. On the references gathered, we exclusively took into account articles written in English, published in internationally indexed scientific journals, and closely associated with the subjects of interest. The selection process resulted in the retention of about 100 papers.

**RESULTS:** The majority of the publications examined (36.4%) discussed the effects of climate change on water resources. The next most prevalent topics of discussion were the effects of climate change on biological elements (15%) and climate change models (11.7%). The economic, medical, and health-related aspects of climate change, the consequences of climate change on tourism, the frequency of natural hazards, the geological and sociological aspects, and the implications on tourism are among the other publications whose percentages are less than 3%.

The total results of the second stage search indicated that, accounting for 44.3% of the examined publications, studies on water resource management are the most prevalent. Papers about water quality status, chemical features of water treatments for safe drinking water (10%), and storage intended to employ solar energy or hydro-power generation production are less common (11%). Articles about biological, ecological, and microbiological carbon storage, or biological purification of drinking water, modelling of water availability changes, effects of climate change on global air circulation, and water availability's economic implications are rare (<8%).

In a further analysis, the distribution of publications by continent (Table 1) as well as the proposals or solutions pertaining to climate change or adaptation that came from various nations within each continent were taken into account (Figure 1). Two additional components were added to the list of continents: "No country," which refers to papers that deal with climate change generally without any particular reference to countries or continents, and "More Countries," which includes papers whose studies discussed the effects of climate change on water resources and potential solutions in more than one country or continent.

**Table 1.**

Number of papers per country. Middle East includes Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Saudi Arabia, Qatar, Syria, United Arab Emirates, Yemen. No country: not geotargeted general aspects.

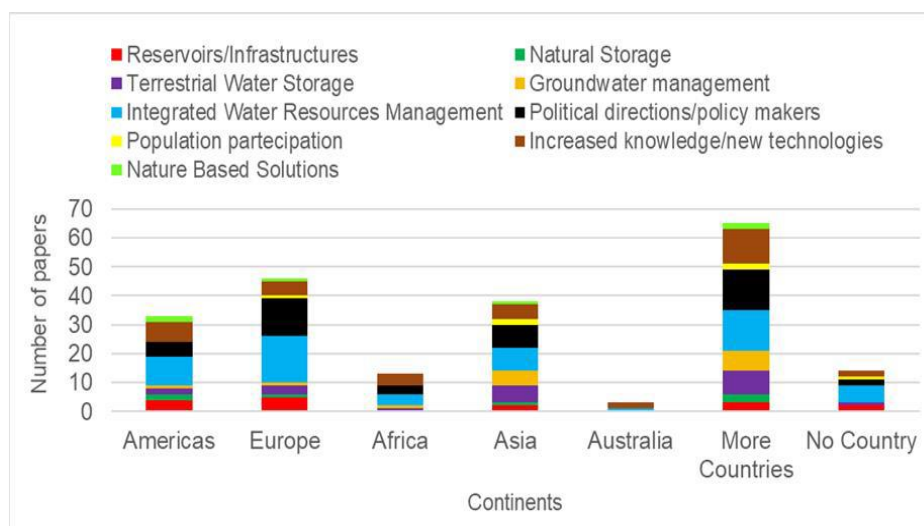
Continent and Countries	Number of Papers
North America and Canada	18
South America	3
northern Europe and UK	10
central Europe	3
southern Europe	8
Africa	6
Asia	17
China and Korea	6
India	6
More countries	43
No country	7

The majority of the chosen papers (33.1%) are aimed at various nations discussing the impact of climate change in emerging nations, arid, alpine, or glacial regions, as well as in Asia and Eastern Europe. Water resources, groundwaters, social, economic, and environmental elements of climate change have been the focus of intense study activity in both the Americas and Asia (17.9% and 17.2%, respectively). Specifically, 21.7% of the articles focused on Asia discussed how climate change might affect China and India's management of water resources, whereas 59.5% of the papers focused on the Americas discussed implications, repercussions, and remedies pertaining to the United States. With 16.4% of the studies on how climate change affects agricultural and economic elements and ideas for common laws and management planning activities, Europe is the third most frequently referred to continent. Just 5% of all papers are about Africa, split equally between North and South Africa. These

papers mostly discuss how water supplies are changing and the social and political ramifications. On the other hand, articles mentioning Australia (2.2%) discussed issues including anticipated effects on water resource management and future climate change scenarios.

In addition to discussing the effects of climate change on water resources, the chosen papers offer strategies for achieving sustainable management of such resources (Figure 1). Reservoirs and TWS together, as well as political movements and public engagement in politics, improved knowledge, and groundwater management, are common examples of solutions. While the increased understanding is viewed as an investment that will significantly improve any other addressed solution, groundwater management is occasionally offered as the one-size-fits-all way to accomplish an integrated water resources management.

Natural Storage and Nature Based Solutions are viewed as innovative solutions and are therefore little treated and considered as a separate topic.



**Figure 1.** Solutions proposed to adapt or deal with climate change, by continents.

Based on integrated water resources management (27.8%) and governmental orientations or decisions (21.2%), as well as new technology or improved understanding (17.5%), the more common suggestion is generally made. Less than 10% of the articles cover groundwater management, reservoirs/infrastructures, natural storage, public participation, and nature-based solutions due to the low representation of innovative solutions. Only 5% of the papers discuss natural storage.

The Integrated Water Resources Management (IWRM) approach is one of the suggested solutions. It is a novel way to manage water resources that encompass all aspects related to water, including natural resources, ecosystems, land uses, agriculture, drinking water, water quality for sustainable development, human health and safety, and high-quality ecosystem services derived from essential ecosystems. As a result, the conventional fragmented approach to water management is superseded by a more comprehensive and coordinated approach that aims to maximise the ensuing economic and social well-being while promoting fairness and maintaining ecological sustainability.

Rather of creating new reservoirs, smart water technologies and infrastructures are frequently linked to reservoir-related solutions. This includes expanding current reservoirs through capacity optimisation and/or enhancing their management and distribution systems. As a result, new technologies become essential for increasing irrigation distribution and water use efficiency while also addressing water demand, monitoring and preventing pollution, improving water quality, combating diseases through water sanitation, desalinating seawater for reuse, and have gained significance in water-scarce nations in recent years.

Finally, nature-based solutions encompass strategies, deeds, and interventions that benefit nature and offer environmental and socioeconomic advantages, enhancing the environment's resilience in which we exist. The enhancement of urban sustainability, restoration of deteriorated ecosystems, application of adaptation and mitigation strategies for climate change, enhancement of risk management, and implementation of resilience encompass activities to safeguard, maintain, or reclassify ecosystems in a sustainable manner that benefits biodiversity and human welfare. All of this is impossible without improving public awareness of the connections between land use and the availability of water resources, the trends and future scenarios of climate change as determined by new modelling or time series analyses, the effects of climate change on ecosystems and how sensitive and adaptable they are to it, and the requirement for more widely accessible and interchangeable hydrological data. All the examined solutions—reservoirs/infrastructures, terrestrial water storage, integrated water resources management, population participation, nature-based solutions, natural storage, groundwater

management, political directions/policy makers, increase knowledge/new technologies—are taken into consideration in Europe, Asia, and other countries. Population participation and groundwater management are not seen as separate solutions in the Americas; instead, they are a part of "Integrated Water Resources Management," which accounts for 19% of all articles, compared to 27% in Europe, 13.6% in Asia, and 7% in Africa. In Africa, the analyses performed are quite comprehensive including "Terrestrial Water Storage", "Groundwater management", "Integrated Water Resources Management", Political directions/policy makers", "Increased knowledge/new technologies" (representing <10% of the total amount of papers).

In Australia we only found papers dealing with "Integrated Water Resources Management" and "Increased knowledge/new technologies".

In Asia suggested solutions included "Reservoirs/Infrastructures" (5.3%), "Terrestrial Water Storage" (15.8%), "Groundwater management" (13.2%), "Political directions/ policy makers" (21%), "Population participation" (5.3%), "Increased knowledge/new technologies" (13.2%), "Nature Based Solutions" (2.6%).

Water resource management involves the distribution of water over larger areas through artificial or natural canals (think groundwater management or Terrestrial Water Storage), and public and stakeholder participation in decision-making. This is especially true for countries that have historically experienced water scarcity, such as those in Africa and Asia.

Worldwide, the more successful and efficient approaches are acknowledged to be Integrated Water Resources Management and Growing Knowledge/New Technologies (since 2000 and 2004). Growing awareness of the implications of climate change on ecosystem services and water resources, with ripple effects on social and economic facets as well, is contingent upon gaining more knowledge. Gaining greater knowledge can also help people realise that becoming more adaptable to climate change and addressing it can be achieved through the use of integrated water resources management.

In 2009, the United Kingdom discussed nature-based solutions; later, in 2018, China, the United States, in 2019 and 2021, and in 2020, other countries used it. Innovative solutions, specifically the proper approach to managing water resources to protect human futures, are represented by Nature Based Solutions. Different approaches and strategies are proposed for solutions in Italy: Reservoirs, Natural Storage, Political Approaches, and Integrated Water Resources Management.

**DISCUSSION:**In general, studies on climate relate to climate variability as a model system and average long-term changes throughout the entire globe. Hence, a comprehensive understanding of the impacts of climate change on biological assemblages and human society is unattainable. The population's expenses associated with these impacts—such as rising rates of food insecurity and pest disease [38], as well as the quality of the water in lakes, streams, and groundwater [23,48] are greatly underestimated.

Because of this, we concentrated on research that described technically and scientifically workable ways to address climate change and its effects on water resources, ecosystems, socioeconomic factors, health, and food security. The supplementary material (Table 1SR) contains the complete list of references. In addition, we presented a comprehensive overview of several global approaches to water resource management in order to provide empirical support for the political and social choices pertaining to water resources that the Italian government and its ministries will need to make.

Numerous studies [15, 19, 21] have emphasised that the absence of suitable locations and environmental sustainability laws makes building new, massive dams in developed nations impractical. Large dams benefit society and the economy, but they also have negative consequences on the environment and society [28].

As a result, it is suggested that reservoir efficiency be increased by employing water storage options based on auxiliary infrastructures, such as raising an existing dam's height or installing an aquifer recharge system that uses artificial groundwater recharge. Other potential Natural wetlands, soil moisture, groundwater aquifers, ponds, and small tanks are examples of natural water storage. Even if using them for drinking water could result in quality issues, the last one offers an option for water supply in impoverished nations [28].

According to other studies, it's critical to manage aquifers as natural storage reservoirs to reduce evaporation losses and the negative effects that big reservoirs have on ecosystems [4], as well as to increase groundwater reservoir capacity in local aquifers [42].

To reduce human vulnerability to climate change and maintain or increase natural and artificial water storage capacity, groundwater management must take surface water and groundwater interactions into account [31]. The sources, annual variation, and availability of these many water resources might vary, and they must balance a range of requirements, supply sources, drought periods, and goals including increasing water for ecosystem health [24]. New technologies and enhanced understanding can facilitate the increase in water storage or improve the efficiency of groundwater recharge, for instance by employing biodegradable hydrogel materials [43].

Furthermore, lakes, reservoirs, wetlands, and trends in the flows of major rivers can be determined by using remote sensing to map the elevations of surface waters [3], which can provide guidance for better water management.

In order to minimise the effects of water scarcity, new technologies can be used to model and conduct in-depth research on water quality, water uses, irrigation management, waste and saline water treatment, adjust agricultural

practices, or introduce new cultivars to reduce the adverse effects on crops [9], human health, and the environment [34] caused by overirrigation and salt intrusion.

The above-described technical solutions can help in improving resilience to water shortage, but it becomes evident that climate change emphasizes the urgent need of a new paradigm to the management of water resources, and of goal-oriented management plans with special attention to mitigation and adaptation strategies [45].

Water Resource Management with Integrated strategies needs to be implemented and supported from a holistic point of view with different adaptation strategy such as: water storage and green infrastructures, agricultural practices, water governance and policies, disaster risk reduction, economic diversification [1], distribution efficiency, leakage control, pressure management and influencing demand. An Integrated Water Resources Management also has the purpose to avoid the degradation of natural resources and ecosystems, to obtain a sustainable development with long-term productivity for the economic growth and in support of ecosystem services. The management plan should also take in account regional differences because each country has its own characteristics and issues to deal with such as coastal and inland areas, island, or desert regions [47].

However, Integrated Water Resources Management is also a political process of decision making [35], that included the four pillars of sustainability: social, economic, environmental, and institutional areas, and must consider physical, biological, chemical, socioeconomic aspects and their relationships [33].

Political direction and policy makers have to address mitigation strategies to minimize the impacts of climate change, and adaptation actions to look at how to reduce the negative effects that climate change imposes and how to exploit the opportunities that arise.

Mitigation strategies balancing global water availability and water demand can reduce the vulnerability of people (at risk for poor health), of society and of ecosystem services [41]. Adaptation measures should incorporate climate considerations into long-term planning and management, and monitoring and advanced modelling to reduce waste, to use and reuse water more efficiently for protecting and restoring biodiversity and natural habitats [26], reducing demands, increase the amount of water expanding reservoir size, reducing water transport outside the catchment, and increasing pumping rate to the reservoir [10].

Therefore, only considering a Population participatory approach to planning and management of water resources, it is possible to minimize the impact and to improve our resiliency to climate change [7]. This is also fulfilled to avoid that rural people, above all in the less-developed countries, remain excluded from decisions concerning natural resources [49]. A bottom-up assessments of vulnerability hold promise as a means of responding to local priorities and complexities [18].

Finally, recent studies [11] on Nature Based Solutions on natural and semi-natural ecosystems show decreasing climate change impacts and supply support to people adaptation [12]. Protected, restored and well-managed natural or semi-natural ecosystems have positive effects on the local economy, supporting the public adaptation to climate change and creating climate resilient communities. An example of a new strategy to solve water management issues in urban context where rapid urbanization, waterlogging, water pollution, ecosystem degradation has caused severe problems, is the Sponge City [46]. This is a holistic integrated urban water management approach using NBS, a starting point for new scientific research to deal with climate change in an innovative way.

A further example of NBS such as natural water retention ponds were developed as a solution to the assessment of water management in agriculture [6]. Ponds showed positive effects on the agricultural landscape, the water availability and on the environmental quality. The presence of ponds increases the water availability for irrigation during the dry season, adding secondary economic benefits improving the product quality under climate change scenario.

Therefore, considering what emerged from the analysis of the 134 papers, we can indicate practicable solutions to be adapted to the Italian context. Considering the climate features of the Italian territory, nature-based solutions are the more effective to deal with water scarcity and floods events. The possibility to define floodplain areas or ponds along rivers so as to distribute the water resource as much as possible, can help to storage water when abundant and to be used when scarce. Another effective solution is to consider groundwater and groundwater management to use as distributed storage, improving infiltration. The political direction towards Integrated Water Resources Management is an important element with whom to define the future actions and solutions to be taken at the government level, to deal with climate change and to preserve ecosystems services, biodiversity and our future.

**CONCLUSION:** Worldwide, due to the increase in population and in water demand for human purposes (i.e. agriculture, industry, hydro-power generation, tourism), the water crisis is a problem even in those areas characterized by high precipitation amount. In some countries, drought and water scarcity are characteristic, affecting the population distribution and causing devastating problems due to the consequences they have on populations well-being and health. Therefore, it becomes crucial to highlight solutions, methods and approaches to better respond in a sustainable way to water scarcity, to food security and health, to ecosystem and biodiversity protection in support of governments and their political decisions.

Water resources management under climate change is a complex issue. Across the world, climate change effects and impacts on water resources have different consequences on the environmental, social and economic aspects.

Scientists from different countries suggested several strategies and solutions according to the physical, morphological, social and political characteristics of their territories, but all together they agree that integrated water resources management, political and planning process, increasing knowledge and applying new technologies are the best approaches to deal with the problem of water resource sustainability. Most of the papers we collected also highlight that the management of water resources must take into account not only the economic and social point of view but also, or above all, ecosystems and their services. Climate change and the lower availability of water resources require a radical change in the management of water resources.

**SUPPLEMENTARY MATERIALS:** It is submitted along with the manuscript. Table 1SR. List of references analysed divided per Country, Topic, and solutions proposed.

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# EVAPOTRANSPIRATION MODELING FOR EFFICIENT WATER RESOURCES MANAGEMENT: A COMPARATIVE STUDY OF TAKAGI-SUGENO FUZZY SYSTEM AND GENERALIZED REGRESSION NEURAL NETWORK MODELS-CASE OF STUDY SEMIARID REGIONS -ALGERIA

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## **ABSTRACT**

*Reference evapotranspiration is the speed at which water evaporates and is transpired from a well-irrigated, actively growing reference crop in specific standard meteorological circumstances. It is often calculated using the Penman-Monteith method which is widely used in different climatic conditions. This method takes into consideration various meteorological data such as solar radiation, air temperature, humidity, and wind speed to accurately determine the reference evapotranspiration. However, in arid and semiarid regions where water deficiency is a major constraint, accurate estimation of evapotranspiration from irrigated areas is crucial for efficient water resources management. The objective of this study is to compare two modeling approaches, the Takagi-Sugeno fuzzy system and generalized regression neural network models, with evapotranspiration calculated by (FAO-56). The statistical results show that generalized regression neural network model provide accurate estimations of evapotranspiration then Takagi-Sugeno Fuzzy System in semiarid regions located in Algeria. The daily data registered from 2000 to 2022 are air temperature<sub>2m</sub> (°C), relative humidity<sub>2m</sub> (%), dew point<sub>2m</sub> (°C), precipitation (mm), surface pressure (hPa), ETO<sub>fao</sub> evapotranspiration (mm), vapour pressure deficit (kPa), wind speed<sub>10m</sub> (km/h), soil temperature<sub>0 to 7cm</sub> (°C), soil moisture<sub>0 to 7cm</sub> (m<sup>3</sup>/m<sup>3</sup>), sunshine duration (s), and terrestrial radiation (W/m<sup>2</sup>). The data were trained (70 %) and validated (15%) and test (15%). To evaluate the two models, several indexes were calculated such as Nash efficiency, coefficient of determination, and root mean square error, mean absolute error, Ratio sum ratio, and Willmott index.*

*The findings of this study suggest that the generalized regression neural network model is more suitable for accurately estimating evapotranspiration in semiarid regions, which can contribute to efficient water resources management in these areas. Proven by value of Nash close to 1, minimum root mean square errors and absolute errors, Ratio sum ratio less than 0.2 and Willmott index superior than 0.9.*

**Keywords:** ET(FAO-56), GRNN, TSFS, SEMIARID, ALGERIA.

# THE NEXUS OF CLIMATE CHANGE AND ECONOMIC GROWTH IN THE CITIES OF DEVELOPING COUNTRY

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## **Abstract**

*Climate change has significant and often disproportionate impacts on developing countries. These impacts are driven by a variety of factors, including their vulnerability to environmental changes, limited resources, and socio-economic challenges. This paper analyses the nexus between climate change and economic growth in developing country like Pakistan. Time series data for the period 1990-2022 on variables is taken from WDI.*

*To capture climate change, annual rainfall, CO2 emission, temperature changes were used; while control variables for the study were taken as labour force, gross capital formation and urbanization. Results show that forest area and CO2 emissions have negative impact on economic growth while temperature changes and rain fall have positive impact on economic growth. The control variables have theoretical signs and are statistically significant. The co-integration test endorses the co-integration existence among variables. Results suggest that policies must be designed for minimization of forest depletion and CO2 emissions for fostering economic growth. Developing countries must establish a proper statutory body to conduct various sessions on national, regional, and local levels to cope with climate change issues.*

**Keywords:** Climate Change, Economic Growth, Co-integration Tests.

# INVESTIGATION OF THE THUNDERSTORM STATISTICS AND STABILITY INDICES ISTANBUL AIRPORT, TÜRKİYE

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## Abstract

Thunderstorms are weather phenomena formed by one or more cumulonimbus clouds. They typically result in heavy precipitation, including rain, snow, and hail. Thunderstorms have adverse effects on flight at both ground level and at upper levels of atmosphere. Thunderstorm characteristics of İstanbul Airport is investigated because it is currently one of the busiest airports in Europe and 7<sup>th</sup> busiest airport in the world. Geopotential height (m), temperature (°C), dew point temperature (°C), relative humidity (%), mixing ratio (g kg<sup>-1</sup>), wind direction (°) and wind speed (knots) data for ground level and upper levels of the İstanbul radiosonde station obtained from Turkish State Meteorological Service for the period of October 29th, 2018, and January 1st, 2023. Thunderstorm statistics, stability indices and meteorological variables at upper levels are evaluated for this period. Thunderstorms are more frequent during the summer, with a total of 51 events. June has the highest number of thunderstorm events with a total of 32, averaging 8 events per year. K index and Total Totals index represents the thunderstorm events better than other stability indices.

**Keywords :** İstanbul Airport, Thunderstorm, Stability Indices, K Index, Total Totals Index

# AN ANALYSIS OF THE UNPLANNED URBANIZATION ON THE ENVIRONMENT OF PESHAWAR, KHYBER PAKHTUNKHWA, PAKISTAN

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## **Abstract**

*In this study, data were collected from both primary and secondary sources including GIS. Results show that the city of Peshawar is urbanizing at an unprecedented growth rate in the last few decades, and in the absence of a proper institutional framework and urban planning the city is experiencing excessive urban sprawl. The major drivers responsible for urban sprawl are centralized services, economic, market forces, and ease of life. This rudderless growth not only causes urban sprawl, the emergence of slums or katchiabadis.*

*To make Peshawar a competitive, resilient, and livable city, there is a need to control the undesirable urban sprawl and associated environmental implications, which are occurring in the absence of implementation of master planning of city supported by a robust legal and institutional framework. There also exist other legal and institutional perplexities with overlapping functions causing sprawl or uncontrolled expansion of the city. It is a need to tackle the issue of overlapping functions among the various institute and develop a proper mechanism of coordination between various entities. The city planner and policymaker give due attention to the problems caused by urban sprawl and develop a framework for implantation to control the further deterioration of the city.*

**KeyWords:** Urbanization, Environment, Peshawar.

# A PRINCIPLED APPROACH TO USING LARGE LANGUAGE MODELS IN METEOROLOGICAL FACT-FINDING

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## **Abstract:**

*The advent of Large Language Models (LLMs) like ChatGPT 3.5 and 4.0 by OpenAI has opened new avenues in data analysis, including meteorological fact-finding. These models, with their vast knowledge base and language understanding capabilities, have shown potential in retrieving and interpreting meteorological data. However, their application often comes with a caveat: the accuracy of the information retrieved can vary, with no guaranteed reliability. This paper proposes a principled approach to utilizing LLMs in meteorological fact-finding that aims to address this challenge.*

*Firstly, we discuss the recent developments in LLMs, highlighting their growing computational power and ability to process complex queries. We then explore the traditional use of LLMs in fact-finding tasks, emphasizing the limitations in accuracy and reliability of the information provided. To overcome these limitations, our approach leverages the advanced features of ChatGPT 4.0, particularly its ability to integrate and analyze user-provided data.*

*We present a methodology where LLMs are used not just as a source of information but as tools to generate analytical code tailored to specific data sets. This approach is exemplified through a case study comparing meteorological data findings from internet sources (such as Google's featured snippets) and LLM-generated analysis. By using ChatGPT 4.0 to create reusable programs for data analysis, we demonstrate a significant reduction in the time and effort typically required for coding and debugging in meteorological research.*

*This paper underscores the importance of a principled approach in employing LLMs for factual inquiries, especially in fields like meteorology where data accuracy is crucial. Our findings suggest that when used judiciously and creatively, LLMs can be a powerful asset in the toolkit of researchers and decision-makers, offering efficient and potentially more accurate ways to analyze and interpret large data sets.*

# REDUCING THE RISK OF WATER CONTAMINATION: THE APPROACH OF CBRN AFTERMATH

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## **Abstract**

*Water contamination, a significant threat post Chemical, Biological, Radiological, and Nuclear (CBRN) events, necessitates comprehensive strategies. This study explores measures to reduce contamination risks, emphasizing avoiding conventional water sources like taps and wells. It highlights risks associated with surface water, groundwater, and drinking water contamination. Drawing from authoritative sources, the study explores health effects, and environmental damage impacts in CBRN scenarios. To address contamination, multifaceted cleanup measures and risk reduction are outlined, with a focus on crucial water treatment before consumption. Decontamination efforts, emphasizing water characterization and treatment, are explored. The study delves into safe water management, calling for environmental impact assessments to plan for CBRN events' consequences on water resources. Proposing a holistic approach, the study combines water treatment, decontamination, safe water management, and legal frameworks to safeguard public health and the environment, ensuring resilience in the face of CBRN challenges. The insights contribute to understanding water contamination complexities, fostering proactive collaboration among scientists, planners, practitioners, and researchers.*

**Keywords: CBRN, Water Management, Decontamination**

## **INTRODUCTION**

The threat of Chemical, Biological, Radiological, and Nuclear (CBRN) incidents, while unconventional, remains a tangible danger for countries. State adversaries may exploit these agents to generate mass impact among civilian or military personnel, while non-state actors pose a potential risk of using CBRN agents to induce panic and disruption [1, 2]. The vulnerable extensive water supply systems and vast water bodies in towns, cities, and metros are susceptible soft targets, with many remaining unprotected [3]. The imminent challenges posed by CBRN emergencies emphasize the utmost importance of preparedness, particularly in securing the water supply—a crucial resource susceptible to contamination in the aftermath of such disasters. The consequences of CBRN incidents extend beyond immediate health risks, encompassing infectious diseases like typhoid and cholera [4], as well as enduring impacts such as arsenicosis and fluorosis [3, 5, 6]. With the goal of creating a resilient national community that can face disasters with the fewest possible casualties, a strong institutionalized framework for disaster management has been put in place to address these worries. This framework includes all of the procedures that are needed to identify, clean, purify, and treat water. Desalination, disinfection, and decontamination are all included [7, 8, 9, 10]. Ongoing efforts are directed towards establishing national standards for post-disaster water

supply, guided by insights from esteemed international organizations such as the UN, IFRCRCS, and WHO [3]. These evolving guidelines aim to foster inclusive and participative approaches, with a specific focus on prioritizing vulnerable groups and fortifying a proactive relief strategy. The collective objective is to fortify the nation's water supply, ensuring greater security and resilience in the face of CBRN emergencies. This study explores comprehensive strategies aimed at reducing the risk of water contamination and mitigating its long-term effects on both human and environmental well-being. The study proposes a holistic approach to reduce the risk of water contamination in the aftermath of CBRN events.

### **POTENTIAL RISKS ASSOCIATED WITH SURFACE WATER, GROUNDWATER, AND DRINKING WATER CONTAMINATION**

Surface water, groundwater, and drinking water contamination pose multifaceted risks to both human health and the environment. Surface water is susceptible to industrial discharges [11, 12], agricultural runoff [13], and urban pollutants, introducing a range of contaminants like heavy metals [14, 15], and toxins that degrade water quality and harm aquatic ecosystems [16]. Groundwater faces threats from landfill leaching, industrial spills, and agricultural practices, potentially leading to the infiltration of hazardous substances into aquifers [17]. Drinking water is at risk from microbial contamination, chemical pollutants, and infrastructure failures, with the potential for waterborne diseases and adverse health effects [18].

### **WATER CONTAMINATION AS A DISASTER SCENARIOS**

The presence of contaminated water poses health risks, giving rise to waterborne diseases that can be mitigated through preventive measures, even at the household level [18]. Ensuring access to safe water for everyone is a formidable challenge. Decades of research efforts in this domain have yielded various processes and technologies [19]. Water contamination is a widespread issue globally, stemming from either geological or anthropogenic sources [20]. Primarily, contaminants contributing to water pollution fall into four categories: biological contaminants, inorganic contaminants, organic contaminants, and radiological contaminants. [21, 22].

Following a CBRN disaster, surface water resources, unprotected storage facilities, and other water sources are frequently subject to contamination. Therefore, it becomes imperative to treat water extracted from these sources before consumption. In order to meet this demand, temporary pipelines must be installed, alternative supplies must be managed through possible small repairs, traditional sources must be revitalized, bottled drinking water must be transported or distributed from nearby places, and other measures must be taken [3]. In scenarios where localized drinking water treatment facilities face destruction or disruption, it becomes essential to treat and disinfect the source water before distributing it for human consumption or any other use [3, 23].

The vulnerability of freshwater resources and water infrastructure to human health, ecosystem stability, and the smooth functioning of commercial and industrial economies makes them potential targets for terrorism [24]. Deliberate contamination of water sources by malicious actors poses a credible threat in the present era, supported by a historical record of such attacks. In 1972, the "Order of the Rising Sun," a right-wing neo-Nazi group, acquired typhoid bacteria cultures with intentions to contaminate water supplies in cities like Chicago and St. Louis. Detailed plans for disseminating the lethal pathogens into water sources were discovered in their possession [25]. Subsequently, in 1973, a German biologist threatened to contaminate water supplies with *Bacillus anthracis* and Botulinum, demanding a ransom of US\$ 8.5 million [26]. Lethal amounts of potassium cyanide were discovered in water tanks at a Turkish Air Force facility in Istanbul during another incident that occurred in March 1992 and involved an attempted chemical poisoning [27].

### **THE IMPACT OF WATER CONTAMINATION**

Water infrastructure can face potential threats either through direct targeting or contamination by the introduction of harmful agents, whether poisonous or disease-causing [28]. Such acts could be motivated by the desire to kill people, contaminate water supplies, or damage infrastructure related to supply and purification. Although it is difficult to cause large-scale casualties by targeting water supplies, there is a high risk of societal unrest, chaos, and panic [29]. Important water facilities, including pipelines, distribution points, reservoirs, and dams, are frequently open to the public at different sites. Urban water supply pipelines are commonly exposed over extended distances and can be found in both urban and rural settings [30, 31]. The possibility that water-soluble CBRN pollutants could be introduced into publicly available water sources by deliberate sabotage or natural/accidental means, raising concerns about the potential for CBRN contamination of water systems. A number of variables, such as the kind of water treatment system, the kind and amount of the contaminant, the amount of poisoning consumed, an individual's resistance, the timing of an attack, and the promptness of local authorities' detection and response, affect the potential number of casualties resulting from CBRN contamination [32, 33]. Routine water treatment methods, such as filtration, ozonation, ultraviolet radiation, chlorination, and other common approaches, prove effective against many pathogens and chemicals [34, 35, 36]. Additionally, exposure to sunlight and natural processes aids in breaking down various contaminants over time [37, 38].

### **STRATEGIES FOR REDUCING THE RISK OF WATER CONTAMINATION**

To address the CBRN threat to water resources, implement a comprehensive plan covering Prevention, Protection, Preparedness, Crisis Management, and Recovery. Prioritize mitigating measures, including safeguarding water facilities, training personnel, procuring emergency logistics, and conducting periodic security checks.

## **PREVENTION**

Mitigating CBRN threats involves conducting vulnerability assessments on water facilities and training personnel. These assessments encompass both natural and man-made risks, offering security upgrade plans [39]. It is imperative to collaborate with security agencies for comprehensive evaluations. Intelligence and security assessments are vital in addressing the increasing risk of terrorist attacks involving CBRN agents, enabling real-time management based on regular evaluations [40].

## **PROTECTION**

The Physical Protection Plan (PPP) is crucial for addressing threats to public water supply systems, including natural and man-made risks [41, 42]. Upgrading existing plans is essential to combat evolving terrorist threats. A comprehensive vulnerability assessment guides improvements to the current physical protection system, focusing on safeguarding water supply facilities, equipment, and vital records [43]. The emergency response plan emphasizes deterrence through multilayered perimeter security, graded access control, inspection, electronic surveillance, and delay measures to prevent attacks. The plan aims to neutralize or minimize intentional or accidental contamination. In order to make prompt decisions that safeguard the public's health against water contamination, the Early Warning System (EWS) is essential for tracking, identifying, evaluating, and interpreting data [44]. A robust EWS should incorporate processes, mechanisms, and technologies to detect contaminants in the drinking water distribution system [45]. Continuous or real-time monitoring is essential, strategically placing systems at vulnerable points identified through a vulnerability assessment.

## **EMERGENCY RESPONSE PLAN**

To ensure a swift and effective response to major events, acquiring detailed technical information about Public Water Supply System assets is vital. This includes system details like name, location, distribution area, contacts, population served, maps, diagrams, operational specifics, emergency procedures, and chemical management. A comprehensive pre-planning strategy involves creating an Emergency Response Plan (ERP) and establishing an Emergency Response Team (ERT) with designated leaders for information evaluation, resource management, and response actions [46]. This collaborative effort includes Public Water Supply System staff, first responders, law enforcement, citizens, and utility administrators, ensuring a thorough and effective ERP and Physical Protection System (PPS). Identifying first responders from various departments and agencies, such as District Administration, Municipal Corporation, Water Supply Board, District Health Administration, District Police, Fire Services, Intelligence Agencies, is crucial for a resilient and coordinated emergency response across diverse community facets.

## **DETECTION**

Surveillance in drinking water focuses on identifying and assessing factors that pose health risks, aiming to promptly recognize and prevent public health issues. In threat detection, recognizing warnings of potential water contamination is crucial. Threats are evaluated based on evidence and intelligence, progressing through stages of "possible," "credible," and "confirmed." The Emergency Response Plan (ERP) is activated upon confirmation, involving coordination with police and security agencies [47]. In confirmed contamination, regular water supply is immediately suspended across the distribution network to mitigate health risks [48].

Establishing a laboratory network is vital for prompt detection, especially as existing laboratories may lack capabilities for Chemical, Biological, Radiological, and Nuclear (CBRN) agent detection. Water facilities should collaborate with primary and reference laboratories possessing the required capabilities. For sampling, trained first responders should collect samples from potential drinking water sources in clean containers, with paired samples for each suspected source [49]. On-site screening tests, including preliminary (turbidity, color, taste, odor, and pH) and definitive screening tests (Water Poison Detection Kit, Severn Trent Field Enzyme Test, presumptive coliform test, Eclox TM kit) aid in rapid evaluation [18, 45, 51]. Confirmatory laboratory testing involves techniques like membrane filtration, colony count, Colilert method, flow cytometry, strip tests, PCR, and advanced methods for biological contamination [52]. Chemical contamination testing employs techniques like chemiluminescence, gas chromatography, biosensors, and detection kits [53]. Radio-Nuclear contamination testing focuses on beta emitters (Sr-90, H-3), tritium detection, and gamma emitters (<sup>137</sup>Cs, <sup>131</sup>I) using in-situ gamma ray spectrometry [54].

## **RISK COMMUNICATION**

In emergencies, clear communication is crucial. Immediate communication with local law enforcement is essential for security breaches or contamination detection. Timely and accurate public communication, managed by a designated Public Information Officer (PIO) with strong communication skills and ERP familiarity, minimizes health hazards. The PIO ensures a calm and informed public response, preventing confusion and panic, and unauthorized personnel should avoid public communication for accurate information dissemination [55].

## **RECOVERY**

In cases of prolonged water contamination, authorities may utilize recommended decontamination methods. One effective method is Reverse Osmosis, which efficiently removes various CBRN agents from water [56]. Another approach, Clay Minerals Adsorption, employs specific clay-based minerals as isotope-selective adsorbents, removing over 90% of radioactivity [57]. Various clay coatings are particularly effective for eliminating iodine isotopes, Strontium-90, and Cesium-137 [58].

## CONCLUSION

In conclusion, this study underscores the urgent challenges of water contamination post-CBRN events, emphasizing the need for comprehensive strategies. The research reveals vulnerabilities in water supply systems, ranging from intentional sabotage to surface and groundwater risks. It highlights the multifaceted impact on public health, the environment, and socio-economic aspects. Key recommendations include prioritizing water treatment to mitigate contamination risks. The study also advocates for enhanced plans, legal frameworks, and environmental impact assessments to decontaminate critical water infrastructure effectively. The proposed holistic approach integrates water treatment, decontamination, safe water management, and legal frameworks to ensure resilience and sustainability. Insights from the study encourage collaboration among scientists, planners, and practitioners for a united response, emphasizing the collective effort needed to safeguard water resources and protect communities from the widespread consequences of water contamination in CBRN incidents.

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# GLOBAL WARMING, WATER SCARCITY AND MICROPLASTICS: A CONTROL APPROACH WITH NONWOVEN FILTERS

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## Abstract

*In a world facing the challenges of global warming, water scarcity, and widespread microplastic pollution, this study advocates for an integrated approach to safeguard the environment and human health. The proposal centers around adopting nonwoven filters as a comprehensive control strategy. Water scarcity, exacerbated by climate change and overexploitation of freshwater resources, is further intensified by microplastic contamination. Microplastics, linked to plastic pollution and climate change, contribute to environmental degradation and worsen the global water crisis. Their intricate relationship with climate change creates a feedback loop, releasing greenhouse gases during breakdown and amplifying global warming. This study highlights nonwoven filters as a viable solution to mitigate the adverse effects of microplastics on water resources and human health. These filters, with small pore sizes and high surface areas, effectively capture microplastics from water supplies. The proposed control approach involves systematic implementation in water treatment processes, addressing sources, selecting filters, and ensuring compliance with regulations. Global regulatory initiatives, like those by the State Water Resources Control Board in California and the European Commission, emphasize the need to regulate and monitor microplastics in drinking water. The adoption of nonwoven filters not only removes microplastics but also contributes to reduced contamination, improved water treatment, and long-term sustainability. This study advocates for a holistic approach to address the complex nexus of global warming, water scarcity, and microplastics for a more resilient and sustainable future.*

**Keywords:** Microplastics, Nonwoven filters, Climate change

## 1. INTRODUCTION

In recent years, the growing environmental concerns associated with microplastic pollution have gained significant attention, underscoring the urgent need for effective control measures. Microplastics have infiltrated aquatic ecosystems, posing considerable threats to environmental stability and public health [1]. The widespread presence of microplastics originates from various sources, including the washing of textiles, emissions from plastic production, and the breakdown of plastic debris during land and maritime activities [2]. Wastewater treatment plants, identified as major contributors, release microplastics into nearby aquatic environments, highlighting the necessity for comprehensive strategies to remediate this issue [3].

Addressing the challenge of microplastic contamination involves two primary techniques: degradation and separation. While degradation methods like biological, photoaging, and mechanical processes exist [4], they come with inherent drawbacks, including the potential risk of residual microplastics posing threats to ecosystems and human health [4]. On the other hand, various physical separation technologies, such as dissolved air flotation,

coagulation, sand filtration, and membrane filtration, provide promising avenues for microplastics removal [5]. Among these, membrane filtration stands out as a particularly viable option due to its scalability, high efficiency, and cost-effectiveness.

This paper explores a control approach focused on nonwoven filters to mitigate the impact of microplastics on the environment and water. Nonwoven filtration, utilizing fibrous filter media, has proven effective in fluid purification. This method offers a strategic response to the challenges posed by microplastics, providing high filtration efficiency, increased pore availability, efficient cake discharge, and cost-effectiveness. Specifically, we delve into the potential of nano-fibrous webs, produced through electrospinning, as a superior choice within the spectrum of nonwoven filters.

## **2. MICROPLASTICS: DEFINITION AND SOURCE OF GENERATION**

Microplastics, tiny fragments resulting from the diverse types of plastic used today, emerge as a consequence of human activities, adding to the growing issue of plastic waste. These little plastic particles traverse several paths to both enter and re-enter the human body. The environment's general dispersion of microplastics, which eventually end up in water bodies, is facilitated by both inherent and environmental factors, such as recalcitrance, density, and hydrophobicity.

The European Chemicals Agency [9] and the U.S. National Oceanic and Atmospheric Administration [7, 8] define microplastics as pieces of plastic that are less than 5 mm in length. Microplastics are defined by the United Nations Environment Program as solid plastic particles that are insoluble in water and have a diameter of no more than 5 mm [10]. The International Organization for Standardization defines microplastics as having dimensions ranging from 1  $\mu\text{m}$  to 1000  $\mu\text{m}$  [11]. The sources of microplastics can be categorized into direct generation and secondary generation, where larger plastic debris undergo weathering and break down into microplastics due to natural environmental processes.

While primary microplastics, such as microbeads, have been banned due to their substantial impact on environmental pollution [12], there remains a concern about the persistence of secondary microplastics, which arise from previously discarded plastics in the natural environment [13].

## **3. MICROPLASTIC IDENTIFICATION**

To find microplastics in water systems, a variety of analytical instruments have been developed. Although SEM can examine the microplastics' nanoscale surface, it cannot identify the different kinds of microplastics and its detection range is yet unknown [14]. During the early phases of the study, procedures based on eye inspection or microscopy were used to quantify microplastics. For the purpose of qualitatively evaluating microplastics of all

shapes and sizes, infrared-based analysis tools are increasingly being used. In addition to other investigations like X-ray CT or energy dispersive spectroscopy (EDS) in scanning electron microscopy (SEM) [14], the Attenuated Total Reflectance mode has been put into practice. Comparing Raman spectrometry to infrared-based techniques, it has recently been apparent that the former has a lower detection limit for microplastics. However, the identification of plastics at the nanoscale remains challenging due to the limitations of spectroscopic analysis, prompting the proposal of pyrolysis–gas chromatography-mass spectrometry (Py–GC-MS) [14].

#### **4. MICROPLASTICS' EFFECT ON THE WATER AND ENVIRONMENT**

##### **4.1. MICROPLASTICS' POSSIBLE HAZARDS IN THE ENVIRONMENT**

Microplastics in the marine environment usually fragment gradually as a result of physical wear, UV radiation, and biodegradation. Geometrically, the number of broken microplastics rises as the size falls [15]. Surface water samples from the Nordic Seas near Greenland revealed microplastics with a flaky and weathered appearance, exhibiting irregular cracks and a film-like surface reminiscent of onion skins [16]. In comparison to non-stormy settings, seawater samples taken after a typhoon revealed greater wear marks, folds, and cracks in microplastics [17]. These surface alterations verify the aging of microplastics, which is ascribed to weathering brought on by UV radiation and the mechanical forces of waves and wind [18]. Furthermore, the fragmentation of microplastics is found to be influenced by flow rate, with increased flow velocity during flood season leading to additional breakdown [19].

In the marine environment, microplastics are constantly decomposing due to a variety of chemical, physical, and biological causes. Environmental factors like sunlight, temperature, water depth, and the presence of microorganisms affect how quickly microplastics break down [20]. Microplastics are hazardous in proportion to their size; marine zooplankton is more vulnerable to small microplastics than to bigger ones [9]. It has been shown that microplastics smaller than 20  $\mu\text{m}$  have the greatest potential to damage marine ecosystems in the coastal surface waters of Okinawa, Japan [21]. Particles smaller than 20  $\mu\text{m}$  have the ability to cross cell membranes, and those with a diameter of less than 1.5  $\mu\text{m}$  can cause direct harm to cells [22, 23]. Furthermore, it was discovered via energy dispersive spectroscopy and scanning electron microscopy research that exfoliated and weathered microplastics can absorb heavy metals [16]. The oxidation level of microplastic particles on coastlines is higher, and their worn and distorted appearance makes it more difficult to determine their source [24]. These results highlight the serious potential threats that old and broken microplastics could bring to the marine environment.

#### **4.2. ADSORBED HARMFUL SUBSTANCES AND MICROPLASTICS' INHERENT TOXICITY**

Based on the chemical makeup of plastic polymers, a thorough study conducted in 2011 evaluated the dangers to the environment and human health. The most dangerous polymers came from polymer types like polyurethanes, polyacrylonitrile, and PVC and were derived from monomers that were categorized as carcinogenic or mutagenic. Through consumption, inhalation, or touch, these plastic goods may be poisonous or have negative impacts [25]. The Changjiang estuary in China was the site of a microplastic risk assessment that was carried out using the percentage distribution of microplastic polymer types gathered at each sample station and hazard scores from an earlier study on plastic polymers [26]. High hazard ratings, which indicate a significant danger, were found for PVC in the research area. Marine animals may die as a result of PVC's release of inherent plasticizers and carcinogenic monomers into the environment [27]. Furthermore, pollutants such as persistent organic pollutants, also known as POPs, can be readily absorbed by PVC's surface, which might have complicated harmful effects [28]. Microplastics appear to be able to absorb heavy metals and POPs in marine ecosystems [15]. There was a trace of zinc bound to microplastics in a sample taken from the Nordic Sea in Greenland [16]. Fish exposed to dangerous substances through plastics may have hepatic stress and endocrine function changes [29, 30]. Coral reefs are highly susceptible to the combined effects of microplastics and pollution [31]. Sigma7PAE concentrations in zooplankton have been found in high quantities in the Mediterranean waters of France [31].

Plastics' toxicity is determined by their shape in addition to their harmful chemical content and makeup. Microplastics that accumulate as fibers are more hazardous than those that do so in the form of pieces or microbeads, according to research on the biological accumulation and toxicity of microplastics consumed by fish [33]. Furthermore, high concentrations of organic compounds are absorbed by old plastics in the shape of pellets [34].

#### **5. AFFECT OF CHANGE IN CLIMATE ON MICROPLASTICS**

The escalating atmospheric temperatures linked to climate change contribute to a range of extreme weather events, encompassing glacier thawing, strong winds, intensified thunderstorms, prolonged droughts, and heightened rainfall. As glaciers thaw, microplastics previously trapped in the ice are released into the sea, carried by ocean currents across extensive distances [35]. Elevated rainfall, coastal flooding, and rising sea levels lead to the displacement of plastic debris and microplastics from shorelines into water bodies. The alterations in wind patterns and ocean currents induced by climate change pose challenges in predicting the ultimate dispersion of microplastics. Extreme weather events like floods and storms can disseminate microplastics to previously unpolluted areas, impacting both aquatic and terrestrial environments [36, 37]. Microplastics' ecotoxicological

effects in the environment are made worse by climate change, which highlights the necessity for a thorough understanding of the relationships between different climate parameters and microplastic fate.

## **6. NONWOVEN FILTRATION**

The use of fibrous filter media has been demonstrated as an effective technique for fluid purification [38,39]. These filter media can be constructed either as woven or nonwoven materials [40,41]. Nonwoven materials are made of a cross-section of randomly arranged threads with linked pores. High filtration effectiveness, more porosity per unit area, effective cake discharge features, low cost, and simplicity of manufacture are the characteristics of nonwoven filter media [42]. Typically, nonwoven media can effectively remove particles within the size range of 1–1000 nm. Various types of nonwovens, such as needle-punched, wet-spun, spun-laced, electrospun, and melt-blown, find applications in industrial filtration processes related to food and beverage, pharmaceuticals, oils, solvents, biotech, water, acids, and bases [43–45]. Among these nonwovens, nano-fibrous webs, typically produced through electrospinning or melt spinning, exhibit notable advantages and potential in filtration.

Several mechanisms, including sieving, interception, impaction, and diffusion, contribute to particle capture in nonwoven materials [45–49]. The fibrous material's porous structure plays a major role in particle retention. The distribution of pore size throughout the nonwoven structure is therefore one of the most important elements in filter construction. Pore distribution can be impacted by a number of material and structural factors, including fiber diameter, mass density, and needle density. Optimizing filter design requires an understanding of these parameters' roles in filtration.

## **7. NONWOVEN ELECTROSPUN FILTERS**

Nanofiber membranes excel over conventional counterparts in large surface area, selectivity, mechanical stability, hydrophilicity, and resistance to water flow [50]. The electrospinning technique, widely employed in recent decades, proves versatile and effective in producing nanofiber membranes. What makes this technique intriguing is its capability to create nanofiber membranes of varying sizes and shapes with porous characteristics, suitable for purifying water from diverse sources like sewage effluent, surface water, and drinking water. These membranes' high porosity is beneficial for pressure-driven membrane filtration procedures including reverse osmosis, ultrafiltration, nanofiltration, and microfiltration since it lowers the energy required for filtration considerably [51, 52, 53].

Moreover, the large specific surface area of electrospun membranes provides additional adsorption sites, making them effective adsorbents for capturing pollutants [54]. These membranes have proven effective in removing small particulate matter, such as  $< 10\ \mu\text{m}$ ,  $< 2.5\ \mu\text{m}$ , and  $< 1\ \mu\text{m}$ , leveraging their size exclusion mechanism [55]. Given

the success of electrospun nanofiber membranes in various applications, they emerge as a promising solution for the environmental remediation community in addressing microplastics removal. Despite limited research on this specific application, a few studies, including one conducted by Wang et al., have explored the removal of microplastics using electrospun nanofiber membranes [56]. Microplastics are removed in a manner that is quite similar to that of conventional membranes: the membrane collects suspended microplastics while permitting water to flow through. The positively charged membrane has an efficiency of about 90% in extracting nanoplastics with a particle size of 50 nm from wastewater. Microplastics of different sizes can be efficiently captured. It also has minimal fouling susceptibility and high flux. However, because of pore obstruction and cake formation brought on by the high retention rate of the nanofiber membrane as it absorbs microplastics, the throughput of permeate may be reduced.

## 8. CONCLUSION

In conclusion, the application of nonwoven electrospun filters emerges as a promising and effective strategy in addressing the pervasive issue of microplastic pollution in water sources. The unique characteristics of nanofiber membranes, including high surface area, small pore size, and porosity, contribute to their exceptional efficiency in capturing microplastics through physical barriers, electrostatic interactions, and adsorption mechanisms. The scalability and cost-effectiveness of the electrospinning process further enhance the viability of this technology for large-scale implementation in wastewater treatment. However, challenges such as potential permeate throughput reduction and environmental considerations necessitate ongoing research and optimization efforts. As we navigate the complex landscape of microplastic contamination, the development and utilization of nonwoven electrospun filters represent a significant stride towards achieving cleaner and healthier water ecosystems, highlighting the importance of continued collaboration among researchers, engineers, and policymakers in addressing this global environmental concern.

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# ACCESSING CLEAN WATER THROUGHOUT AGES

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## **Abstract**

*Water, one of the indispensable resources of human life, carries vital importance for all organisms. Throughout history, humans have been able to survive in regions where water exists. Even today, the lands irrigated by the Tigris and Euphrates rivers, which originate in our country and flow into the Persian Gulf, including Anatolia and Mesopotamia, as well as the lands irrigated by the Yellow River in Asia and the Nile in Egypt, have been the lands where world civilizations began and developed.*

*However, the "scarce Water Resources" on Earth are still limited and restricted. Increasing population density, rapid technological changes, and the resulting increased consumption increase the global demand for fresh water, while climate change and environmental degradation also lead to loss of water quality. The problems arising under these conditions sometimes lead to conflicts and sometimes to wars extending to the loss of countries.*

*How did the civilizations that developed in history solve this problem in their life processes? For example, in the 2nd millennium BC, how did the Great Hittite Empire, which started from the Kızılırmak basin in Anatolia and extended to Syria and Egypt, resolve the water problem? How did they transport water to the capital, Hattusa, located much higher than the plain, and ensure the quality and safety of the water?*

*In short, water has always been important in history, and the first engineering applications have also developed in this field.*

**Keywords:** Clean water, water scarcity, quality

# INVESTIGATION OF EXTREME WEATHER EVENTS: ANTALYA INTERNATIONAL AIRPORT EXAMPLE

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## ABSTRACT

*Although extreme weather conditions occur rarely, they can lead to significant loss of life and property when they do occur. Besides the financial burden that countries face during these events, human lives are also at stake. Looking at the frequency of occurrences globally, temperatures have risen by more than 1,3°C compared to pre-industrial levels, altering the balance of the hydrosphere, biosphere, lithosphere, cryosphere, atmosphere, and consequently, climate cycles. This changing equilibrium has resulted in an increase in the frequency and intensity of extreme weather conditions. The shift in balances has posed challenges, particularly exacerbating certain difficulties for the aviation sector, which has continued to grow post-pandemic, including delays, diversions, and flight cancellations. Flight safety is the foremost and non-negotiable issue in aviation. In this study, Antalya International Airport was selected as the study area, and the data analyzed consisted of METAR and SPECI observations published by the Turkish State Meteorological Service (MGM) covering a 15-year period from 2008 to 2022. The analysis of the observations revealed that 122 days experienced extreme weather events. Of these events, 94 were thunderstorms with heavy rain (+TSRA), 22 were showers with heavy rain (+SHRA), 5 were thunderstorms with hail and heavy rain (+TSGRRA), and 1 was a thunderstorm with hail (+TSGR). Since radiosonde observations were not conducted in Antalya, the damage in the region was examined through news reports and observations obtained from Turkish Meteorological Service.*

**Keywords:** Extreme weather conditions, climate change, Antalya International Airport

## **CLOSING SESSION+CONTRIBUTIONS BY STUDENTS CLUBS**

**Görkam KAYA:** Director of Industrial Engineering and Engineering Faculty Community Student Club

The vision of the club, especially its working goals on guiding them in their careers in the industry was mentioned. It was stated that there was a work calendar for the second term and that many different events were planned. It was announced that these events included conferences, training programs, technical trips and social responsibility projects. It was emphasized that the Industry 4.0 Summit was being organized and that this summit was a sustainable event. It was stated that there would be participation from major companies such as Ford, Renault and Mercedes at the summit.

**Vision Ahi:** Head of Sustainability and Environment Club

He is the President and Vice President of the Sustainability and Environment Club. The Environment and Sustainability Club was established in 2019 and many different projects were implemented during this period. It was also announced that European Union projects were being worked on and development projects were being carried out in Africa. It was stated that documentaries were on environmental education in Africa and these documentaries were being presented to the European Union. It was emphasized that many events were being organized together with other clubs in IAU and the faculty members were thanked for all their support. At the end of the closing session, the Student Club Representative and Conference Chair thanked all participants' speakers who made it possible to come together during this conference both online and in face-to-face sessions. The Chair thanked everyone who contributed to the Organization Committee and the participants separately, wishing that the information presented and the discussions held would be useful, and ended the meeting with the wish to come together at the second conference planned to be held in Uzbekistan.

## 1st. International Hybrid Conference

### Role of Climate Change on Water Resources Management for a Sustainable Future (ICCW2024)

Water scarcity has incrementally exacerbated in many parts of the world due to climate changes compounded by population growth, overexploitation of freshwater resources, and a lack of proper management. This upsurge has sparked worldwide interest in understanding the potential impacts of climate change on water resources. Climate change is often entwined with alterations in both water quantity and quality, aggravating the fast-growing water crisis. In envisioning a sustainable future, the capability of adapting to climate change and ensuring the sustainable management of water resources and urban planning, reflecting the urgent need for resilience and responsible stewardship in a world where water scarcity and unpredictability are increasingly prevalent are among the important aspects to consider. Investments in resilient infrastructure, such as flood defences and improved irrigation systems, are essential to cope with changing climate conditions.

Utilizing advanced technology for data collection, analysis, and modelling can help anticipate and respond to challenges related to water resources. Governments and regulatory bodies need to develop and enforce policies that ensure equitable access to water resources and sustainable management practices. Collaborative approaches to water management, including the sharing of water resources across regions and countries, can enhance resilience in the face of changing climate patterns. Furthermore, precise definitions of regional and global action plans for climate change need to be considered.

The ICCW2024 conference aims to be a step towards bringing together scientists, planners, practitioners, and researchers to discuss recent issues and those expected to emerge in the future before the problems become too perplexing to solve for a sustainable future on this globe. Following table shows some numbers on papers and authors.

**Table- Details on Conference Papers**

COUNTRY	No of Paper	No of Chairs	No of Authors
Algeria	1	—	1
Azerbaijan	1	1	1
France	2	1	2
India	3	—	3
Pakistan	6	1	16
Türkiye	18	6	55
Tunisia	1	1	2
USA	2	—	3
Total	34	10	83

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