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GUEST EDITORIAL

Adaptive Water Resources Management Under Climate Change: An Introduction

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Readers of this journal are well aware of the challenges of managing one of our planet's most critical natural resources: water. We professionals, the people we serve, and indeed the entire world's population, depend on this resource, not only to stay alive and maintain our health and productivity, but also to sustain our economies, the quality of our environment and the biodiversity of our natural ecosystems. The quantity and quality of water that we manage as well as the goals we are trying to achieve while managing this resource changes and the extent of those changes is often unpredictable. Managing water is both complicated and complex and to do it requires us to constantly acquire, evaluate, and apply the latest engineering and scientific knowledge, as applicable. It also requires our ability to understand and work within a social and political environment in which water resource management decisions, whether at local, regional, or global scales, are made.

Although managing water in this changing and uncertain physical and social environment is not sufficiently challenging enough, we are now having to deal with the impacts of a changing climate.

Our climate is getting hotter. The Earth is now about 1.1°C warmer than it was in the late 1800s. The last decade (2011–2020) was the warmest on record. The last year was the warmest on record. Without a substantial reduction in greenhouse gas concentrations – currently at their highest levels in 2 million years – our climate is only going to get hotter. Dry areas will get drier and wet areas wetter. There will be an increase in the unpredictability of water flows, linked to more frequent and extreme weather events and temporal and spatial shifts in rainfall patterns resulting in more intense floods and droughts, severe forest fires, rising sea levels, flooding, melting polar ice, catastrophic storms and declining biodiversity.

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The overall effect will be to exacerbate risk and vulnerability, threatening, if not directly at least indirectly, the livelihoods, health and security of all of us.

It is obvious that temperature rise is only the beginning of the story. Because the Earth is a system, where everything is connected, changes in one area can influence changes in all others. People are experiencing climate change in diverse ways.

Climate change is affecting our health, our ability to grow food, produce energy, and provide safe housing along rivers and coasts. Conditions like sea-level rise and saltwater intrusion have advanced to the point where whole communities have had to relocate, and protracted droughts are putting people at risk of famine. In the future, the number of "climate refugees" is surely going to increase.

Arguably, the changes we are observing in our climate are mostly felt because of their adverse impacts on the quantity and quality of our water resources. How best to adapt to and mitigate against this increasing threat of having too much, or too little, or too polluted water and the accompanying adverse impacts is the major issue confronting water managers. To address this issue requires innovative adaptive approaches to water management, focusing on understanding, monitoring, and managing not only the water resources themselves but also the interactions among the various physical and social system components whose benefits and performance are dependent on and influenced by water resources and how they are managed.

This Special Issue offers some suggestions and examples of how to address this challenge. It contains the current thoughts, perspectives and insights, and modelling approaches of the contributing authors on just how we might address, at least in part, these complicated and complex challenges resulting from climate change. Its aim is to contribute to the dialogue on how we water resource managers can more effectively and sustainably manage water in the face of anticipated changes in the hydrological cycle and their economic, ecologic, environmental, and social consequences. Researchers addressing these issues typically refer to relevant historical data. But we have no historical data of future events. What all of us do know is that the data we have on how the climate and its impacts have been changing are non-stationary. Existing statistical approaches for generating insights from time-series data obtained in the past are not very suitable for predicting statistical measures of the future. We need new methods of analysis and prediction. Journals such as this one, and the collection of papers in special issues such as this one, are among the forums where proposed new approaches to meet this challenge can be presented, debated, applied, and evaluated.

This Special Issue aims to contribute to the discussion of the identification and quantification of climate change impacts on various water resource systems and thus to aspects of our lives that water serves. Papers in this Special Issue identify and discuss effective water resources management practices that are adaptive to the changing conditions over time. In addition, this Special Issue presents the results of research on water management institutions and issues of governance that are needed in this political decision-making environment.

This Special Issue is being published at a time when there is wide agreement among international organizations that integrated and adaptive water resources management is a key to meeting water-related targets or goals related to the reduction of times when, and places where, water is either too much, too little, or too polluted. Global assessments of the progress toward meeting established targets or goals made by governments worldwide prove that actual progress is still behind that needed to meet these established targets. This can be seen in studies contained in this issue showing that the water security targets and water-related Sustainable Development Goals (SDGs) are far from being achieved in many regions of the world.

One of our colleagues who devoted much her professional life to these challenges and how they may be addressed, especially in Turkey, was Nilgun Harmancioglu. This Special Issue is dedicated to her memory. Before her premature death, Nilgun Harmancioglu lead the water resource systems engineering program at Dokuz Eylul University in Izmir, Turkey. Her interests and contributions spanned almost every aspect of watershed and water resources planning and management. With her associates she applied her knowledge of hydrology, hydraulics, and environmental and systems engineering to water management and policy issues in an effort to improve the existing water management practices in many river basins. Some of her last published papers and congress presentations focused on issues of sustainability, integrated water resources management, global water resources security and water-related Sustainable Development Goals.

In addition to her successful research and teaching, Nilgun Harmancioglu undertook many activities that contributed to the successful growth and recognition that this journal and its sponsoring association has experienced. She served as an active member of the Executive Committee of the European Water Resources Association (EWRA) and member of the Editorial board of this journal for many years. Among others, Nilgun organised the very successful 9th World Congress of EWRA in Istanbul in June 2015.

Closing this brief introduction of this Special Issue on “Adaptive Water Resources Management under Climate Change”, we would like to briefly review the contributions accepted for this issue.

Loucks (2022) in his article «Meeting Climate Change Challenges: Searching for more Adaptive and Innovative Decisions» refers to the decision support systems which are now needed to address and analyse possible decisions that may help all of us adapt to, and mitigate the adverse impacts caused by, a changing climate. In fact, the article considers what might be done to assist decision makers improve the decisions in the post-analysis stages of decision-making processes. Finally, the article presents a case study for illustrating how these methods can help enable more adaptive and innovative planning and management decisions.

Hjorth and Madani (2023) in their contribution «Adaptive Water Management: On the Need for Using the Post-WWII Science in Water Governance» pointed out that although the UN concluded in 1997, that water would be the most contentious issue of the 21st century, water governance is still confused, nearly everywhere. Also, although the global community has adopted sustainable development as a common vision and guide for the future, the adoption of the underlying principles of sustainable development has been slow in the various sectors including the water sector. The paper presents a historical overview for the period after the Second World War (WWII), of events that have had an impact on water management frameworks. The authors argue that water resources management is still based on century-old, technocratic, and instrumental methodologies that fail to take advantage of recent important scientific advancements in the fields of science, policy, and management and remain unable to properly deal with real-world complexities and uncertainties such as those resulting from climatic change.

Cunha (2023) in her article «Water and Environmental Systems Management under Uncertainty: from Scenario Construction to Robust Solutions and Adaptation» deals with strategies, plans, and actions to achieve sustainable development of water and environmental systems in a context of uncertainty, granted that the complexity of such systems incorporates both human and natural landscapes and their interactions. The author argues that future decisions will benefit by being informed using comprehensive decision frameworks involving multiple processes (institutional, political, social, economic, biophysical, etc.) and that policy makers and society in general, especially knowledge producing centres, need to shift from rhetoric to intervention, to tackle the many changing tendencies of today.

Noto et al. (2022) in their paper «Climate change in the Mediterranean Basin: induced alterations on climate forcings and hydrological processes» (Part I) aim at reviewing the main observed and predicted effects of climate change on hydrological processes directly related to the water availability in the Mediterranean Basin. The in-depth discussion about possible future water scarcity problem in the Mediterranean area and the sources of uncertainty affecting future climate projections and impact assessments is presented in the second paper of the authors. In the first paper their study highlights how most of the recent studies for the Mediterranean region are concordant and recognize a general increasing future trajectory in both the mean and extreme values of air temperatures. They also conclude that on the contrary, there is much less agreement about the intensity and directions of future projections for the other variables of the hydrological cycle. The second paper «Climate change in the Mediterranean Basin (Part II): a review of challenges and uncertainties in climate change modelling and impact analyses» by Noto et al. (2023) focuses on the problem of water availability and water scarcity. It also discusses the most relevant sources of uncertainty related to climate change with the aim to gain awareness of climate change impact studies interpretation and reliability.

Yang et al. (2022) in their contribution «Multi-objective optimisation framework for assessment of trade-offs between benefits and co-benefits of Nature-Based Solutions» mention that the increasing uncertainty of urbanization and climate change has prompted authorities and stakeholders to realise the importance of sustainable solutions. They argue that nature-based solutions have gradually become an alternative to sustainable solutions as they are more ecosystem-friendly. The NBS aim is to enhance the natural water storage capacity to reduce urban floods by promoting the urban hydrological cycle processes. The main aim of their paper is to establish a framework to optimise the effectiveness of NBS on flood risk reduction and the co-benefits as well as to define the trade-offs among these co-benefits. The proposed framework combines the use of 1D-hydrodynamic models with multi-objective optimisation algorithms. In a case study they examined four measures: the green roof, the permeable pavement, the bio-retention ponds and the open detention basins.

The paper «Application of a distributed hydrologic model to assess the impact of climate and land-use change on surface runoff from a small urbanizing watershed» by Sabitha et al. (2022) describes the impact of future land-use and climate change on the surface hydrology of a watershed using an event-based hydrological model. An Artificial Neural Network (ANN) model and Monte-Carlo Cellular Automata (CA) were used to generate future land-use scenarios of an urbanising watershed. Then simulations were performed using a hydrological model to assess the expected changes in runoff. In the case studied they concluded that in the worst case, considering the combined effect of climate and land use changes, significant increases of the peak flood discharge and small decreases of the time to peak will be expected in the next several decades.

Elnashar and Elyamany (2022a, b) in the paper «Adapting Irrigation Strategies to Mitigate Climate Change Impacts: A Value Engineering Approach» accept the fact that climate change will increase water demand and decrease crop yields. This paper proposes a framework for selecting the most efficient irrigation strategy to mitigate the impacts of climate change and achieve food security. Value engineering methodology is used together with the life cycle cost technique to provide the optimum irrigation strategy from an economic perspective.

Rossi and Peres (2023) in their article «Climatic and other global changes as current challenges in improving water systems management: lessons from the case of Italy» point out that the issue of climate change pushes us to tackle the expected risks in the water sector through a comprehensive revision of the existing paradigms. Based on the evolution of these paradigms in Italy, the authors discuss the main characteristics of an adaptive approach to climate change and other global changes as they impact water infrastructures, legislative and institutional frameworks. They claim that the objective of adaptation strategies is the increase of resilience of water systems, emphasizing the capability of reducing both physical and socio-political vulnerability, improving the governance of water services.

In their paper entitled «Updating IDF Curves under Climate Change: Impact on Rainfall2 induced Runoff in Urban Basins» Kourtis et al. (2022) presented the development of new IDF curves by considering future climate projections and predicted the impact of climate change on rainfall induced runoff in urban drainage networks. The IDF curves were developed based on 1-hour annual maxima series, using the Generalized Extreme Value and Gumbel distributions. The climate change impact on the urban drainage networks was assessed based on future IDF curves by employing the Storm Water Management Model. The results revealed that by the year 2100, rainfall intensities of 1-hour duration are projected to increase under the mean climate scenario for all return periods examined. Finally, the predicted urban runoff presented significant variability depending on the selected future climate scenario.

Elnashar and Elyamany (2022a, b) in the paper «Managing Risks of Climate Change on Irrigation Water in Arid Regions», propose a systematic approach to identify, analyse, and respond to the risks of climate change on irrigation water in arid regions using a Risk Management process. The compound effect of risks was analysed using Monte Carlo simulation, which indicated a 69% loss in crop production due to climate change at a 90% confidence level. The proposed responses to the risks of climate change include strategies to avoid, transfer, mitigate, and/or accept these risks. The study argues for adopting a well-recognised risk management methodology in climate change studies, for quantifying the compound effect of climate change risks on irrigation water in arid regions, and for recommending response strategies to help policymakers mitigate the harmful effects of climate change on irrigation water.

Moradian al. (2022) in their paper «Future Changes in Precipitation over Northern Europe Based on a Multi-model Ensemble from CMIP6: Focus on Tana River Basin» analysed the performance of a CMIP6 (Climate Model Intercomparison Project Phase 6) multi-model ensemble for Northern Europe precipitation data. First, they evaluated the overall performance of 12 CMIP6 models from GCMs in 30 years of 1985–2014. Then, future projections were analysed between 2071 and 2100 using SSP1-2.6 and SSP5-8.5 (Shared Socioeconomic Pathways). Finally, the simulations were statistically improved using an ensemble method to correct the systematic error of the CMIP6 models and then the capacity of postprocessed data to reproduce historical trends of climate events was investigated. The results of the study, based on Tana river basin, show that different CMIP6 models do not have the same accuracy in estimating precipitation. They concluded that the ensemble method can be effective in increasing the accuracy of the projections.

Fiorillo et al. (2022) in their article «Drainage Systems Optimization under Climate Change Scenarios» point out that the increasing frequency of extreme rainstorms due to climate change calls for cost-effective methodologies to optimize drainage networks and flood risk mitigation practices. The paper presents a methodology which combines two well-known methods to optimize the drainage network design. The methodology uses the Harmony Search algorithm to identify the best design for the drainage network and the simulations obtained through the Storm Water Management Model. The proposed methodology is able to identify the optimum allocation and volumes of detention ponds for runoff control for various rainfall regimes. The methodology is able to indicate how to prevent floods by decreasing the channel filling rates.

The paper «A Non-stationary based Approach to Understand the Propagation of Meteorological to Agricultural Droughts» by Das et al. (2022) points out that agricultural droughts significantly affect the socio-economic sectors in the agrarian countries. In an application in India they study the time to propagation from meteorological to agricultural drought using drought indices incorporating large-scale climatic oscillations and regional hydro-meteorological variables. The time to propagation is calculated based on three different approaches. In addition, the internal characteristics of agricultural drought development are computed. They reach significant results concerning the time of propagation, the internal drought development and recover periods that can be used mainly to guide future early warning and monitoring systems for agricultural drought at the regional level.

Bai et al. (2022) in their article «Impact of climate change on water transfer scale of inter-basin water diversion project» present a systematic approach for runoff prediction, impact analysis, and risk assessment under climate change. An integrated hydrological model was used incorporating single and multi-objective reservoir operations, and risk assessments of multiple schemes. The inter-basin water diversion project from Hanjiang to Weihe River was used as a case study. Three main results were (a) the negative impacts of climate change on water transfer, net power generation, and the transformation ratio between them are quantified, (b) the difference in water transfer scale between single-objective and multi-objective caused by climate change is analysed, (c) scheduling schemes are recommended balancing benefits and risks and coping strategies to help policymakers mitigate the effects of climate change.

Garrote et al. (2023) in their article «Effectiveness of Adaptive Operating Rules for Reservoirs» proposed a methodological tool for developing an adaptive decision support system for reservoir management. The system is based on an optimisation model that determines operating rules that meet certain optimality conditions based on the state of the reservoir at a certain time and on a streamflow forecast. The proposed model is based on an earlier developed methodology to specify static operating rules for reservoir systems. The proposed methodology is modifying this optimisation procedure to dynamically update operating rules to adapt management to the changing conditions. The methodology was applied to the Pisuerga-Carrión reservoir system in the Spanish part of the Duero basin. The adaptive rules were found to lead to better operating results, particularly if successful streamflow forecasts are available.

The contribution of Sadeghi et al. (2022) is entitled «Systemic Management of Water Resources with Environmental and Climate Change Considerations». In the study presented, water supply and demand in five sub-basins of Aras River (Iran) were investigated using the WEAP MABIA model. Four separate scenarios, including a reference scenario (S1), the reference scenario with a priority of meeting environmental demands (S2), and climate scenarios (S3, S4) under general circulation models (GCMs) based on the IPCC Sixth Assessment Report (AR6) were produced for the near (2021–2040), middle (2041–2060), and far (2061–2080) future periods. They came to important conclusions for the decision makers of the future, emphasizing the water stress under some scenarios caused or accelerated by climate change.

Mikaeili and Shourian (2022) in «Assessment of the Analytic and Hydrologic Methods in Separation of Watershed Response to Climate and Land Use Changes» investigate separately the influence of climate and land use changes in the streamflow. Three methods including a hydrological sensitivity procedure, the slope change ratio of cumulative quantity, and the hydrological SWAT model were used. Minab River in southern Iran served as the case study. Nine scenarios were defined for the development of agricultural land and urbanisation to evaluate the effect of climate change and human activities using the SWAT model. The scenario that includes the development of agricultural land and urbanization by 30% compared to the present situation is expected to reduce the streamflow by about 90% which is the highest reduction among the analysed scenarios. Also, the results indicate that human activities are the main reason for the expected streamflow reduction.

Imteaz and Hossain (2022) in their paper «Climate Change Impacts on 'Seasonality Index' and its Potential Implications on Rainwater Savings» used the "Seasonality Index" which is based on historical rainfall data of each locality. The paper presented the expected changes in the future Seasonality Index values for the largest city of Australia (Sydney) based on projected future rainfall scenarios for the city. The paper further illustrated potential water savings through rainwater tanks under projected climate change scenarios using a daily water balance model.

In the paper «Reservoir Evaporation Forecasting based on Climate Change Scenarios using an Artificial Neural Network Model», Ahi et al. (2022) dealt with the process of evaporation under climate change and its effects on water resources. The study was carried out to estimate evaporation in the Karaidemir Reservoir in Turkey with artificial neural networks (ANNs). The daily meteorological data covering the irrigation season were provided for a 30-year reference period and used to develop artificial neural network models. Predicted meteorological data based on climate change projections of HadGEM2-ES and MPI-ESM-MR under the Representative Concentration Pathway (RCP) 4.5 and 8.5 future emissions scenarios between 2000 and 2098 were used for future 30 evaporation projections. Useful projections of surface water evaporation for the long term (2080–2098) were derived to inform those responsible for future water resources management.

Lyra and Loukas (2022) in their contribution «Simulation and Evaluation of Water Resources Management Scenarios under Climate Change for Adaptive Management of Coastal Agricultural Watersheds» analyse the impact of climate change on water resources management and groundwater quantity and quality in a coastal agricultural basin, in Greece (Almyros). Intensive groundwater abstractions for irrigation and nitrogen fertilization for crop production maximization, have caused a large water deficit, nitrate pollution, as well as seawater intrusion in the aquifer system. Multi-model climate projections for Representative Concentration Pathways (RCPs 4.5 and 8.5) from the Med-CORDEX database for precipitation and temperature have been used to evaluate the impacts of climate change on the study area. Simulation of coastal water resources was performed using an Integrated Modelling System (IMS) that integrates interconnected models for surface hydrology (UTHBAL), groundwater hydrology (MODFLOW), crop growth (REPIC), nitrate pollution (MT3DMS) and seawater intrusion (SEAWAT). Results show that combinations of deficit irrigation, rainfed cultivation schemes, with or without operation of reservoirs, could be applied to overcome the expected degradation of groundwater quality and quantity in the basin under study.

Gunacti et al. (2022) in «Evaluating Impact of Land use and Land Cover Change under Climate Change on the Lake Marmara System» studied the Marmara lake- Gediz river basin. The area is under threat, especially after the construction of a reservoir on upstream reach and the combined impacts of both climate and land use/cover changes (LULCC). The study investigated the environmental effects of these changes and used water balance modelling to help examine hydrologic conditions of the lake under climate change. The study evaluated future hydrologic conditions with RCP 8.5 climate change scenario, while combining future LULCC and water demand projections. These various pressures were incorporated into modelling scenarios for the state of the lake for the year of 2050. The study revealed that in all scenarios analysed the lake dries out and is incapable of maintaining the required water volume to sustain its wildlife and ecosystem. As a result, some new water allocation policies and strategies are essential for the survival of the lake and its ecosystem.

Booker and Snelder (2022) in their contribution «Climate Change and Local Anthropogenic Activities Have Altered River Flow Regimes Across Canterbury, New Zealand» focused on the flow regimes as influenced by the combined changes in climate and several local anthropogenic activities across Canterbury, New Zealand. Trends were assessed for a period that started immediately after a change in the regulatory regime in 1991 and ended in 2020, that coincided with increases in water abstraction and changes in water management practices. Trends in observed summer conditions indicated that rainfall was stable, temperature increased, and flows decreased for many sites during the assessed period. They concluded that changes in both climate and local activities have combined to alter flow regimes, suggesting that hydrological impacts of local activities should be considered alongside climate change when making river flow management decisions.

The impact of climate change on a river streamflow is the topic of the paper «Future Climate Change Impact on the Streamflow of Mahi River Basin under Different General Circulation Model Scenarios» by Maurya et al. (2023). In this case study (Mahi river basin, India) the authors examined bias corrected, statistically downscale models drawn from the NASA, Earth Exchange Global Daily Downscaled Projections - Coupled Model Intercomparison Project Phase 5 (NEX-GDDP-CMIP5) over the study region. The rainfall and temperature projection output from the INMCM-4, MRI-CGCM3 and their ensemble mean performed well over the basin. Useful results were derived for the annual average streamflow, the mean monthly streamflow in the rainy season and in the summer season.

The article «The Great Salt Lake Water Level is Becoming Less Resilient to Climate Change» by Hassan et al. (2022) pointed out that climate change and water diversions are putting the Great Salt Lake (GSL) at risk. Projections indicate a continued decrease in the water surface elevation (WSE) which would lead to several catastrophic consequences. The objectives of the study reported were to: (1) examine the impacts of historical drought and development on the GSL resilience and (2) determine future WSE resilience under a range of hydroclimate and development scenarios. The historical resilience was analysed considering three periods with different development conditions: (1) less developed (1901–1950); (2) moderately developed (1951–2000); (3) highly developed (2001–2020). The historical analysis showed a significant decline in resilience during the highly developed period compared with the moderately developed period. According to the results of the study future scenarios of climate change and development revealed that the mean surface water level for the 2021–2050 period may drop by 0.93 m, while the resilience may be reduced by 30%, and 38% using RCP4.5 and RCP8.5 scenarios when compared to the less and medium developed historical periods, respectively.

The paper by Lewis et al. (2023) « Business as Usual Versus Climate-responsive, Optimised Crop Plans - A Predictive Model for Irrigated Agriculture in Australia in 2060» is dealing with future water availability, crop water requirements, crop yields, market costs and returns of current crops in Australia under future climatic conditions. The work used predictive methods able to simultaneously consider many climate change models. The results showed that "business as usual", in terms of the quantity and types of crops that can be grown presently, will not be sustainable in the medium and long term future. Instead, changes in production and land use will be needed to adapt to future conditions and deliver climate smart agriculture.

The contribution of Bridhikitti et al. (2022) has the title «How do sustainable development-induced land use change and climate change affect water balance? A case study of the Mun River Basin, NE Thailand». The study has as main objective to investigate the effects of the climate and land-use changes on water balance by 2037, the end of the National Strategy (2018–2037), for the Mun River Basin, NE Thailand. The simulated climate dataset used ensemble means from IPCC AR5 Global Circulation Models for representative concentration pathway (RCP) 4.5 and 8.5 climate scenarios. The land-use change was simulated using the Dyna-CLUE (Conversion of Land Use and its Effects) model. The Soil and Water Assessment Tool (SWAT) was used to assess the water balance. According to the study for the sustainable development under the National Strategy (2018–2037) could be supported by soil-water conservation measures which are recommended.

Estrela-Segrelles et al. (2023) in their paper « » admit that the Mediterranean region is one of the most vulnerable regions of the world to climate change impacts. The risk of habitat loss and ecosystem damage is very high in Mediterranean rivers. In their study the authors used a risk assessment methodology that integrates indicators of hazard, exposure, and vulnerability. They also produced risk maps to prioritize the areas in which adaptation measures should be implemented for improving the adaptive capacity of ecosystems. The authors propose the restoration of the riverside vegetation as the main adaptation measure to reduce the stream temperature.

The contribution of Asif et al. (2023) has the title «Climate Change Impacts on Water Resources and Sustainable Water Management Strategies in North America». According to this paper water scarcity is increasing in many regions across North America because of climate change compounded by population growth, overexploitation of freshwater resources, and lack of proper management. The paper examined the climatic factors impacting the hydrological regime in North America, including changes in surface runoff, groundwater storage, and the forested watershed, based on current trends and future projection scenarios. The study proved that many areas of North America are exposed to extreme events such as prolonged droughts, devastating floods, wildfires, and altering precipitation patterns. Consequently, these changes are triggering wide-ranging impacts on water resources, leading to water supply deficiencies and influencing water flows and quality in the Southwestern United States, prairie provinces in Canada, and Mexico. In conclusion, an integrated water resource management approach is required, along with climate-induced innovative technologies, to secure the water resources in the future.

In «Integrated Water Resources Management in Cities: Global Challenges» Grison et al. (2023) argue that water scarcity and accessibility remain amongst the most prominent global challenges. The paper analyses the challenges of water, wastewater, municipal solid waste and climate change in 125 cities. The authors applied the City Blueprint Approach and developed a statistical model to estimate IWRM performances of additional 75 capitals reaching in total 200 cities which represent more than 95% of the global urban population. Based on these data, the existing gaps in achieving water-related Sustainable Development Goals (SDGs) were evaluated. The results show that most cities do not yet manage their water resources wisely and are far from achieving the SDGs. Challenges mainly regarding sanitation, solid waste management, climate adaptation, and people living in informal settlements are high in cities in Africa, Asia, and Latin America.

In the paper «Complex policy mixes are needed to cope with agricultural water demands under climate change» by Martinez-Valderrama et al. (2023) the authors argue that the forecast of the water gap (difference between agricultural water use and annual supply of water resources) will continue to widen, affecting the water security of a large part of the world's population. The increase in demand is attributed to both the growing population and the high-water consuming lifestyle. Also, climate change is increasing aridification and the spatio-temporal precipitation heterogeneity worldwide. The water gap will be particularly severe in drylands, where development and food security has been based on high exploitation of water resources. The authors analyse the mechanisms underlying this water gap, mainly of agricultural origin, and suggest suitable solutions for improvement. They point out that water consumption is growing exponentially. This explosive behaviour is explained by a series of mechanisms that need to be understood. For solving the water gap, they propose eight lines of action that can be combined and tailored to each territory. Results show that there is an urgent need to plan an integrated management of water resources to avoid water scarcity under future climatic conditions.

The paper «Climate Change Impacts on Water Balance Components/Blue and Green Water of Meki River Sub-basin» by Hordofa et al. (2023) analysed the spatiotemporal variations of blue and green water resources under baseline and future climate conditions by applying the SWAT+model to the Meki River, in Ethiopia. The SWAT+model was validated for the period from 1993 to 2000 and 1987 to 1992, respectively. The model was used to assess the effects of CC (representative concentrations pathways, RCP, 4.5 and 8.5) on the blue and green water components of the Meki River. It was found that blue water is expected to decrease under both RCPs (4.5 and 8.5) scenarios, but anticipated to show a more significant decline under the RCP 8.5 scenario. On the opposite, green water is expected to increase under both scenarios with RCP8.5 expected to cause the most significant increase when compared to the baseline.

Ramabrahmam et al. (2023) in their paper «Climate Change Impact on Water Resources of Tank Cascade Systems in the Godavari sub-basin, India» estimate the impact of climate change on future water availability in river basin scale in India. Maner river, one of the major tributaries of Godavari River, is taken as the case study. The study used RCM models from NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) namely

CCSM4, MPIESM-LR and MIROC-ESM-CHEM, for historic and future climate periods under RCP 4.5 and RCP 8.5 scenarios. The SWAT hydrological model was used to simulate runoff and water availability. Based on these procedures useful quantification of climate change impact was achieved for near, mid and far future for different scenarios in a rather complex hydrological system. They recommended that the expected excess inflow can be stored in artificial ponds downstream to improve groundwater recharge and to supply tail end tank command as an adaptation strategy to future conditions.

In the study «Evaluation climate change impacts on water resources over the upper reach of the Yellow River Basin» by Zhuang et al. (2023), a climate-streamflow modelling framework (CSF) was used to generate future climate projections and assess climate change impacts on water. The proposed CSF incorporated global climate models (GCMs), meteorological factors, and stepwise-clustered hydrological model. The proposed model was capable to transfer large scale climate variables from global climate models to high-resolution meteorological datasets and quantify the climate change impacts on streamflow by employing the stepwise cluster analysis method. The upper Yellow River basin was selected as the case study. Results showed: (i) an increasing trend of average temperature with the highest temperature increments in November; (ii) increasing precipitation with the increments that could reach more than 200 mm in July in 2030s; (iii) greater streamflow rates in most months except November. Finally future monthly streamflow could reach double rates in July and August compared with the historical flow rates.

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