Water Security and Climate Change Conference

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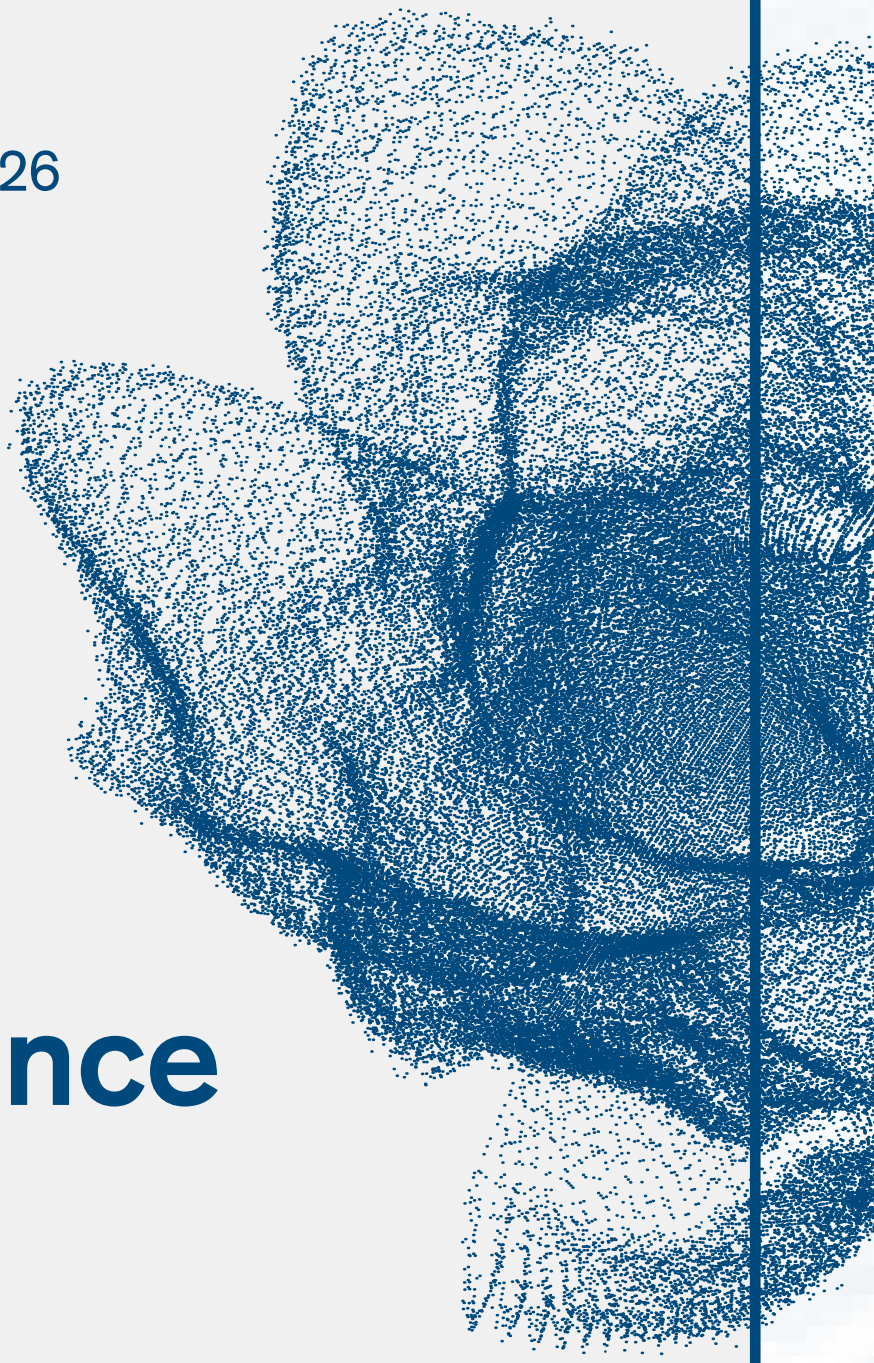
Giessen, Germany
06–08 October 2026



Conference Booklet

Rethinking Nexus Approaches in a Complex and Uncertain World

SDG nexus network · DAAD exceed Deutscher Akademischer Austauschdienst German Academic Exchange Service · Federal Ministry for Economic Cooperation and Development · CNRD Centers for Natural Resources and Development · University of Hohenheim · Technische Universität Braunschweig · AIT Asian Institute of Technology

Justus Liebig University Giessen
SDG[nexus] Network
Senckenbergstraße 3
D-35390 Gießen, Germany

T: +49 641 99 12701
F: +49 641 99 12709

http://www.sdgnexus.net
sdgnexus@zeu.uni-giessen.de

The SDG[nexus] Network and the WSCC2026 are funded by the German Academic Exchange Service (DAAD) from funds of the Federal Ministry for Economic Cooperation (BMZ) - (grant number 57753302), program “exceed - Hochschulexzellenz in der Entwicklungszusammenarbeit”

Version: 05.10.2026 16:24

Preface

Welcome to the 10th Water Security and Climate Change Conference (WSCC) — a decade of dialogue, exchange, and innovation at the interface of science, policy, and practice in addressing the world's most pressing water and resource challenges.

The challenges before us are no longer singular. Climate change, resource exploitation, environmental degradation, inadequate waste management, rapid urbanization, geopolitical instability, and deepening social inequalities interact, compound, and cascade. Water, energy, food, land, and ecosystems form a tightly coupled system. Decisions are never isolated. They resonate across sectors, scales, and generations.

In 2026, Central Europe has experienced a succession of dry summers, with river levels falling low enough to disrupt navigation, power generation, and affect aquatic ecosystems, while recurring heatwaves have exposed the vulnerability of cities, agriculture, and public health. What unfolds here in a comparatively resource-rich setting is felt far more acutely elsewhere — a reminder that water security is a shared concern demanding shared solutions.

Nexus approaches have become indispensable for making sense of these interdependencies and for managing the trade-offs and synergies they produce. Yet today's complexity calls for a critical rethinking of how nexus thinking is conceptualized and applied. Translating conceptual insight into operational management and effective governance remains a major hurdle.

The WSCC 2026 therefore explores three core topics: (1) Strengthening Water Security through Integrated Nexus Management; (2) Transdisciplinary Pathways for Governing the Nexus under Climate Change; and (3) Quantifying Interdependencies through Data and Modelling. This year's format has been designed to keep the community together and to turn discussion into results. Mornings are dedicated to shared plenary debates, complemented by lightning talks. The afternoons belong to the writeshops. The early evenings will conclude with poster sessions and our social framework program.

The WSCC is our invitation to you: a platform not only to present your work, but to co-create the next contribution with colleagues you may only meet here. Debate, disagree, write, and build something that lasts beyond these three days.

Welcome to Giessen!

On behalf of the Scientific Committee,

Dr. Björn Weeser

Managing Director
SDGnexus Network

WSCC 2026 - A Platform for Exchange

The SDG^{nexus} Network, the Centers for Natural Resources and Development (CNRD), the International Network on Sustainable Water Management in Developing Countries (SWINDON), the University of Hohenheim, and the Asian Institute of Technology (AIT) are pleased to invite the community of water and climate experts to the Water Security and Climate Change Conference (WSCC), 06 - 08 October 2026 to be held in Giessen, Germany.

Achieving water security under climate change conditions is one of the major challenges faced by society today – both globally and locally. By building bridges between disciplines, sectors and different stakeholders, the conference provides a platform for international exchange. Consequently, interdisciplinary links are revealed and synergies between scientific evidence and societal and political decisions are released. The conference thus contributes to the formulation of sustainable strategies for water resources management in the face of climate change.

The WSCC 2026 is supported by the exceed program (Higher Education Excellence in Development Cooperation) and follows a successful series of conferences implemented in Thailand, Germany, Kenya, Mexico, Vietnam, Ecuador, and Uzbekistan between 2016 and 2025.

Background

Climate change, exploitation of resources, environmental degradation, poor waste management, rapid urbanization, geopolitical instability, and growing social inequalities are deeply intertwined global challenges that constantly interact to amplify global risks. Together, these compounding and cascading crises place unprecedented strain on vital natural resources and the societal systems that depend on them.

Water, energy, food, land, and ecosystems are deeply interconnected. Decisions made in one sector inevitably generate cascading effects across others, spanning multiple spatial and temporal scales. Climate change puts additional strain, which leads to further complexities. In this context, nexus approaches have emerged as an essential framework for understanding these complex interdependencies and for managing the resulting trade-offs and synergies in an integrated, sustainable manner.

However, the complexity of today's dynamic world calls for a critical rethinking of how nexus approaches are conceptualized and applied. While nexus thinking has significantly advanced our understanding of interconnected resource systems, translating these theoretical insights into operational management and effective governance remains a major challenge. Technical interconnections alone are not enough to explain resource dynamics or guide sustainable solutions. Questions of inclusive governance, climate resilience, power relations, and the ability to accurately quantify and model these systems through robust data are equally crucial for shaping equitable outcomes. To respond effectively, there is an urgent need for approaches that are transdisciplinary, evidence-based, and grounded in both scientific rigor and societal realities.

The WSCC2026 provides a collaborative platform for researchers, practitioners, policymakers, and stakeholders to exchange perspectives on how nexus thinking must evolve to address current and future complexities. The conference aims to foster dialogue across disciplines and sectors, identify innovative analytical methods and governance strategies, and explore pathways toward more resilient, inclusive, and sustainable resource management. It invites participants to reflect on both the opportunities and practical limitations of nexus frameworks, and to discuss how they can support evidence-based decision-making and the transformative management of interconnected systems.

Topics

A: Strengthening Water Security through Integrated Nexus Management

Water security is increasingly recognized not as an isolated challenge, but as a critical outcome of complex, interconnected resource systems. While water is fundamental for sustaining life, agricultural and industrial production, and energy generation, the competing demands from these sectors, coupled with changing climate and land use and ecosystem degradation, place unprecedented pressure on water availability and quality. Yet, resource management practices often remain confined to sectoral silos, leading to operational inefficiencies, resource depletion, and unintended physical consequences across the nexus. These compounding pressures frequently unfold across diverse spatial scales and ecosystems, making traditional, single-sector management approaches insufficient to ensure long-term water security.

This conference topic focuses on integrated management strategies and operational solutions that actively safeguard water resources. It invites contributions that explore practical, conceptual, technological, and ecological approaches to balancing competing water demands while managing physical synergies and trade-offs across sectors. Relevant themes may include integrated resource planning, climate-resilient infrastructure, nature-based solutions for watershed protection, circular water-energy-food systems, and technological innovations to optimize water-use efficiency in agriculture, waste management and energy production.

The topic encourages participants to examine how operationalizing nexus-driven solutions can move beyond theoretical frameworks to actively enhance water security on the ground. It seeks insights into overcoming the practical challenges of integrated management, optimizing physical infrastructure, and translating nexus interdependencies into effective operational strategies and sustainable management practices in diverse geographic and environmental settings.

B: Transdisciplinary Pathways for Governing the Nexus under Climate Change

Resource management challenges are not only technical but deeply political and institutional - a reality increasingly amplified by the frequency and intensity of climate extremes. As droughts, floods, and heatwaves place unprecedented stress on interconnected resource systems, access to water, energy, food, land, and ecosystems is profoundly shaped by governance structures, power relations, institutional fragmentation, and unequal participation in decision-making processes. Navigating these compounding crises requires moving beyond traditional, top-down approaches to embrace collaborative problem-solving.

This conference topic addresses the governance dimensions of nexus thinking and explores transdisciplinary pathways for more resilient, inclusive, sustainable resource and waste management. It welcomes contributions on institutional coordination, multi-level governance, policy coherence, rights-based approaches, gender and social equity, and conflict and cooperation. Crucially, it highlights the need for transdisciplinarity by integrating scientific research with policy-making and local, indigenous, and traditional knowledge to co-produce actionable solutions. Attention is given to how governance systems can adapt to climate shocks, navigate deep uncertainty, and manage competing interests and cross-sectoral trade-offs under extreme conditions.

By focusing on inclusive governance and transdisciplinary action, this topic seeks to better understand how decision-making processes can support the equitable, transparent, and effective management of interconnected resources. Ultimately, it encourages participants to examine how robust institutional frameworks and collaborative pathways can overcome fragmentation and build societal resilience in an era of climate extremes and rapid transformation.

Topics

C: Quantifying Interdependencies through Data and Modelling

Understanding and managing complex resource interdependencies require robust analytical tools capable of capturing dynamic interactions across sectors, spatial scales, and time horizons. Data and modelling play a critical role in quantifying these connections, assessing cross-sectoral trade-offs, exploring future scenarios, and supporting evidence-based decision-making within nexus approaches. At the same time, significant challenges remain regarding data availability and integration, handling deep uncertainty, resolving scale mismatches, and effectively translating complex model outputs into actionable insights for policy and practice.

This conference topic focuses on quantitative and analytical approaches to decoding interconnected resource systems. It invites contributions that utilize data-driven and conceptual methodologies, integrated assessment models, system dynamics, spatial analysis, remote sensing, scenario development, digital tools, and advanced decision-support systems. Submissions should aim to quantify interdependencies across water, energy, food, land, and ecosystems, while integrating related compounding factors such as climate change, land-use dynamics, and health.

Ultimately, the topic aims to explore how cutting-edge advances in data and modelling such as AI and big-data can improve the rigorous analysis of resource interdependencies. It encourages participants to demonstrate how robust quantification can support strategic planning under uncertainty, bridge the gap between scientific modeling and real-world application, and provide a strong evidence base to inform integrated resource management and governance.

Agenda / Venue

Agenda

Time	Tuesday 06.10.2026	Wednesday 07.10.2026	Thursday 08.10.2026
09:00 - 10:30	Welcome Session & Group Formation	Plenary Talk 1	Plenary Talk 2
10:30 - 11:30	Coffee Break		
11:30 - 13:00	Lightning Talks Topic A	Lightning Talks Topic B	Lightning Talks Topic C
13:00 - 14:00	Lunch		
14:00 - 16:00	Writeshops A | B | C		
16:00 - 18:00	Poster Sessions		Closing Session
18:00 - 19:30	Networking & Ice Breaker	Video-Presentation	City Tour & Museum

Venue

Margarete-Bieber-Saal	Ludwigstraße 34, 35390 Giessen, Groundfloor
Rekotrenzimmer	Ludwigstraße 23, 35390 Giessen, 1. Floor
Senatssaal	Ludwigstraße 23, 35390 Giessen, 3. Floor
Gustav-Krüger-Saal	
S315	
Ludwigstr. 21	Ludwigstraße 21, 35390 Giessen, 1. Floor

General Sessions

Welcome Session

Date	06.10.2026
Time	09:00 - 10:30
Venue	Margarete-Bieber-Saal

Welcome to the Water Security and Climate Change Conference 2026! This Opening Session is the kick-off for our three days of collaboration, networking, and transdisciplinary dialogue.

To begin, representatives from the DAAD, the SDGnexus Network, and the WSCC Scientific Committee will deliver words of greeting, officially opening the conference and outlining our shared mission.

Directly following the welcome, we are thrilled to feature a special presentation of the book Water Security and Climate Change: Adaptation for Sustainable and Resilient Development. Born out of a previous WSCC, this publication stands as a testament to the tangible impact our community can create and serves as perfect inspiration for the work ahead.

Afterwards, the session will take a practical turn. We will walk you through the conference structure, giving you a clear roadmap of what to expect. Finally, we will introduce the unique format of our afternoon writeshops, explaining how we will transition from morning presentations into collaborative, goal-oriented think tanks designed to turn our shared expertise into actionable output.

This session is your starting point to meet the organizers, understand the flow of the event, and prepare for a interactive conference experience.

Welcome Adresse	Björn Weeser SDG^{nexus} Network Lars Gerold DAAD - German Academic Exchange Service		
Book Presentation	Mukand Babel Asian Institute of Technology (AIT)		
General Conference Information	Iuliia Horn SDG^{nexus} Network		
Introduction Writeshops	Lars Ribbe & Mukand Babel TH Köln & AIT	Andreas Haarstrick & Julia Gebert TU Braunschweig	Alejandro Pieters & Min Liu Universität Hohenheim & SDG^{nexus} Network

Closing Session

Date	08.10.2026
Time	16:00 - 18:00
Venue	Margarete-Bieber-Saal

As our three-day conference comes to a close, we will gather to reflect on the diverse insights and inspiring inputs of the past days. A major highlight of this final session will be the presentation of our Writeshop outcomes. The three working groups will share their collaboratively developed ideas and outlines for joint publications and policy briefs, showcasing how our discussions translate into real-world impact.

Following this academic wrap-up, we will transition into our social program. Participants are invited to unwind and conclude the conference with either a guided city tour or a visit to the historic Liebig Museum.

Plenary Sessions

General Description

The plenary sessions break away from the traditional solo keynote format to focus on dynamic cross-disciplinary debates about the trade-offs and synergies at the heart of Nexus research. Each plenary features two experts from different disciplines or regions. Guided by a moderator, the two experts will tackle a specific question, challenging each other's assumptions and exploring how their differing paradigms intersect. This format is designed to expose blind spots, bridge disciplinary divides, and set a highly engaging intellectual tone for the rest of the day.

Plenary Session I

Date	07.10.2026
Time	09:00 - 10:30
Venue	Margarete-Bieber-Saal
Moderation	Lars Ribbe

Efficiently translating scientific insights into policy, industrial innovation, and public action remains one of the most critical challenges of our time. Yet, a noticeable gap persists: researchers often feel that society and decision-makers overlook complex evidence or demand oversimplified answers, while representatives from administration, industry, politics, and civil society frequently find scientific knowledge too abstract, delayed, or misaligned with real-world decision-making timelines and demands. This panel discussion brings together key actors from both sides of the interface—academia on one hand, and policy, industry, and civil society on the other—to analyse the root causes of this structural disconnect. Rather than dwelling on past shortcomings, the debate aims to foster a vivid dialogue on systemic barriers, communication bottlenecks, and conflicting incentives. Ultimately, the session will focus on concrete solutions: How can we redesign the science-society interface so that demand is articulated clearly, evidence is delivered effectively, and actionable impact is achieved together?

Special Guests on Stage

Bert Dorste-Franke
Head of System Evaluation and Societal Sustainability
IQIB – Institut für qualifizierende Innovationsforschung und -beratung GmbH

Raffaele Vignola
Assistant Professor- Ecosystem-based adaptation planning and management
Wageningen University & Research

Plenary Session II

Date	08.10.2026
Time	09:00 - 10:30
Venue	Margarete-Bieber-Saal
Moderation	Julia Gebert & Andreas Haarstrick

This second Plenary Session focusses on the enablers and disablers of safeguarding water resources due to risks to ground- and surface water quality caused by contamination. Using the example of PFAS, this session examines the link between the high risks to human health and the environment, the enormous clean-up costs and their technical feasibility and, on the other hand, the effectiveness of the policy frameworks designed to reduce contaminant release. We discuss how risks could be effectively mitigated and which steps would be required to achieve this. How efficient are the decision-making processes and the implementation of effective measures, and what constructive role do stakeholders from the worlds of industry, science, politics and society play in this regard?

Special Guest on Stage

Heijo Scharff
Environmental consultant
Landfill.pro

Lightning Talks

General Description

The Lightning Talks are designed to showcase a wide breadth of cutting-edge research and innovative solutions in a condensed timeframe. Two rounds of four selected participants will take the stage in rapid succession, each given a strict five-minute limit to present the core of their work, a novel methodology, or a bold new idea. After each round of four presentations, the speakers will gather on stage for a joint Q&A session with the audience. This format strips away lengthy presentations to focus purely on the most impactful takeaways, maximizing the time spent on audience interaction, debate, and synthesis of the ideas presented.

Topic A

Operationalizing Water Security: From Circular Technologies to Nature-Based Nexus Solutions

Date	06.10.2026
Time	11:30 - 13:00
Venue	Margarete-Bieber-Saal
Moderation	Alejandro Pieters

Water security can no longer be achieved through isolated, single-sector management. To safeguard our resources against climate extremes and growing demand, we must move beyond theoretical frameworks and operationalize integrated solutions on the ground. This session explores practical, technological, and ecological strategies that actively balance competing water demands, manage physical trade-offs, and enhance resilience across the Water-Energy-Food-Ecosystem (WEFE) nexus. Spanning case studies from India, Uzbekistan, Bolivia, Ecuador, Brazil, Bangladesh, and Thailand, participants will be taken on a journey across different spatial scales of intervention. From AI-driven greywater recycling and the 'groundwater recharge paradox' to nature-based solutions and basin-scale modeling, this session showcases how to translate complex nexus interdependencies into actionable real-world strategies.

Presenters

Name	Title	ID
Ria Singhal	A Self-Operating Solar Greywater Recycling System: Edge-AI Automation for Decentralized Water–Energy–Food Security	124
Kustomo	Green Engineered Nanobiochar from Agricultural Biowaste for Sustainable Removal of Emerging Pollutants: A Circular Approach to Climate-Resilient Water Security	55
Svetlana Rajabova	Adoption of Water-Saving Irrigation and Sustainable Land Management Practices: Impacts on Farm Revenue in Uzbekistan	350
Ivan Alexis Chavez Flores	The Groundwater Recharge Paradox on Climate Change Adaptation in Peri-urban Agriculture in the Andean Valleys of Bolivia	496
Dalma Orellana-Peralta	Forest canopy and artificial shade buffer frost impacts on planted tree seedlings in tropical montane forest restoration	360
Jocimar Coutinho Rodrigues Junior	Nature-Based Solutions for Water Security and Climate Resilience: Integrating Land-Use Change, Ecosystem Services and Carbon Storage in a Tropical Coastal Zone	435
M Tauhid Ur Rahman	Operationalizing Nexus-Driven Water Security in Salinity-Affected Coastal Bangladesh through Nature-Based Solutions and Circular Water-Energy-Food Systems	268
Kaushal Chapagain	Water–Energy–Food Nexus under Climate and Land-Use Change: Evaluating Intervention Pathways for Synergies and Trade-offs in the Ping River Basin, Thailand	184

Lightning Talks

Topic B

Power, Institutions, and Inclusive Governance in the WEFE Nexus

Date	07.10.2026
Time	11:30 - 13:00
Venue	Margarete-Bieber-Saal
Moderation	Julia Gebert & Andreas Haarstrick

As climate extremes—from severe droughts to urban floods—place unprecedented stress on interconnected resource systems, it becomes clear that resource management is not merely a technical challenge, but a deeply political one. Access to water, energy, food, and land is profoundly shaped by governance structures, power relations, and institutional fragmentation. This session explores the governance dimensions of nexus thinking, moving beyond traditional top-down approaches to uncover transdisciplinary pathways for resilient, equitable, and inclusive resource management.

Presenters

Name	Title	ID
Erali Abdumajidov	Spatiotemporal analysis of extreme indices derived from daily precipitation and temperature for climate change detection over the Kashkadarya River Basin, Uzbekistan	439
Sandhya Babel	Mapping urban waterlogging susceptibility under climate change scenario using integrated PCA-XGBoost models and potential mitigation framework for Bangkok, Thailand	144
~~Resham Jung Singh~~	~~Building Climate-Resilient WASH Systems in Nepal: A Nexus Assessment of Climate Risks, Impacts, and Adaptation Gaps~~	~~335~~
Umme Ruman Siddiqi	Adaptive Governance under Climate Extremes, Transdisciplinary Pathways for Managing Cross-Sectoral Trade-offs in the Water-Energy-Food Nexus of Coastal Bangladesh	269
André Große-Stoltenberg	Diagnosing Water Security through Land-Use Change, Ecosystem Services, and Territorial Governance: A Multiscale Territorial Doughnut Approach in Montes de María, Colombia	208
Manuel Diaz	Linking Forms of Power with Actor-Centred Mechanisms in Polycentric Water Governance: Evidence from Mount Kilimanjaro	406
Zainab Oyetunde-Usman	Contesting livestock transition pathways: Neo-Gramscian analysis of power, institutions and environmental governance	487
Gabriela Morales Aguilar	Rethinking Water Security Beyond the State: Women's Autonomous Water Governance in a Groundwater-Depleted Basin of Central Mexico	198

Lightning Talks

Topic C

Decoding Resource Interdependencies: From Data to Robust Decisions in the WEFE Nexus

Date	08.10.2026
Time	11:30 - 13:00
Venue	Margarete-Bieber-Saal
Moderation	Lars Ribbe & Mukand Babel

Understanding and managing the complex interdependencies between water, energy, food, land, and ecosystems (the WEFE Nexus) is one of the greatest challenges of our time. As climate extremes intensify and human demands grow, how can we leverage cutting-edge data and modeling to move from observation to evidence-based action?

This session explores the quantitative and analytical tools necessary to decode these interconnected resource systems. We invite participants on a global journey—spanning the Atlantic Forest, the Andes, the Himalayas, and the Middle East—to demonstrate how robust quantification supports strategic planning under deep uncertainty.

Presenters

Name	Title	ID
Santiago Penedo	Monitoring and Modelling the Impacts of Different Land Uses on Fluvial Water Quality Focusing on Nitrogen in the Mata Atlântica: The Guapi-Macacu River Basin	49
Maria de Lourdes Florencio dos Santos	Hydroclimatic Drivers of Agricultural Water Demand in a Brazilian Semiarid Region: Insights from Water Footprint Assessment	391
Adriana Priscila Sumba Naula	Water Consumption Patterns and Their Drivers Across the Urban–Rural Continuum in the Ecuadorian Andes: A Machine Learning Approach	290
Archana Sathyan	Linking Surface Energy fluxes to Flash Drought and Terrestrial Water Storage Dynamics in the Humid Tropics	429
Qais Daraghma	Quantifying Groundwater-Vegetation Interdependencies under Drought Stress: An Integrated VHI-SWAT-SPI Approach in the Faria Catchment, Palestine	139
Diwakar Adhikari	Hydroclimatic Changes in the Marsyangdi River Basin, Central Himalaya under CMIP6 Scenarios: Implications for the Water–Energy–Food–Ecosystem Nexus	169
Arash Malekian	Quantifying Water–Land–Climate Interdependencies to Anticipate Policy Rebound: Coupled Scenario Modelling for Water Security in a Water Stressed Basin	336
Ella Steins	Robust decision-making for emergency water supply planning under parametric, structural, and deep uncertainty	461

Poster Sessions

General Description

The poster session is designed to serve as a central intellectual and networking forum. The session will commence on the main stage with brief, two-minute introductory presentations from each poster author. This format provides the audience with a comprehensive overview of the featured research, enabling attendees to strategically prioritize which posters they wish to visit. Following the on-stage introductions, presenters will transition to their posters, at which point the gallery will be opened to the audience. We invite attendees to enjoy refreshments, circulate through the exhibition, and engage in the collegial, one-on-one dialogues that foster genuine collaboration.

Day 1

Date	06.10.2026
Time	16:00 - 18:00
Venue	Margarete-Bieber-Saal (MBS) (Pitch-Talks) & Rektorenzimmer (Poster-Display)
Moderation	Andreas Haarstrick

Display	Name	Title	ID
1	Maria de Lourdes Florencio dos Santos	Integrating Water Quality Modeling and Multi-Criteria Decision Analysis for Climate-Resilient Watershed Management: A Case Study from Northeastern Brazil	397
2	Jocimar Coutinho Rodrigues Junior	Long-Term Assessment of Water Quality in the Ipojuca River Basin (Brazil) Using the Water Standards Compliance Index (WSCI)	437
3	Kehinde Oluseyi Olagunju	From Exposure to Impact: Estimating the Welfare Losses from Climate-Driven Water Shocks in Nigerian Agriculture	506
4	Kamalbek Karymshakov	Repeated Drought and Migration: Evidence from the Kyrgyz Republic	151
5	Solomon G Gebrehiwot	A Socio-hydrological systems analysis for social and ecological resilience in the East African Region	140
6	Sandhya Babel	Integrating PCA-GIS and Machine Learning to Predict Arsenic-Related Drinking-Water Security in Tube-wells, Thakurgaon District, Bangladesh	146
7	Julio Joaquín Álvarez Estrella	Does elevation-based training data selection improve Long Short-Term Memory streamflow predictions in mountain catchments?	233
8	Rustam Rakhmetov	Hidden Water Losses in Irrigation Systems: Remote Sensing Evidence and Economic Implications for Agricultural Water Use in Kazakhstan	453
9	Yanet Diaz Esteban	Impact of land-use change on discharge dynamics in tropical regions: a Machine Learning perspective	246
10	Gayathry Damarla	Satellite – Based Modelling of Agricultural Exposure, Recovery Recovery and Reslience to Floods and Droughts in Andhra Pradesh, India	476

Poster Session - Day 1

Display	Name	Title	ID
11	Nagashree Gowdajjagala Ekanthappa	Understanding the Drivers and Mechanisms of Water Scarcity through an Integrated Water–Energy–Food–Ecosystem Nexus Framework	361
12	Douglas Andrés Gómez Latorre	Morphometric characterization and multifractal analysis of the river basins of the Colombian Orinoquia using SRTM digital elevation models and automated geospatial processing	389
13	Ashutosh Singh	Menstrual Health at the Water–Health–Gender Nexus: Unequal Preparedness in Flood-Prone Bihar, India	460
14	Anam Munawwar	Bridging Governance Gaps for Climate-Resilient Resource Nexus Management in Pakistan: A Transdisciplinary Framework for Equitable and Adaptive Decision Making	180
15	Grigol Abramia	Integrated Ecological Management of Paliastomi Lake under Climate Change: Challenges, Water Security Implications, and Nexus-Based Solutions	18
16	Antonio Cardona Benavides	Quantifying Health-Driven Trade-Offs in Groundwater Monitoring: A Geostatistical Optimization Framework	316
17	Akshita Sharma	Governing Spring Systems Under Climate Uncertainty: Community Resilience and Water Security in the Indian Himalayas	79
18	Gerardine Djabou Dairou Epse Dama	Quantifying the Interdependencies Between Aging Infrastructure and Drinking Water Security: A Geospatial Modeling Approach in Nkongsamba, Cameroon	245
19	Camila Zamora Forero	Supporting Water Security through Forest Transformation: Quantifying Soil Water Availability in Climate-Adapted Forests	426
20	Aliya Assubayeva	Transdisciplinary research on water security in transboundary river basins	234

Poster Sessions

Day 2

Date	07.10.2026
Time	16:00 - 18:00
Venue	Margarete-Bieber-Saal (MBS) (Pitch-Talks) & Rektorenzimmer (Poster-Display)
Moderation	Alejandro Pieters

Displays

Display	Name	Title	ID
1	Maria de Lourdes Florencio dos Santos	Hydroclimatic Vulnerability of Rainfed Sugarcane Cultivation Across a Humid-to-Semiarid Gradient in Northeastern Brazil	398
2	Jocimar Coutinho Rodrigues Junior	Integrating Water Quality and Watershed Sustainability Assessments to Support Water Security in a Tropical River Basin	438
3	Kenneth Gutiérrez García	Integrating Water Quality and Watershed Sustainability Assessments to Support Water Security in a Tropical River Basin	330
4	Alicia Beatriz Correa Barahona	Quantifying Hydrological Functioning across Tropical Environments: From Observations to Integrated Assessments	475
5	Asha Verma	Empowering with Resource Nexus thinking: a learning pathway from open online learning to doctoral research	212
6	Asib Ahmed	A Comparative Machine Learning Assessment for Urban Flood Susceptibility Modeling and Future Flood Projections in Dhaka Metropolitan Area (DMA) of Bangladesh	302
7	William Alfonso Leon Rueda	Spatial Analysis of Climate Risk for Water Security in the Colombian Orinoco Basin	399
8	Mohsin Ullah	The Resilient Spring: Indigenous Stewardship, Water Security, and Landscape Governance among the Gujar Community in Swat Valley, Pakistan	494
9	Aditya Sharma	Earth Observation for Quantifying Water–Agriculture–Biodiversity Nexus Interdependencies in Climate-Vulnerable Landscapes of India	285
10	Antonio Cardona Benavides	From Network Design to Community Action: Operationalizing a Health-Driven Groundwater Monitoring Network Through Citizen Science in the Comarca Lagunera, Mexico	387
11	Rolando Célleri	Integrated Water Resources Management in the Southern Ecuadorian Andes: Addressing Emerging Water Challenges using the Nexus approach	474
12	Juan Pesántez	Natural Hydrogeochemical Constraints on Water Security in High-Andean Páramo Catchments	500
13	Muhammad Muzammil	Water Security Implications of the Indus Water Treaty Suspension: An Integrated Nexus Assessment	313

Poster Session - Day 2

Display	Name	Title	ID
14	María Inés Coronel Ordoñez	An Integrated Socio-Hydrological Framework for Urban Water Demand: Combining Machine Learning and Agent-Based Modelling	493
15	Kory Celeste Sánchez Gamarra	Designing for an Uncertain Climate: Hydrological Performance of Mine Cover Systems in the Peruvian Andes	323
16	Juan Carlos Cueva Orjuela	Developing Indicators of water security from Indigenous Knowledge perspective in the Amazon Indigenous communities	503
17	Abdulkhakim Salokhiddinov	Long-Term Streamflow Assessment in the Amu Darya Runoff Formation Zone Using Historical Hydrometric Records and Hydrological Analogy	228
18	Swatantra Kumar Dubey	Multi-Temporal Soil Moisture Prediction Using Google Earth Engine and XGBoost Machine Learning in the Kashkadarya Region, Uzbekistan	229
19	Aakash Kumar Subramaniyan	Assessing the impact of agricultural virtual water exports on water security in the Indian Indus River Basin (I-IRB): A Resource Nexus perspective on food-water-trade	371
20	Anil Aryal	Nexus governance in practice: a stakeholder-driven framework for groundwater sustainability in Barahathawa Municipality, Madhesh Province	306
21	M Tauhid Ur Rahman	Modelling Water-Energy-Food Nexus Interdependencies under Climate Uncertainty Using an Integrated AI, Remote Sensing, and System Dynamics Framework in Southwest Coastal Bangladesh	264

Writeshops

General Description

To move discussions into impact and strengthen collaboration within the nexus research community, the afternoons are dedicated to highly interactive, goal-oriented writeshops. The audience will be divided into three continuous working groups – each aligned with one of the core conference themes. Meeting every afternoon, these groups will serve as collaborative think tanks. Over the course of the three days, participants will brainstorm, debate, and synthesize their collective expertise with a clear, shared objective: gathering ideas and outlining a joint, high-impact publication or policy brief.

WS1: Water security through integrated water and waste management and risk assessment

Date	06.10.2026 – 08.10.2026
Time	14:00 – 16:00
Venue	Senatssaal
Moderation	Julia Gebert & Andreas Haarstrick

Impluse

Climate change aggravates the risks posed by improper disposal of waste and inadequate management of contaminated sites. Heavy rainfall, flooding and wind contribute to the contamination of inland waters, groundwater reservoirs and the seas through erosion of uncovered solid waste, landsliding of instable waste bodies, scouring or direct seepage of leachate, causing pollutant release and dispersion in the environment. As a result, security and resilience of water supply are directly linked to and under pressure by wastewater and waste management, especially in densely populated areas. This has economic, political and social dimensions; for example, regarding the equity of access to clean water and the role and resilience of the societal structure developing around the informal waste management sector. At international level, safeguarding the quality of transboundary surface waters is affected by (in)adequate national and regional wastewater and waste management issues.

Activity, output and outcome

Interested conference participants are invited to form a ‘writeshop team’ to explore the impulse topic through the following pathways:

A. Draft a shared review publication

The paper shall highlight risks of inadequate wastewater and waste management for water supplies, identify gaps in problem-solving, propose implementation strategies and analyse economic and societal consequences in the face of future climate-related extreme events. A comparative risk assessment could also be included, examining the scenarios of (1) genuine change through political, legal and societal measures versus (2) continuing with ‘business as usual’. Such a review could form the basis for a future research proposal. Drafting the review paper’s structure would be an output of the writeshop, the final publication for submission an outcome.

B. Scoping for a shared research proposal

The writeshop participants formulate an approach for a research project, which could include the examination of the risks of wastewater and waste management systems for water supplies, predictive quantification of waste material flows, analysis of leaching mechanisms and subsequent contaminant release, as well as the dynamics of the erosion of landfill or informal waste disposal sites and release of solid waste into the environment within the context of climate adaptation, including an integrated risk assessment. Deciding on a title for the research proposal, structuring its content, defining its objectives and formulating the research questions would be an output of this meeting, whilst the completed research proposal would be an outcome of this meeting. For both options (review paper, research proposal), the writeshop team would need to establish a network of committed participants with a binding commitment to contribute, with the dedication continuing beyond the time frame of the conference itself.

Writeshops

WS2: Data and Information Management for Water Security and Resilience

Date	06.10.2026 – 08.10.2026
Time	14:00 – 16:00
Venue	Gustav-Krüger-Saal
Moderation	Lars Ribbe & Mukand Babel

Impluse

Data and information management are essential foundations for strengthening water security and resilience in the face of climate change. Reliable, accessible and well-structured information supports evidence-based decision-making, enables cooperation across disciplines and sectors and helps identify effective responses to water-related risks. However, challenges remain in connecting data, knowledge and action in ways that are useful for science, policy and practice. This writeshop invites participants to jointly explore how data and information can be better managed, shared and applied to support resilient water systems. The format is designed to foster transdisciplinary interaction and to create tangible, high-impact outcomes, such as project proposals, research networks or other initiatives in the interest of participants.

Activity, output and outcome

Interested conference participants are invited to form writeshop teams around jointly developed ideas related to data and information management for water security and resilience. Participants may propose collaborative endeavours by outlining a core topic or research question, the tasks to be addressed during the writeshop and the intended deliverable, documentation method and potential long-term impact beyond WSCC 2026. Proposed ideas will be shared among the participants and selected through a joint process, after which teams of approximately 4 to 10 members will be formed. Each team will organize its work internally, including the selection of a moderator to support alignment on the topic, tasks and target deliverables.

During the writeshop, teams will elaborate their selected topics through focused collaboration, develop core content, draft materials and structure their intended outputs. Depending on the interests of the participants, these outputs may include the outline of a research proposal, the concept for a research network, a joint initiative, methodological guidance, a documentation framework or another concrete product relevant to improved data and information management for water security and resilience. The writeshop will conclude with the finalization and presentation of team results, including a summary poster that documents the main outcomes and future roadmap. Selected representatives may present their results in a plenary setting and discuss the broader relevance and potential impact of the work. Immediate outputs include the jointly prepared group deliverables, posters and presentations, while expected outcomes may include continued collaboration, project proposal development, research networks or other follow-up initiatives extending beyond the conference.

Writeshops

WS3: Interconnecting societal processes, breaking the silos for water security under competing demands

Date	06.10.2026 – 08.10.2026
Time	14:00 – 16:00
Venue	S315 & Ludwigstr. 21
Moderation	Alejandro Pieters & Min Liu

Impluse

Food production, energy, industrial (human direct use) and technological development are crucial processes to human society but have competing demands for water use. These tensions are further exacerbated when climate change and land-use changes are incorporated as factors that influence water availability and quality. Inefficiencies within each of these sectors add complexity and impose further pressure on water resources. Despite their fundamental relevance to society and their interconnectivity, impacts of food, energy and technology on water resources have been addressed in isolation. This writeshop is intended to explore the possibilities for linking all or some of the sectors in integrated management strategies and operational solutions that can lead to a more secure and resilience water use.

Activity, output and outcome

Participants are invited to form teams (4-10 members) and identify potential linked food, energy/industry and technological processes (case studies) that can be analysed in terms of 1. Water demand (current and forecasted); 2. Impact on quality of water resources; 3. Identification of tensions among sectors for water resources; 4. Potential for integrated solutions. Teams may propose ideas on how to tackle the envisioned case study, identify knowledge gaps and access to required information/data, which would lead to deciding which output is expected/feasible (publication -research paper, review paper- research proposal, research network, etc.). During the writeshop teams will prepare the backbone of the selected output including target journals, target funding agencies or supporting institutions and an expected time plan to reach objectives.

Abstracts

18 | Integrated Ecological Management of Paliastomi Lake under Climate Change: Challenges, Water Security Implications, and Nexus-Based Solutions

Grigol Abramia PhD[1]; Leila Gverdtsiteli Prof. Dr.[2]; Dimitri Eristavi Prof Dr.[2]; Besik Kalandadze Prof Dr.[3]; Akaki Girgvliani Prof Dr.[4]; Gero Weber[5]

[1] International Center for Environmental Research, 47 Kostava Street, 0179,Tbilisi, Georgia

[2] Department of Environmental Engineering and Ecology, Georgian Technical University, 77 Kostava St., Tbilisi, Georgia

[3] Tbilisi State University, Georgia, 1 Ilia Chavchavadze Avenue, Tbilisi 0179

[4] Akaki Tsereteli State University, Kutaisi, 59 King Tamar Street., KutaisiGeorgia

[5] Saarland University, Campus, 66123 Saarbrücken, Germany

Paliastomi Lake, located in the Colchis lowland of western Georgia, represents one of the most ecologically significant aquatic ecosystems in the Black Sea region. In recent decades, the lake has experienced increasing environmental stress caused by climate variability, anthropogenic pressure, hydrological alterations, eutrophication, and biodiversity degradation. These processes threaten local water security, ecosystem resilience, fisheries, and the socio-economic stability of surrounding communities.

This study examines emerging ecological challenges affecting Paliastomi Lake and evaluates integrated management approaches within the framework of the water–ecosystem–climate nexus. The research combines hydrological observations, ecological assessments, and environmental management analysis to identify the main drivers of ecosystem degradation and their interdependencies. Particular attention is given to the impacts of fluctuating salinity, sedimentation, pollution inflows, and changing climatic conditions on the lake's ecological balance.

The findings demonstrate that sustainable management of Paliastomi Lake requires coordinated interdisciplinary strategies that integrate water resource governance, ecosystem restoration, climate adaptation, and stakeholder participation. The study further highlights the importance of transboundary and regional cooperation for protecting wetland ecosystems with both local and global environmental significance. Proposed management measures include adaptive monitoring systems, restoration of natural hydrological regimes, improved watershed management, and implementation of climate-resilient ecological policies.

The research contributes to current discussions on nexus-based environmental governance and offers practical recommendations.

Abstracts

49 | Monitoring and Modelling the Impacts Of Different Land Uses On Fluvial Water Quality Focusing on Nitrogen In The Mata Atlântica: The Guapi-Macacu River Basin

Santiago, Penedo[1, 2]; Lars, Ribbe[1]; Udo, Nehren[1]; Christoph, Schüth[3]; Rachel, Bardy Prado[4]; Annika, Künne[5]

[1] TH Köln
[2] Promotionskolleg NRW
[3] TU Darmstadt
[4] Embrapa Meio Ambiente
[5] Thüringer Landesamt für Umwelt, Bergbau und Naturschutz

Water resources are vital to societies and to natural ecosystems. The environmental degradation observed during the last decades has encouraged the research community and policymakers to understand the principles governing hydrology and water quality as well as to create legal frameworks to protect water resources.

This research aims to contribute to this body of research by assessing the impacts of different land uses on water quality, especially nitrogen, in the Guapi-Macacu River Basin in the Atlantic Forest in south-east Brazil by implementing a hydrological and water quality monitoring network to calculate a water quality index (WQI), implement a hydro-chemical model, and evaluate management scenarios.

A comprehensive monitoring network was established, targeting key parameters with the rationale of generating new data on a relatively high spatial resolution to capture the dynamics of the basin. The resulting data enabled the calculation of a WQI, able to quantify the impacts of untreated sewage and nonpoint source pollution from agricultural activities. To deepen the understanding, a physically based hydro-chemical model (J2000-S) was calibrated, and validated using both monitored and historical data.

The model successfully simulated streamflow (r^2= 0.90, NS = 0.88, LNS = 0.89, for the calibration period and r^2= 0.85, NS = 0.85, LNS = 0.88, for the validation period) and nitrogen dynamics (with an underprediction of ~5% of the nitrogen loads) at a monthly and yearly scale, and was used to assess the effect of restoring riparian vegetation, predicting a 10% reduction in nitrogen loads. This integrated approach demonstrates how monitoring and modelling are powerful tools for understanding and managing water resources, especially in data-scarce regions.

55 | Green Engineered Nanobiochar from Agricultural Biowaste for Sustainable Removal of Emerging Pollutants: A Circular Approach to Climate-Resilient Water Security

Kustomo[1, 2]; Sam Fong Yau, Li[2]

[1] Department of Chemistry, Faculty of Science and Technology, Universitas Islam Negeri Walisongo Semarang, Indonesia
[2] Department of Chemistry, Faculty of Science, National University of Singapore

Emerging organic contaminants increasingly threaten water security, particularly under climate change conditions that intensify wastewater generation, water scarcity, and pollutant accumulation in aquatic environments. Developing low-carbon, resource-efficient treatment technologies from renewable waste streams is therefore critical for sustainable water management. In this study, engineered nanobiochar (NBC) was produced from pomegranate peel waste through pyrolysis, followed by ball milling and ultrasonication. Physicochemical characterization confirmed successful nanoscale transformation, yielding particles of 5–7 nm with a high surface area (360.8 $m^2\ g^{-1}$), abundant oxygen-containing functional groups, and enhanced surface reactivity. The material was evaluated for the removal of 4-nitrophenol (4-NP), a representative emerging contaminant frequently detected in industrial wastewater. Under optimized conditions (pH 6, 15 mg adsorbent dosage, 298 K, 90 min), NBC achieved >94% pollutant removal and a maximum adsorption capacity of 84.75 mg g^{-1}. Adsorption followed the Langmuir isotherm and pseudo-second order kinetics, while thermodynamic analysis confirmed spontaneous adsorption (ΔG = –3.764 kJ mol^{-1}). Regeneration studies demonstrated strong reusability, with alkaline-treated NBC retaining 85.76% removal after three cycles, whereas acid-treated NBC declined to 20.53%. The findings demonstrate a sustainable route for converting agricultural biowaste into engineered NBC without chemical activation, reducing environmental burdens while enabling efficient removal of emerging pollutants. By integrating waste valorization, circular bioeconomy principles, and advanced water treatment, the material offers a scalable and climate-smart approach to strengthening water security.

Abstracts

79 | Governing Spring Systems Under Climate Uncertainty: Community Resilience and Water Security in the Indian Himalayas

Akshita, Sharma[1, 2]

[1] Forest Research Institute, Dehradun, India
[2] Indian Institute of Forest Management, Bhopal, India

In the Western Himalayas, springs serve as critical socio-ecological lifelines, as they sustain local ecosystems, agrarian livelihoods, and domestic water security. Their recharge and flow regimes are in most cases closely tied to the condition and governance of surrounding forests. Yet, nearly 40% of Himalayan springs have dried up or become seasonal.

This paper attempts to examine the governance of spring-dependent communities through the lens of social-ecology, exploring community participation, local knowledge, and stakeholder interactions' influence over the water management of an endangered source: springs. Data were collected through household interviews, stakeholder consultations, spring mapping and location surveys, seasonal discharge measurements, water quality assessments, and observations of surrounding land-use characteristics.

The findings indicate that spring resilience is shaped by the interaction of ecological processes and governance arrangements. Community stewardship practices, cultural norms associated with water sources, and locally embedded knowledge systems continue to support conservation efforts in several locations. However, weakening collective action, changing livelihood aspirations, and uneven participation in decision-making processes were found to constrain adaptive responses to emerging water challenges. The study further considers how climate change is creating unprecedented climate extremes exposing limitations within existing governance structures. Addressing these challenges requires governance systems that are flexible, inclusive, and capable of integrating local knowledge with broader policy and management frameworks to enhance long-term social-ecological resilience.

124 | A Self-Operating Solar Greywater Recycling System: Edge-AI Automation for Decentralized Water Energy Food Security

Ria Singhal[1]; Harshit Sharma[1]; Saurabh Singhal[2]

[1] Vellore Institute of Technology (VIT) University, Vellore,632014, Tamil Nadu, India
[2] DSM Degree College, Kanth, 244001 , Moraradabad, Uttar Pradesh India

Cities reuse far too little of the water they already have. In Indian buildings, 40–50% of daily freshwater leaves as greywater from bathing, laundry, and cooling, yet recovering it usually means power-hungry plants, chemical dosing, and filters that clog and demand constant manual cleaning. So reuse rarely survives real operating conditions, and a clear water–energy–food nexus opportunity goes unused. We address this with a decentralized greywater recycling system designed to run unattended. Treatment happens at the source via gravity flow, so it draws only ~11 W and runs off-grid on a small solar panel. Water passes through seven stages: a self-cleaning intake mesh, a pressure-stabilised buffer, sediment and activated-carbon filtration, optional zeolite softening, UV disinfection, and an ultrafiltration membrane, with an optional nutrient-dosing stage that tailors output for irrigation. Its defining feature is onboard intelligence. An edge controller continuously reads pressure, flow, turbidity, TDS, and pH; when differential pressure signals clogging, it brushes and flushes the mesh by itself, ending the manual cleaning that sinks most reuse projects. Safety logic recirculates off-spec water, halts if the UV stage fails, and closes inlet valves when flow patterns suggest a leak. A companion app shows live water quality and predicts part wear, prompting maintenance before failure. Built to scale in identical modules from 500 to 100,000 litres per day, validated pilots recovered nearly 87% of input water chemical-free and cut freshwater bills by 40–70%. Because the output can be nutrient-enriched for rooftop and community farms, it ties household water savings to local food production, while solar operation keeps its energy footprint near zero.

Abstracts

139 | Quantifying Groundwater-Vegetation Interdependencies under Drought Stress: An Integrated VHI-SWAT-SPI Approach in the Faria Catchment, Palestine

Qais, Daraghma[1]

[1] Energy, Water and Food Security Research Center-SAGE Centre, Scientific Centers, An-Najah National University, P.O. Box 7, Nablus P4110257, Palestine

Agricultural drought threatens water and food security in semi-arid Palestine. This study assesses climate-groundwater-vegetation interdependencies in the Faria Catchment (2013–2021) using remote sensing, SWAT hydrological modeling, and climate data.

Enhanced VHI was computed from 144 Landsat-8 images by combining VCI and TCI. Land cover was classified into eight agricultural classes, with zonal statistics extracting annual VHI per class. Groundwater recharge was derived from a previously calibrated and published SWAT model using area-weighted averages. SPI was calculated from six rainfall stations based on 1991–2021, following WMO recommendations.

Three key findings emerged: strong VHI–SPI correlation ($R = 0.735$, $P<0.05$), confirming VHI reflects climatic drought; strong VHI–groundwater correlation ($R = 0.70$), showing vegetation health depends significantly on groundwater storage; and an average recharge ratio of 28.3% (20.8% in dry 2014, 31.9% in wet 2020), with near-perfect SPI correlation ($R = 0.989$), validating SWAT performance.

Annual VHI anomaly analysis identified 2013 and 2016 as driest, 2019 and 2020 as wettest, consistent with SPI. Applying Kogan's (1995) classification, 2013 fell under moderate drought (VHI = 29.03), while 2014–2021 fell under mild drought (VHI: 30.27–34.02). Crop-specific analysis showed drip-irrigated (VHI = 29.28) and rainfed (VHI = 29.42) areas were most affected, while palm (VHI = 36.92) and olive (VHI = 34.54) groves most resilient.

This study is the first in Palestine to integrate enhanced VHI with SWAT-based groundwater modeling and SPI to quantify groundwater-vegetation interdependencies at the crop-type level, offering a novel decision-support tool for sustainable agricultural and water resource planning under climate change.

140 | A Socio-hydrological systems analysis for social and ecological resilience in the East African Region

Solomon Gebreyohannis Gebrehiwot[1, 2]; Lutz Breuer[1]

[1] Inst. Landscape Ecology and Resource Management, Liebig University, Heinrich-Buff-Ring 26, 35392 Giessen, Germany

[2] Inst. Water, Environment and Climate Research, Addis Ababa University, Ethiopia

In East Africa, the social and ecological situation is dire, mainly due to water issues. The impacts of climate change, natural variability and poorly managed water resources are cited as the main causes of water insecurity. Specifically, areas with higher levels of land degradation and frequent population movement exhibit tipping points with regard to water. To investigate the link between water and social and ecological systems, the socio-hydrological system (SHS) framework, a derivative of the socio-ecological system (SES) framework, can be tested and applied. This framework has been used to analyse and classify the different levels of water insecurity in the Awash River Basin in Ethiopia. The SHS framework is currently being studied to identify areas of critical social resilience in the Lake Turkana Basin in Kenya. The results from the Awash River Basin identified areas requiring priority management for water security interventions. Overall, SHS analyses are expected to inform future modelling and planning that considers water resource dynamics and socio-ecological systems in the region. Additionally, SHS analysis is expected to address the issues arising from data scarcity and uncertainty by unravelling the complexities of natural systems.

Abstracts

144 | Mapping urban waterlogging susceptibility under climate change scenario using integrated PCA-XGBoost models and potential mitigation framework for Bangkok, Thailand

Mehedi, Hasan[1]; Sandhya, Babel[1]

[1] Sirindhorn International Institute of Technology, Thammasat University, Khlong Luang, Pathum Thani 12120, Thailand

Urban waterlogging has emerged as a major environmental and infrastructural challenge in Southeast Asia, including Bangkok, due to climate changes causing extreme rainfall events. Recurrent waterlogging poses a challenge to water security, as heavy rainfall can inundate drainage and canal systems, thereby exacerbating water pollution. The aim of this study was to identify the most influential factors driving urban waterlogging under extreme climate events, create a susceptibility map, and propose a new waterlogging mitigation framework, named "Bangkok 2055: A Resilient Sponge & Smart City." To address this, Principal Component Analysis (PCA) and Extreme Gradient Boosting (XGBoost) machine learning models were used. A total of 21 spatial variables were standardized across 2,700 sampling points, with 80% used for training and 20% for testing. The XGBoost achieved an accuracy of 91.4% and an area under the curve (AUC) of 0.93, demonstrating excellent predictive performance. Results show that the drainage density, water retention capacity, land use pattern, and canal conditions are the most critical determinants of waterlogging. The susceptibility map identified Lat Krabang, Min Buri, Nong Chok, Prawet, and Bang Na districts as high-risk zones, covering about 26% of Bangkok's urban area. Based on the model, the proposed waterlogging mitigation framework integrates structural (drainage upgrading, underground storage), nature-based (wetlands, green-blue networks), and governance (early warning, data integration) measures. This integrated approach will assist in enhancing urban water security by strengthening drainage reliability, retention capacity, canal function, and early warning under future hydroclimatic stress by identifying the most vulnerable factors.

146 | Integrating PCA-GIS and Machine Learning to Predict Arsenic-Related Drinking-Water Security in Tube-wells, Thakurgaon District, Bangladesh

Mehedi, Hasan[1]; Sandhya, Babel[1]

[1] Sirindhorn International Institute of Technology, Thammasat University, Khlong Luang, Pathum Thani 12120, Thailand

Safe drinking water is essential for human health, water security, and achieving Sustainable Development Goal 6 (SDG 6). Thakurgaon District in northwestern Bangladesh is dependent on tubewell where arsenic (As) contamination raises serious public health concerns and challenges reliable access to safe water. This study aims to identify the sources and hotspots of As and predict drinking-water potability and assess water security. Principal Component Analysis (PCA) was applied for source identification, while GIS-based Inverse Distance Weighted (IDW) interpolation was used for hotspot mapping. A total of 40 tube-wells samples from five sub-districts were analyzed at the certified Water Quality Research Lab in Dhaka, Bangladesh. Support Vector Machine (SVM), Random Forest (RF), and XGBoost models were developed with 80% training and 20% testing subsets. XGBoost achieved a superior accuracy of 0.97. Findings from PCA indicated that the critical source of As is natural and geogenic, mainly arsenic-bearing iron oxyhydroxides (FeOOH) in alluvial and deltaic sediments from the Ganges, Brahmaputra, and Teesta rivers. Hotspot analysis showed higher As risk in Thakurgaon Sadar and Ranishankail, while moderate risk in Baliadangi Upazila. Extreme climate change can lead to drought which can further stress these alternative safe water supplies. Arsenic was detected in 12 tube-wells, with concentrations ranging from 0.44 to 25.29 µg/L. This integrated modeling approach offers a rapid, low-cost method to assess rural drinking-water supply safety. Dependence on groundwater as sole source of water supply can intensify water-security risks in climate-sensitive Bangladesh.

Abstracts

151 | Repeated Drought and Migration: Evidence from the Kyrgyz Republic

Kamalbek, Karymshakov[1]; Dastan, Aseinov[1]; Dina, Azhgaliyeva[2]

[1] Kyrgyz-Turkish Manas University, Bishkek, Kyrgyz Republic

[2] Asian Development Bank, Manila, Philippines

Climate change is intensifying drought frequency in Central Asia, yet how repeated exposure shapes household migration remains unquantified. We test whether successive drought episodes amplify or deplete migration responses, using a six-year balanced panel of 3,919 Kyrgyz households (2019-2024) linking the Kyrgyz Integrated Household Survey to MERRA-2 satellite precipitation data. Drought is defined at the community level as agricultural-season precipitation below the historical 30th percentile, yielding two distinct episodes (2021, 2023) separated by a precipitation-normal year. We apply the de Chaisemartin-D'Haultfoeuille (2024) dynamic difference-in-differences estimator, robust to non-absorbing, staggered-timing treatment, to identify period-specific and cumulative effects on international and internal migration. Drought significantly raises international out-migration (cumulative effect: 0.051 additional migrants per household, $p<0.05$) while suppressing internal migration, the latter driven by contraction of the primary north-central destination corridor. Repeated exposure produces depletion: the second-episode international response is substantially smaller than the first. Heterogeneity analysis reveals a non-monotone, income-contingent pattern: the two lowest income quartiles show no statistically significant migration response in either episode, consistent with binding liquidity constraints, while a durable positive response emerges only among middle-income households. These findings quantify migration as a climate-adaptation channel that is exhaustible rather than permanently renewable under high-frequency shocks, with direct implications for designing social protection and migration-facilitation policy around repeated, rather than singular, climate stress.

169 | Hydroclimatic Changes in the Marsyangdi River Basin, Central Himalaya under CMIP6 Scenarios: Implications for the Water–Energy–Food–Ecosystem Nexus

Diwakar, Adhikari[1]; Madhav, Upadhaya[1]; Nitesh, Khadka[2]; Deep Narayan, Shah[1]; Lal Bahadur, Thapa[3]; Ram Kailash Prakash, Yadav[3]; Ramesh Raj, Pant[1]

[1] Central Department of Environmental Science, Institute of Science and Technology, Tribhuvan University, Nepal

[2] Center for Water Resources Research, Institute of Engineering, Pulchowk Campus, Tribhuvan University, Nepal

[3] Central Department of Botany, Institute of Science and Technology, Tribhuvan University, Nepal

Climate change is fundamentally altering hydroclimatic regimes across the Himalayas, with cascading impacts on water, energy, food, and ecosystem (WEFE) systems. Here, we applied the SWAT+ hydrological model in the Marsyangdi River Basin (MRB) of central Nepal, using bias-corrected CMIP6 projections under SSP2-4.5 and SSP5-8.5 scenarios to study hydroclimatic regimes. We employed an envelope approach spanning warm-wet, warm-dry, cold-wet, and cold-dry states to capture plausible futures for mid-century (2041–2070) and end-century (2071–2100). By end-century, warming reaches +3.0 °C (SSP2-4.5) and +5.0 °C (SSP5-8.5), with precipitation increasing by 13% and 27%, respectively, driven by monsoon intensification. Annual discharge rises by >30% and >50%, yet snowfall declines by ~20% and ~35%, eroding the cryospheric buffer that sustains dry season flows. Pre-monsoon discharge decreases under both scenarios, exacerbating early-season water scarcity. Climate extremes intensify with extremely wet-day contributions increasing up to 85% under SSP2-4.5 and more than triple under SSP5-8.5, daily rainfall intensity strengthens by 45–55%, and consecutive dry days lengthen by 30–87%, signaling concurrent flood and drought risks. Sectoral consequences are compounding with dry-season hydropower deficits reach 44% under drier futures, while wheat irrigation demand nearly doubles by end-century under SSP5-8.5; paddy remains stable and maize rainfed. Our findings reveal a pronounced seasonal mismatch between water availability and cross-sectoral demand in the MRB, underscoring the urgent need for coordinated, climate-state-informed WEFE planning to enhance resilience under future conditions.

Abstracts

180 | Bridging Governance Gaps for Climate-Resilient Resource Nexus Management in Pakistan: A Transdisciplinary Framework for Equitable and Adaptive Decision Making

Anam Munawar[1]; Areeba Amer[1]; Syed Amer Mahmood[1]

[1] Institute of Space Science, University of the Punjab, Lahore, Pakistan

Pakistan faces escalating climate-induced disasters, including recurrent floods, prolonged droughts, heatwaves, glacier melt, and rapid urbanization, exposing weaknesses in the governance of interconnected water, energy, food, land, and ecosystem (WEFLE) systems. Although advances in hazard monitoring have improved risk assessment, fragmented institutions, overlapping mandates, weak policy integration, and limited stakeholder participation continue to hinder effective resource management. This paper proposes a transdisciplinary governance framework to strengthen climate resilience through an integrated resource nexus tailored to Pakistan's socio-environmental context. The framework integrates Earth observation, artificial intelligence, and geospatial decision-support systems with participatory governance involving government agencies, academia, local communities, indigenous knowledge holders, and the private sector. It promotes institutional coordination, policy coherence, equitable resource allocation, and evidence-based decision-making under deep uncertainty. Particular emphasis is placed on managing trade-offs among water security, agricultural productivity, energy demand, urban development, and ecosystem conservation under intensifying climate extremes. The framework supports adaptive planning through scenario analysis, spatial risk assessment, and continuous stakeholder engagement. By integrating scientific innovation with inclusive governance, it provides a practical pathway for reducing institutional fragmentation, improving policy effectiveness, and strengthening climate resilience across Pakistan. The proposed approach also advances the Sustainable Development Goals, the Sendai Framework for Disaster Risk Reduction, and Pakistan's long-term climate adaptation.

184 | Water–Energy–Food Nexus under Climate and Land-Use Change: Evaluating Intervention Pathways for Synergies and Trade-offs in the Ping River Basin, Thailand

Kaushal, Chapagain[1]; Mukand S., Babel[1, 2]; Daniel, Karthe[2, 3]

[1] Centre for Water and Climate Adaptation (CWCA), Asian Institute of Technology (AIT), Klong Luang, Pathum Thani 12120, Thailand

[2] UNU Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES), Ammonstraße 74, 01067 Dresden, Germany

[3] Faculty of Environmental Sciences, Dresden University of Technology (TUD), Mommsenstraße 6, 01069 Dresden, Germany

Climate and land-use change are intensifying competition across water, energy, and food (WEF) systems, yet it remains unclear which management measures relieve this pressure without shifting the burden to another sector. Building on a previously validated integrated model for the Ping River Basin, Thailand, this study evaluates portfolios of sectoral interventions for their WEF synergies and trade-offs.

Water-, energy-, and agriculture-focused measures were simulated in the coupled WEAP–MABIA–GIS model under four CMIP6 GCMs (SSP2-4.5, SSP5-8.5) and five Dyna-CLUE land-use pathways, and scored by their offsets to water demand, energy demand, and agricultural productivity.

No single-sector fix proved trade-off-free. Water measures (non-revenue-water reduction, rainwater harvesting, wastewater reuse) cut water demand 7–27% but raised energy demand 7–20%. Energy measures (solar, biomass) cut energy demand 10–20% but reduced agricultural productivity up to 13% through land and water competition. Agricultural measures (improved practices, modern irrigation technology) cut water demand 10–32% and raised productivity 5–17%, yet increased energy demand up to 20%.

Because every intervention cascades across sectors, water, energy, and food security cannot be pursued in isolation; only integrated, cross-sector packages can balance them, giving planners an evidence base for robust adaptation under deep uncertainty.

Abstracts

198 | Rethinking Water Security Beyond the State: Women's Autonomous Water Governance in a Groundwater-Depleted Basin of Central Mexico

Morales Aguilar, Gabriela[1]

[1] National Autonomous University of Mexico (UNAM), Carretera a Querétaro 140, 37748, San Miguel de Allende, Guanajuato, México

Water security commonly assumes that security depends primarily on institutional coordination and state-led management. This proposal questions that assumption by examining how autonomous women's organizations produce water security where institutional responses remain fragmented or absent.

This research draws on twenty-two months of qualitative fieldwork in rural communities of the Independence Basin, Mexico, combining semi-structured interviews, participant observation, community accompaniment, and a critical review of scientific literature on groundwater quality and rainwater harvesting. The study documents how rural women collectively organize the construction, maintenance, and governance of household rainwater harvesting systems through local knowledge, reciprocal community networks, and donations, with minimal state intervention. Scientific evidence indicates that harvested rainwater contains concentrations of dissolved minerals below WHO guideline values and, after basic treatment, presents no health risks than groundwater supplied through public wells affected by geogenic contamination after over-exploitation, that have caused major health problems in the region.

This proposal argues that these experiences constitute a bottom-up nexus governance model linking water, health, gender, and climate adaptation. Rather than replacing public institutions, autonomous community governance expands current understandings of water security by demonstrating that resilient resource management can emerge through women's collective action. Recognizing and scaling these practices offers an actionable pathway for strengthening climate-resilient, socially just, and transdisciplinary nexus governance across the Global South and other water-stressed regions.

208 | Diagnosing Water Security through Land-Use Change, Ecosystem Services, and Territorial Governance: A Multiscale Territorial Doughnut Approach in Montes de María, Colombia

Miguel, Ramirez[1]; Sergio, Angel[2]; André, Große-Stoltenberg[2]; Iván, Lizarazo[3]

[1] Ingeniería Catastral y geodesia, Universidad Distrital Francisco José de Caldas, Bogotá, Colombia.

[2] Institute of Landscape Ecology and Resource Management, Research Centre for Biosystems, Land Use and Nutrition (iFZ), Justus Liebig University Giessen, Giessen, Germany

[3] Departamento de Agronomía, Facultad de Ciencias Agrarias, Universidad Nacional de Colombia, Bogotá, Colombia.

Water security in rural territories depends on how land-use change redistributes ecosystem services, water access, and governance capacity across scales. This poster presents the Territorial Sustainability Doughnut Model (TSDM), a multiscale framework for diagnosing whether land-use transitions remain ecologically compatible, institutionally supported, and socially viable under climate-related uncertainty. The framework was applied in Montes de María, Colombia, a post-conflict rural landscape affected by hydroclimatic variability, agricultural expansion, land-tenure insecurity, and disputes over water and productive land. The analysis combined multitemporal LULC mapping for 2010, 2016, and 2023; agrological vocation and municipal zoning overlays; an ecosystem-service directional matrix focused on hydrological regulation, food, wood, energy, and climate regulation; and evidence from 35 semi-structured interviews evaluating six social factors: land-use perception, water access, economic subsistence, communal governance, territorial ownership, and land-tenure security. Results show that localized ecosystem-service gains, including hydrological and climate regulation, do not automatically scale upward into regional territorial sustainability. At broader municipal and subregional levels, water security remains constrained by institutional fragmentation, insecure tenure, and asymmetric capacity to negotiate land and water decisions. Ultimately, the TSDM advances nexus thinking by linking spatial data, local knowledge, and governance conditions in a visual diagnostic tool. It identifies key intervention points where land-use planning, ecological restoration, tenure security, and water governance must converge to support climate-resilient territorial sustainability.

Abstracts

212 | Empowering with Resource Nexus thinking: a learning pathway from open online learning to doctoral research

Asha Verma[1]; Serena Coetzee[1, 2, 3]

[1] United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU Resource Nexus), Ammonstrasse 74, 01067 Dresden, Germany

[2] Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Pretoria, South Africa

[3] Dresden University of Technology, Dresden, Germany

The growing complexity of sustainably managing environmental resources amid climate and resource degradation has strengthened calls for integrated management. A Resource Nexus perspective considers synergies and trade-offs between interconnected resources such as water, energy, food and ecosystems in pathways toward sustainability, addressing challenges like climate change, rapid urbanisation and unsustainable production and consumption.

While nexus approaches offer valuable frameworks for managing resource interdependencies, implementation remains constrained by limited capacities among researchers, practitioners, and decision-makers. This contribution presents learning pathways for strengthening capacities in water security through Resource Nexus thinking, drawing on the digital teaching infrastructure of the Global Water and Climate Adaptation Centre in Aachen, Bangkok, Chennai and Dresden.

The pathway begins with free self-paced online material on the conceptual foundations of the Resource Nexus. Two semester-based modules for master's and doctoral students combine extended online materials with guest lectures and assignments on real-world scenarios, advancing from conceptual understanding to application, analysis and evaluation. Master's students are subsequently co-supervised on projects that employ a nexus perspective, while doctoral candidates integrate the approach into their research methods to analyse synergies and trade-offs, informing policy recommendations for sustainable, integrated solutions

The pathway follows a flexible, demand-driven model enabling integration of Resource Nexus thinking into university curricula and lifelong learning. Partnerships with universities, researchers and practitioners are welcome.

228 | Long-Term Streamflow Assessment in the Amu Darya Runoff Formation Zone Using Historical Hydrometric Records and Hydrological Analogy

Abdulkhakim Salokhiddinov[1]; Andrey Savitskiy[1]; Cristian. Siderius[2]; Olga.Ashirova[3]; Poshoazima Khakimova[1]; Swatantra Kumar Dubey[1]; Erali Abdumajidov[1]

[1] Tashkent Institute of Irrigation and Agricultural Mechanization Engineers - National Research University, Uzbekistan

[2] Wageningen University & Research, Wageningen, the Netherlands

[3] Environment and Environmental Protection Technologies Scientific Research Institute

Reliable long-term streamflow records are essential for understanding hydrological variability and supporting sustainable water resources management in transboundary river basins. In the Amu Darya runoff formation zone, sparse hydrometric observations and gaps in historical discharge records limit reliable assessment of long-term water availability. This study reconstructed long-term streamflow by integrating historical hydrological observations, hydrochemical records, remote sensing data, and hydrological analogy methods. Statistical analyses of more than 100 years of hydrometric records were used to identify relationships among major tributaries and develop empirical regression models for reconstructing missing discharge data. Streamflow was estimated for poorly monitored rivers, including the Pamir and Wakhan Darya, providing the first long-term discharge estimates despite the absence of direct observations. Hydrochemical data were incorporated to improve the continuity and reliability of the reconstructed series. The resulting datasets enabled assessment of water and salt balances upstream of the Termez gauging station. An improved stage-discharge relationship was developed for the Termez station by combining continuous water level observations with reconstructed discharge estimates, extending the available flow record. Validation against observed discharges at key gauging stations showed good agreement, confirming the reliability of the methodology. The reconstructed datasets provide a consistent long-term hydrological record for the Amu Darya runoff formation zone and support water resources assessment, transboundary river management, and climate change impact studies in Central Asia.

Abstracts

229 | Multi-Temporal Soil Moisture Prediction Using Google Earth Engine and XGBoost Machine Learning in the Kashkadarya Region, Uzbekistan

Swatantra Kumar, Dubey[1]; Abdulkhakim, Salokhiddinov[1]; Erali, Abdumajidov[1]

[1] Tashkent Institute of Irrigation and Agricultural Mechanization Engineers - National Research University, Uzbekistan

Soil moisture monitoring is essential for sustainable water resource management and agricultural productivity in semi-arid regions. This study investigated the spatiotemporal dynamics of the Standardized Soil Moisture Index (SSI) and its relationships with precipitation, land surface temperature, evapotranspiration, the Normalized Difference Vegetation Index, and the Modified Normalized Difference Water Index in the Kashkadarya region of Uzbekistan. Multi-source satellite datasets from Sentinel-2, MODIS, CHIRPS, and ESA CCI Soil Moisture were integrated in GEE to assess hydroclimatic variability during 2014–2024. Three machine learning models, XGBoost, LightGBM, and a PyTorch-based multilayer perceptron (MLP), were developed to predict SSI using remote sensing variables and engineered features. XGBoost achieved the best performance (R2 = 0.743, RMSE = 0.0637, MAE = 0.0424), outperforming LightGBM (R^2 = 0.606) and MLP (R2 = 0.383). SHAP analysis identified precipitation as the primary driver of soil moisture variability, followed by MNDWI and temperature-related variables, while engineered features such as LST2 and NDVI × precipitation improved prediction accuracy. Results revealed strong seasonal and spatial variability, with higher soil moisture, vegetation growth, and ET during winter and spring, and drier conditions with vegetation stress during summer. Eastern and northeastern areas consistently exhibited greater moisture availability than western regions. The proposed framework demonstrates the value of integrating remote sensing, cloud computing, and machine learning for accurate soil moisture estimation, providing a scalable and cost-effective tool for irrigation management, drought monitoring, and climate-resilient agricultural planning in Central Asia.

233 | Does elevation-based training data selection improve Long Short-Term Memory streamflow predictions in mountain catchments?

Julio, Álvarez-Estrella[1]; Alicia, Correa[1]; Lutz, Breuer[1, 2]

[1] Centre for International Development and Environmental Research (ZEU), Justus Liebig University, Senckenbergstrasse 3, 35390 Giessen, Germany

[2] Institute for Landscape Ecology and Resources Management (ILR), Research Centre for BioSystems, Land Use and Nutrition (iFZ), Justus Liebig University, Heinrich-Buff-Ring 26, 35392 Giessen, Germany

Reliable streamflow simulations are essential for water security, flood-risk assessment, and climate-impact analysis in mountain regions, where physiographic features strongly influence runoff responses. Long short-term memory (LSTM) networks are increasingly used for rainfall–runoff modelling, typically trained on large and physiographically diverse multi-catchment datasets. However, it remains unclear whether adding more catchments to the training of these models improves predictions for mountainous catchments or restricting the training data to mountain catchments based on elevation can achieve comparable or more robust performance.

This ongoing study investigates how the elevation-based training data selection influences the performance and robustness of LSTM networks for daily streamflow simulation. We use the CAMELS-Colombia dataset, which provides hydro-meteorological time series and catchment attributes across Colombia. After identifying mountain catchments as the target, we compare LSTM models trained on i) all available sites and ii) subsets within similar elevation ranges. Model performance is assessed using standard hydrological metrics and by evaluating prediction consistency across simulated mountain catchments.

By focusing on elevation as a simple and interpretable criterion for training data selection, this study aims to clarify whether broader multi-catchment training improves model skill or if targeted elevation-based subsets may provide comparable or more robust predictions in mountain terrain. The results will contribute to more transparent applications of data-driven hydrological modelling and support water-resource planning by improving the understanding of how elevation-related variability affects streamflow prediction in mountain regions.

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234 | Transdisciplinary research on water security in transboundary river basins

Aliya Assubayeva[1, 2]; Stefanos Xenarios[3]; Alicia Correa[3]; Jorge Forero[4]

[1] Graduate School of Public Policy, Nazarbayev University, Astana, Kazakhstan
[2] Centre for Internationnal Development and Environmental Research, Justus Liebig University Giessen, Giessen, Germany
[3] Commonwealth Scientific and Industrial Research Organization (CSIRO), Environment, Canberra, Australia
[4] Sociology and Gender Studies Department, Latin American School of Social Sciences (FLASCO), Quito, Ecuador

Wicked problems, such as water security, require a shift to transdisciplinary research by bringing disciplinary perspectives, conducting participatory research, and developing case-specific solutions. Translational research (TR), one of the transdisciplinary approaches, was applied in our study to translate the broad theoretical framework and research implications of water security into practical considerations, priorities, and actionable measures to better define the research-policy-society interactions that emerged in the Aral Sea basin in Central Asia and the Mira-Mataje basin in Latin America. The implementation of TR revealed notable differences in the water security priorities of the two case studies; however, there are similarities regarding increasingly competing water needs, the urgency of rehabilitating and expanding aging and limited water infrastructure, low preparedness for climate-related hazards, and weak water governance mechanisms. The application of TR in transboundary basins reveals the need for knowledge synthesizers and knowledge brokers to bridge the gap between research, policy, and society.

245 | Quantifying the Interdependencies Between Aging Infrastructure and Drinking Water Security: A Geospatial Modeling Approach in Nkongsamba, Cameroon

djabou Dairou gerardine epse Dama[1, 2]

[1] Camwater
[2] CVPT

Drinking water security in secondary sub-Saharan African cities depends on interdependencies between infrastructure condition, production capacity, and demographic pressure, rarely quantified in an integrated way. In Nkongsamba, Cameroon, 54.5% of households report dissatisfaction with water quality and 31.1% report abusive supply interruptions. This study models the drinking water supply network using a Geographic Information System (GIS), combining quantitative pressure and consumption data with qualitative interviews of water sector stakeholders. Pipeline age, network pressure zones, and electricity supply reliability were spatially mapped and cross-analyzed to identify recurring failure patterns. Low-pressure segments were found to coincide with older pipeline sections and areas most exposed to contaminant intrusion risk, while electricity disruptions to production pumps compounded these vulnerabilities during peak demand periods. The resulting spatial model quantifies how infrastructure age, hydraulic pressure, and energy reliability interact to shape water security outcomes at the neighborhood scale, rather than treating each factor independently. This integrated, data-driven approach produces a reproducible vulnerability map that prioritizes rehabilitation zones where multiple risk factors converge, offering a transferable framework for water utilities operating in resource-constrained, data-scarce urban contexts across the region.

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246 | Impact of land-use change on discharge dynamics in tropical regions: a Machine Learning perspective

Yanet, Diaz-Esteban[1]; Alicia, Correa[1]; Lutz, Breuer[1, 2]

[1] Center for International Development and Environmental Research (ZEU), Justus Liebig University 35390 Giessen, Germany
[2] Institute for Landscape Ecology and Resources Management (ILR), Research Centre for BioSystems, Land Use and Nutrition (IFZ), Justus Liebig University, 35392 Giessen, Germany

Understanding the relationship between land-use change and hydrological response is essential for regional water security. However, regional modelling remains challenging because traditional hydrological models require basin-specific calibration. This study uses a data-driven regional approach implementing Long Short-Term Memory (LSTM) networks to model rainfall-runoff relationships simultaneously across 206 river basins in tropical regions. The main objective is to quantify the impact of land-use and climatic drivers on streamflow dynamics, while assessing the added value of incorporating dynamic land-use information into regional streamflow prediction. LSTMs are trained on meteorological time series, catchment attributes, and observed streamflow, using data from the GRDC-Caravan data set over the period 1990-2020. Two experimental scenarios are designed: one treating land-use as time-invariant (static), and one updating LSTMs annually using data derived from satellite retrieval provided by the Copernicus Climate Change Service. Model performance is assessed on 42 held-out basins unseen during LSTM training. The effect of land-use change on discharge is estimated by comparing the two scenarios and quantifying the ranges of streamflow variation, with focus on specific sections of the hydrograph: low and peak flows. Preliminary results show a good performance of the LSTM regional approach, with 75% of the testing basins showing a NSE > 0.8. This work demonstrates how deep learning can disentangle multi-scale interactions between land surface processes and the rainfall-runoff response, emphasizing the importance of reliable regional modeling frameworks for water resource management in ungauged catchments, which can be particularly vulnerable under environmental change.

264 | Modelling Water-Energy-Food Nexus Interdependencies under Climate Uncertainty Using an Integrated AI, Remote Sensing, and System Dynamics Framework in Southwest Coastal Bangladesh

M Tauhid Ur, Rahman

MIST, College Avenue, Mirpur Cantonment, 1216 Dhaka, Bangladesh

Most of the nexus studies in coastal Bangladesh still consider water, energy, and food as separate systems and static data cannot be used to reflect the interactions of salinity intrusion, cyclones and groundwater stress over time. The study develops an integrated framework that combines AI based classification, satellite remote sensing and System Dynamics simulation to quantify these interdependencies across Khulna, Satkhira and Bagerhat, going beyond the single model approaches commonly used in earlier nexus research. We trained a hybrid Random Forest and LSTM model to map soil salinity, land use change and groundwater depth using Sentinel 1/2 and MODIS imagery from 2010-2024, achieving 89 percent classification accuracy against 85 ground monitoring stations, some 18 percent better than standard classifiers used alone. Rather than use these maps as static inputs, we used them as direct inputs to a System Dynamics model that captures the ongoing feedbacks between expansion of prawn farming, energy use for irrigation, and freshwater competition. The model was tested under RCP4.5 and RCP8.5 scenarios through 2050. The simulation revealed a compounding pattern not previously considered in other studies: a 19 percent expansion of prawn aquaculture will increase groundwater pumping energy demand by 28 percent and decrease freshwater availability in the dry season by 34 percent by 2050. Sensitivity analysis showed that groundwater recharge rate and energy subsidy levels have the highest impact. A 15 percent reduction in energy subsidies reduces groundwater stress by 22 percent in our simulation, a concrete finding which planners can act upon.

Abstracts

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268 | Operationalizing Nexus-Driven Water Security in Salinity-Affected Coastal Bangladesh through Nature-Based Solutions and Circular Water-Energy-Food Systems

M Tauhid Ur, Rahman

MIST, College Avenue, Mirpur Cantonment, 1216 Dhaka, Bangladesh

Intensifying salinity intrusion in coastal Bangladesh threatens access to freshwater, crop viability, and energy security; however, most interventions remain fragmented, addressing water, energy, or food needs in isolation instead of as a connected system. This study operationalizes a nexus-driven water security framework by integrating nature-based solutions into a circular water-energy-food model across salinity-affected zones in Khulna, Satkhira, and Bagerhat. Here we pilot three nature-based interventions, namely managed aquifer recharge through pond-sand-filter networks, floating vegetable beds on saline-affected water bodies, and mangrove-buffered rainwater harvesting, across 03 villages over a 12-month monitoring period. Freshwater yield, salinity reduction, and household energy use for pumping were tracked at 10 sites using field sensors and monthly water-quality sampling. Results show that managed aquifer recharge reduced groundwater salinity by 31 percent and reduced diesel-based pumping energy demand by 26 percent, while floating bed agriculture increased dry-season vegetable yields by 22 percent using recycled pond nutrients, closing a key food-energy loop. Mangrove-buffered harvesting provided 40 percent of household freshwater needs during peak salinity months, reducing reliance on energy-intensive reverse osmosis units by 35 percent. The originality of this work lies in connecting these nature-based interventions into a single circular system in which water saved through natural filtration reduces energy demand, and the resulting energy savings are reinvested in productive food systems, rather than analyzing each intervention in isolation.

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269 | Adaptive Governance under Climate Extremes, Transdisciplinary Pathways for Managing Cross-Sectoral Trade-offs in the Water-Energy-Food Nexus of Coastal Bangladesh

Umme Ruman, Siddiqi

DGHS, Mohakhali, 1000 Dhaka, Bangladesh

The water, energy, and food institutions in coastal Bangladesh generally work independently, and current governance structures are seldom nimble enough to respond to the cyclones, salinity surges, and extended droughts that pit competing sectors against each other for the limited resource base. This study considers the potential of adaptive, transdisciplinary governance to better address cross-sectoral trade-offs in Khulna, Satkhira, and Bagerhat. We combined institutional mapping, semi-structured interviews with 62 officials across water boards, agriculture extension, and energy agencies, and participatory workshops with 180 community members, to identify governance bottlenecks and co-design response pathways. A cross-sectoral trade-off matrix was then constructed to score conflicts between irrigation water allocation, embankment management, and rural electrification choices during the 2023 and 2024 dry seasons. Research found that 68 percent of conflicts in the survey were caused by overlapping jurisdiction between water boards and local government, rather than resource scarcity itself. In two upazilas, introducing a pilot multi-stakeholder coordination platform reduced average dispute resolution time from 47 days to 12 days and improved irrigation water release timing by 30 percent during peak salinity months. Community co-management of sluice gates, based on local tidal knowledge and hydrological data, reduced waterlogging incidents by 24% compared to agency management alone. The resulting coordination model offers a transferable governance blueprint for climate-stressed nexus regions struggling with deep uncertainty and competing sectoral interests.

283 | Climate smart rice production through alternate wetting and drying (AWD): driving water efficient and low carbon systems in Kerala

Withdrawn

R. Arockia Infant Paul[1]; A. Latha[2]; V. Thulasi[2]; TS. Sadhya[2]; Panneerselvam Peramaiyan[3]; Prakashan Chellattan Veettil[4]

[1] International Rice Research Institute, Thrissur, Kerala, India

[2] Kerala Agricultural University, Thrissur, Kerala, India

[3] Internaitonal Rice Research Institute South Asia Regional Centre, Varanasi, Uttar Pradesh, India

[4] International Rice Research Institute, New Delhi, India

Rice cultivation is a major contributor to global freshwater consumption and agricultural methane emissions. In Kerala, rice is grown under diverse agroecological conditions with various hydrological irrigation regimes. Optimizing water management is critical for improving water productivity while mitigating methane emissions in Kerala. This study evaluated the effectiveness of alternate wetting and drying (AWD) as a climate-smart irrigation strategy across various rice ecosystems in Kerala. Field experiments were conducted during 2024-25 and 2025-26 at research station in Mannuthy and Pattambi region, using two irrigation regimes: continuous flooding (CF) and AWD. Additionally, six types of soil amendments were applied in these two irrigation regimes. Across both years, AWD reduced irrigation water use by 7-13% at Mannuthy and 10-22% at Pattambi, while increasing irrigation water productivity to 0.27-0.45 and 0.31-0.51 kg m?³, respectively, over CF. Grain yields under AWD (5.31-5.39 t ha?¹ at Mannuthy; 5.50-5.55 t ha?¹ at Pattambi) were comparable with CF (5.42-5.53 and 5.19-5.69 t ha?¹, respectively). Among the soil amendments, lime + phosphogypsum produced the highest grain yields (5.64-5.84 t ha?¹ at Mannuthy; 5.45-5.56 t ha?¹ at Pattambi), followed by biochar (5.18-5.51 and 5.52-5.62 t ha?¹, respectively). Moreover, AWD reduced methane emissions by 62-69% relative to CF, and integrating AWD with soil amendments further enhanced mitigation, achieving 68-81% lower emissions than CF. Integrating AWD with lime+phosphogypsum or biochar represents an effective climate-smart strategy for enhancing rice productivity, improving water-use efficiency, and mitigating methane emissions across Kerala's diverse rice ecosystems.

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285 | Earth Observation for Quantifying Water–Agriculture–Biodiversity Nexus Interdependencies in Climate-Vulnerable Landscapes of India

Aditya, Sharma[1]; Rajarshi, Dasgupta[1]

[1] Indian Institute of Technology (IIT) Delhi Hauz Khas, New Delhi - 110016, India

Climate change and agricultural intensification are increasing pressure on water resources, biodiversity, and ecosystem resilience in India's ecologically sensitive landscapes, highlighting the need for integrated approaches to strengthen water security. This study develops a multi-source Earth Observation (EO)-based nexus assessment framework to quantify interactions among water resources, agriculture, biodiversity, climate variability, and socio-economic systems across Assam, a globally significant biodiversity hotspot. High-resolution satellite observations and multi-sectoral indicators were integrated into a Composite Environmental and Socio-economic Stress Index to identify environmentally stressed agricultural hotspots and assess cumulative pressures across interconnected resource systems. Results reveal pronounced spatial trade-offs between agricultural intensification and ecosystem integrity, with intensive farming areas exhibiting higher groundwater stress, land degradation, methane emissions, biodiversity loss, and climate vulnerability. Several hotspots overlap with protected and biodiversity-rich landscapes, identifying priority areas where water security, food production, and ecosystem conservation objectives increasingly compete. The proposed framework transforms EO data into a scalable spatial decision-support system for climate-resilient agriculture, watershed restoration, and integrated landscape planning. By quantifying nexus interdependencies, the study provides an evidence-based foundation for adaptive policies that strengthen water security, conserve biodiversity, and promote sustainable resource governance in climate-vulnerable regions.

290 | Water Consumption Patterns and Their Drivers Across the Urban–Rural Continuum in the Ecuadorian Andes: A Machine Learning Approach

Adriana, Sumba[1]; Alicia, Correa[1]; Lutz, Breuer[1, 2]

[1] Centre for International Development and Environmental Research (ZEU), Justus Liebig University Gießen, Senckenbergstrasse 3, 35390 Gießen, Germany

[2] Institute for Landscape Ecology and Resources Management (ILR), Research Centre for BioSystems, Land Use and Nutrition (IFZ), Justus Liebig University Gießen, Heinrich-Buff-Ring 26-32, 35392 Giessen, Germany

Water consumption is increasingly shaped by climate variability, demographic growth, and land-use change, yet high-resolution analyses across the urban-rural continuum remain scarce in developing countries. We investigate whether distinct water consumption regimes emerge along this continuum and identify their climatic, demographic, and socio-economic drivers. The analysis draws on 17 million monthly billing records from 181,200 georeferenced meters (commercial, industrial, residential; 2017-2025), combined with meteorological data (precipitation, temperature, humidity, solar radiation), population growth, and GDP growth. The pipeline comprises five stages: (1) data cleaning for missing values, consecutive zero consumption, and outliers; (2) spatial aggregation to H3 hexagonal grids at optimal cell size; (3) spatio-temporal analysis deriving cell-level metrics; (4) clustering via STL decomposition, k-Shape, and hierarchical clustering; and (5) explainable machine learning (Random Forest, XGBoost, SHAP) to identify drivers and nonlinear interactions. Preliminary results reveal a clear urban-rural gradient: higher, more variable consumption in the urban centre and lower, more stable values in peripheral zones. The southwest shows rising demand linked to agriculture and livestock, while northern areas reflect residential expansion. Commercial consumption has grown more heterogeneous since 2021, industrial consumption remains stable with extreme outliers, and residential consumption has slightly declined since 2024. Linking cluster patterns to their drivers via interpretable machine learning yields a transferable, data-driven decision-support framework for utility planning, demand forecasting, and climate adaptation in rapidly urbanising Andean cities.

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302 | A Comparative Machine Learning Assessment for Urban Flood Susceptibility Modeling and Future Flood Projections in Dhaka Metropolitan Area (DMA) of Bangladesh

Dr. Asib, Ahmed[1]; Mahinoor Islam, Tonmoy[2]

[1] Professor, Department of Geography and Environment, University of Dhaka, Dhaka-1000, Bangladesh

[2] Post Graduate, Department of Geography and Environment, University of Dhaka, Dhaka-1000, Bangladesh

Urban flooding is an increasing concern in the Dhaka Metropolitan Area (DMA), where rapid urbanization, rainfall variability, low-lying terrain, and drainage constraints interact to intensify flood exposure. This study developed an integrated machine learning and geospatial framework to evaluate the baseline and future flood susceptibility using SAR-derived flood inventory data, 13 flood-conditioning factors, CMIP6 rainfall projections and CA–Markov land-use/land-cover simulations. A total of 1,451 valid sample points were used for training and comparing the Random Forest, XGBoost and LightGBM models, including 468 flood locations verified in the field and literature. Among the models, LightGBM achieved the best overall classification performance with accuracy of 0.91, ROC–AUC of 0.969, F1-score of 0.861, Kappa of 0.790, recall of 0.901 and MAE of 0.098. High and very high flood susceptibility were consistently observed in baseline maps in eastern and southeastern Dhaka, especially in low-lying and river-adjacent areas. Future LULC projections showed growth of built-up from 61.2% in 2040 to 76.8% in 2060, along with a decrease in vegetation, waterbody, agricultural land, and barren land. The future projections indicated that the combined high and very high susceptibility would be 23.83% under SSP2-4.5 and 23.15% under SSP5-8.5 in 2051–2060. The findings offer practical spatial evidence for interventions in Dhaka to reduce flooding, improve drainage, regulate land use, protect retention areas, and build climate-resilient urban development. The framework further provides for anticipatory planning in flood-risk megacities undergoing rapid urbanization worldwide.

306 | Nexus governance in practice: a stakeholder-driven framework for groundwater sustainability in Barahathawa Municipality, Madhesh Province

Anil Aryal[1]; Saurav KC[1]; Sumitra KC[2]

[1] Center of Research for Environment, Energy, and Water (CREEW), Kathmandu, Nepal

[2] International Water Management Institute, Kathmandu, Nepal

Groundwater, a critical resource in the water-food-energy-ecosystem (WEFE) nexus, underpins food security and livelihoods globally and regionally. This study applies a contextualized framework – co-developed with local stakeholders – to assess groundwater governance in Barahathawa Municipality, Madhesh Province of Nepal, where 85% of irrigation and domestic needs rely on this resource. The framework evaluates 32 indicators across technical, legal and institutional, cross-sector policy, and operational dimensions, synthesizing findings into a Groundwater Governance Index (GGI). Results reveal a transitional governance system (GGI: 1.03, "early acceptable") with fragmented technical capacity (midway between non-existent and basic) due to unmonitored extraction, unmapped recharge zones, and sparse hydrogeological data. Legal and institutional gaps such as absence of permitting systems, unenforced pollution controls, and inequitable access highlight systemic risks to sustainability. Cross-sector coordination ("acceptable" state) and operational transparency (initial "acceptable" state) reflect growing synergies between agriculture, urban planning, and community actors, yet marginalized groups remain underrepresented. Lens-based analysis underscores lagging "state" governance relative to the "community" and "market" lens, necessitating prioritized investments in participatory hydrogeological mapping, localized regulations, and inclusive decision-making. The framework guides the management of competing needs by offering practical solutions such as better irrigation practices, gender-sensitive budgeting, and partnerships with local drillers. By bridging technical, legal, and social gaps, this approach offers a replicable model for agrarian-urbanizing regions in western Nepal.

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313 | Water Security Implications of the Indus Water Treaty Suspension: An Integrated Nexus Assessment

Muhammad Muzammil[1]; Muhammad Imran[2]; Umar Farooq[3]; Lutz Breuer[4]

[1] Department of Irrigation and Drainage, University of Agriculture, 38040 Faisalabad, Pakistan

[2] Department of Economics and Business Management, University of Veterinary and Animal Sciences, Lahore 54000, Pakistan

[3] CSIRO Agriculture & Food, Black Mountain, ACT, Australia

[4] Institute for Landscape Ecology and Resources Management (ILR), Research Centre for BioSystems, Land Use and Nutrition (IFZ), Justus Liebig University, 35392 Giessen, Germany

The Indus River Basin, among the world's largest irrigated agricultural systems, underpins Pakistan's water, food, and economic security. The suspension of the Indus Water Treaty in 2025 has heightened concerns about the future availability of water for downstream agriculture. This study evaluates the socio-economic and environmental impacts of reduced transboundary surface-water supplies through an integrated water–food–energy nexus perspective. A scenario-based modeling framework is employed to assess five levels of surface-water reduction (10–50%). The analysis quantifies effects on agricultural profitability, groundwater abstraction, irrigation-related CO_2 emissions, and farmers' socio-economic vulnerability. Under baseline conditions, irrigated agriculture generates an estimated annual net profit of US$9.6 billion, relying on 66 km³ of groundwater and producing 3.67 Mt CO_2 from groundwater pumping. As surface-water availability declines, dependence on groundwater rises, resulting in reduced farm profitability, greater energy consumption, and higher carbon emissions. In the most severe scenario, annual net profit falls by up to 74%, groundwater abstraction increases by 51%, and irrigation-related CO_2 emissions rise by 44%. Farmers also face increased socio-economic vulnerability due to rising production costs and uncertainty in water supply. The findings illustrate how disruptions in transboundary water allocation can trigger cascading effects across water, food, energy, and livelihoods. The study underscores the need for integrated water-security strategies—including improved irrigation efficiency, sustainable groundwater management, and climate-resilient agricultural planning—to enhance resilience in transboundary river basins.

316 | Quantifying Health-Driven Trade-Offs in Groundwater Monitoring: A Geostatistical Optimization Framework

Antonio, Cardona-Benavides[1]; Heriberto, González-Sánchez[2]; Jorge, Aceves de Alba[3]; Hugo Enrique, Júnez-Ferreira[3]; Javier, Castro-Larragoitia[4]

[1] Engineering Faculty, Earth Science Department, Autonomous University of San Luis Potosi, San Luis Potosi, Mexico

[2] Multidisciplinary Graduate Program in Environmental Sciences, Autonomous University of San Luis Potosí, San Luis Potosi, Mexico.

[3] Academic Unit of Science and Technology of Light and Matter, Autonomous University of Zacatecas, Zacatecas, México

[4] Engineering Faculty, Earth Science Department, Autonomous University of San Luis Potosi, San Luis Potosi, Mexico

The reliable management of groundwater in arid regions is heavily dependent on robust monitoring networks, particularly for toxic trace elements such as arsenic and fluoride. This contribution presents a data-driven geostatistical framework, operationalized through a newly developed, open-access web platform (https://gw-monitoring.network/), designed to quantify the interdependencies between spatial optimization and human health priorities. Using a dataset of 116 existing wells in the Comarca Lagunera in North-Central Mexico, this online tool was applied to run a multicriteria prioritization model that contrasts purely variance-based network configurations against health-weighted scenarios. Through this spatial modeling, the operational cost of prioritizing chronic human exposure was quantified: achieving a 90% reduction in spatial variance required 63 wells in a combined-contaminant scenario, whereas health-weighted models required up to 89 wells. By mapping the spatial divergence between these scenarios, the platform reveals how health-priority weighting fundamentally redirects data collection toward zones of high vulnerability rather than mere geographic distribution. Ultimately, the proposed approach successfully isolated a critical core of 39 wells—a minimum viable data nucleus—demonstrating a replicable, freely accessible methodology for translating complex hydrochemical data into actionable groundwater management strategies in data-scarce environments. By making this framework freely available, policymakers gain a transparent, data-driven tool to visualize the link between environmental monitoring (SDG 6) and public health (SDG 3), ensuring resources are directed to protect vulnerable populations.

Abstracts

323 | Designing for an Uncertain Climate: Hydrological Performance of Mine Cover Systems in the Peruvian Andes

Kory Celeste, Sánchez Gamarra[1]; Miluska Anthuannet, Rosas Barturen[1]

[1] Pontificia Universidad Católica del Perú, Facultad de Ciencias e Ingeniería – Sección Ingeniería Civil, Lima, Perú

Mining is a major economic activity in Peru; however, its legacy includes abandoned tailings deposits that can pose long-term risks to water resources. Rainfall infiltration may promote contaminant mobilization long after mining ceases, while the explicit consideration of future climate conditions in mine closure design remains limited in Peru.

This research assesses the hydrological performance of cover systems for the abandoned Mesapata tailings deposit in the Peruvian Andes by integrating CMIP6 climate projections with numerical water-balance modelling. Ten CMIP6 global climate models were evaluated, and precipitation and temperature were bias-corrected using the multivariate MBCn method. Subsequently, future conditions under SSP5-8.5 for 2035–2064 and 2071–2100 were propagated through the Hydrologic Evaluation of Landfill Performance (HELP) model to quantify net percolation across alternative cover designs. Results indicate that precipitation may increase by approximately 9% (–6% to 32%) at mid-century and up to 38% (18% to 65%) by late century, while temperature may rise by about 2°C (1.3–2.7°C) and 4–5°C (2.4–5.8°C), respectively. Accordingly, the permeable cover showed the greatest sensitivity, with net percolation increasing from about 35% historically to 40–45% by late century. In contrast, the geomembrane alternative maintained values near 2–3%, while low-hydraulic-conductivity clay covers remained near 5–7%. Overall, low-permeability covers exhibited more stable hydrological performance under future climate conditions. Therefore, integrating climate projections and hydroclimatic characterization into mine closure design can support long-term decisions aimed at reducing water ingress and the generation of contaminated drainage.

330 | From complex environmental data to actionable insights: A data-driven diagnostic workflow for high-frequency cross-scale monitoring

Kenneth, Gutiérrez García[1, 2]; Gunnar, Lischeid[1, 2]; Gökben, Demir[1]; Christian, Markwitz[3]; Maren, Dubbert[1]; Alexander, Knohl[3]; Michael, Rode[4]

[1] Leibniz Centre for Agricultural Landscape Research, Eberswalder Straße 84, 15374 Müncheberg, Germany

[2] University of Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany

[3] University of Göttingen, Büsgenweg 2, 37077 Göttingen, Germany

[4] Helmholtz Centre for Environmental Research-UFZ, Brückstraße 3a, 39114 Magdeburg, Germany

Managing environmental resources under climate change requires analytical tools that characterize complex dynamics across multiple temporal and spatial scales. High-frequency networks generate data-rich time series linking water, climate, ecosystems and land use. However, these datasets challenge quality control based on manual inspection and fixed thresholds, as anomalies, non-linear dynamics, overlapping drivers, and scale mismatches can obscure process interactions. This study presents a diagnostic, data-driven workflow that reduces complexity while characterizing process interdependencies without a priori model assumptions. We combine Principal Component Analysis (PCA) with Self-Organizing Maps and Sammon Mapping (SOM-SM) for nonlinear dimensionality reduction and visualization. The workflow projects high-dimensional datasets into diagnostic spaces, revealing statistical fingerprints and structural anomalies. The methodology was evaluated in two contrasting sites in Germany. In the Bode River Basin, seven years of 15-minute water-quality data from five stations showed PCA components linked to discharge seasonality, land-use contrasts, agricultural nitrate dynamics, saline groundwater inputs, and turbidity responses. At an experimental farm in Göttingen, SOM-SM integrated soil, atmospheric, energy-balance, and groundwater-related variables, separating water-related dynamics from thermal structures while highlighting potential sensor anomalies and regime shifts. Overall, the framework offers a scalable basis for assessing resource interdependencies across sectors and monitoring contexts, supporting hypothesis generation, and cross-sectoral assessment under uncertainty. It provides evidence for adaptive resource management within integrated nexus governance.

Abstracts

335 | Building Climate-Resilient WASH Systems in Nepal: A Nexus Assessment of Climate Risks, Impacts, and Adaptation Gaps

Resham Jung, Singh[1, 2]; Nurazim, Ibrahim[1]; Vishnu Prasad, Pandey[3]

[1] Kuala Lumpur University of Science and Technology (KLUST), De Centrum City, Jalan IKRAM-UNITEN, Kajang, Selangor Darul Ehsan 43000, Malaysia

[2] Signature Engineering Pvt. Ltd., Lalitpur, Nepal

[3] Department of Civil Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Lalitpur, Nepal

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Climate change intensifies hydro-meteorological hazards threatening community-managed WASH systems in Nepal. Critical gaps persist between policy intent and operational resilience. The mixed-methods study across three physiographic regions (high-mountain (Jumla), middle-mountain (Baglung), and hill (Sindhuli)), integrated: (i) historical climate analysis (1994–2024) and CMIP6 projections under SSP245 and SSP585; (ii) surveys with 103 Users Committee members and 103 caretakers assessing climate perceptions and sustainability; (iii) adaptation practices survey with 402 households; and (iv) systematic policy review. Results reveal 63% of water sources are depleted and 5% dried up, with only 3% of systems performing satisfactorily and 32% of taps functioning well. Historical trends report rising temperatures and declining precipitation. Future climate projections show a steady increase in temperature. By 2100, in Sindhuli, summer temperatures may rise by 5.3°C under SSP585, intensifying droughts, while Jumla faces winter warming up to 7.3°C, threatening snowmelt-dependent sources. Future precipitation extremes are projected to increase rapidly, increasing floods and landslides in all study areas. Policy analysis reveals moderate governance but limited institutional capacity, financing, and coordination. Community adaptations like source protection, water rationing, and rainwater harvesting remain fragmented and insufficient. Climate extremes are already undermining WASH functionality and sustainability, yet the enabling environment remains constrained. This research proposes an integrated resilience framework embedding climate projections into planning, financing, and implementation, offering actionable pathways for climate-resilient WASH systems in Nepal.

336 | Quantifying Water–Land–Climate Interdependencies to Anticipate Policy Rebound: Coupled Scenario Modelling for Water Security in a Water Stressed Basin

Arash, Malekian[1, 2]; Bing, Liu[1]; Elaheh, Ghasemi Karakani[2]

[1] State Key Laboratory of Ecological Safety and Sustainable Development in Arid Lands, China and Iran Joint Laboratory on Agriculture and Ecology in Arid Regions, Linze Inland River Basin Research Station, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou 730000, China

[2] University of Tehran,Iran

Water, land, food, and ecosystems are deeply interconnected: policy interventions in one sector cascade across the others. Irrigation efficiency improvement exemplifies this challenge - its basin-scale outcome depends on the land-use responses it triggers, yet these cross-sectoral feedbacks are rarely quantified before implementation. We couple the Dyna-CLUE land-use change model with the InVEST water-yield model to quantify water-land-climate interdependencies in Iran's North Karun River Basin, supplying ~20% of national surface runoff. Calibrated on 1999-2020 data, the framework projects coupled dynamics to 2050 under a scenario matrix crossing three irrigation-efficiency interventions (efficiency raised from 35% to 50%, 70%, 85%) with three climate pathways (SSP2.6, SSP4.5, SSP8.5), explicitly confronting deep uncertainty. Historical analysis attributes a 55% streamflow decline to a 59.9% loss of forest cover and a 327% expansion of water-intensive orchards, showing land-use change can eclipse climate signals. Under business-as-usual, water yield declines a further 39.3% by 2050. All interventions reverse this decline, but gains are climate-contingent: 28% under SSP2.6 versus 11.9% under SSP8.5. Critically, the coupled model quantifies a cross-sectoral trade-off invisible to single-sector analysis: at the highest efficiency level, freed water enables an 8% net orchard expansion - a rebound effect partially offsetting the intended conservation gain. Translating model outputs into actionable insights for policy, we propose transferable safeguards: binding consumptive-use caps, land-use limits on high-water-demand crops, and valuing upland forests as hydrological infrastructure - a replicable methodology for evidence-based water governance in semi-arid basins.

Abstracts

350 | Adoption of Water-Saving Irrigation and Sustainable Land Management Practices: Impacts on Farm Revenue in Uzbekistan

Svetlana Rajabova[1]; Muhammad Bilal[1]

[1] WIUT Business School, Westminster International University in Tashkent, Tashkent, Uzbekistan

Sustainable agricultural practices and technologies (SAPs) are increasingly important for addressing water scarcity, soil degradation, and climate challenges in agriculture. However, evidence on their economic impacts remains limited in Central Asia, particularly in Uzbekistan. This study evaluates the effect of adopting water-saving irrigation technologies (drip and sprinkler irrigation) and land management practices (low tillage and sustainable manure application) on farm revenue among commercial farmers in Uzbekistan. Using data from the 2024 UzFarmBarometer survey of 1,216 farms (421 SAP adopters and 795 non-adopters) across four regions, we apply an Endogenous Switching Regression model to account for self-selection in adoption decisions. Descriptive comparisons show higher average revenue among adopters. However, the econometric results reveal significant negative selection bias, indicating that farmers facing greater production constraints are more likely to adopt SAPs. After controlling this selection, adoption is associated with a negative and statistically significant average treatment effect on the treated (ATT = -0.12), suggesting short-term revenue losses among adopters. This means that SAPs adoption in Uzbekistan is primarily a response to climate and production challenges rather than a choice driven by higher economic performance. We find that access to water-efficiency training is the strongest factor increasing adoption, while cooperative membership improves farm revenue but does not encourage adoption. These findings highlight the importance of complementary policies, including farmer training, improved institutional support, and financial mechanisms, to enhance the economic viability of SAPs and strengthen climate resilience in water-scarce regions.

360 | Forest canopy and artificial shade buffer frost impacts on planted tree seedlings in tropical montane forest restoration

Dalma, Orellana-Peralta[1, 2]; Marijn,?Bauters[1]; Hans, Verbeeck[1]; Thomas, Sibret[1]; Mike, Perring[4]; Selene, Báez[3]; Sebastián, Tello[5]; Ximena, Palomeque[2]

[1] Q-?ForestLab, Department of Environment, Ghent University, 9000, Ghent, Belgium

[2] Departamento de Recursos Hídricos y Ciencias Ambientales, Facultad de Ciencias Agropecuarias de la Universidad de Cuenca, Cuenca, Ecuador

[3] Escuela Politécnica Nacional, Quito, Ecuador

[4] UK?centre?of?Ecology,?and?Hydrology,? United Kingdom

[5] Missouri?Botanical?Garden?, United States

Tropical montane forests are biodiversity-rich ecosystems that provide ecosystem services, including water regulation, but have been extensively reduced by conversion to cattle pastures. Restoring these landscapes is a major conservation priority, yet tree planting can be constrained by harsh microclimatic conditions. At high elevations, near-ground freezing may represent an important but poorly quantified barrier to seedling establishment.

We investigated frost exposure across a 1000-m elevational gradient (~2300–3300 m a.s.l.) in the tropical Andes of southern Ecuador and its relationship with planted seedling performance. At three elevations, plots were established in forest, artificially shaded pasture, and open pasture, with 1,944 seedlings of five native tree species. Air temperature was continuously recorded 15 cm above ground. Frost duration and intensity were integrated into a Frost Intensity Index (FII) and related to seedling condition and survival.

Frost exposure varied strongly across elevation, treatment, and time. No frost occurred at the lowest elevation or beneath forest canopy. At higher elevations, frost occurred predominantly in open pasture and was reduced by artificial shade, with temperatures reaching -8.5 °C during the most severe period. Higher cumulative frost exposure was associated with lower seedling survival and poorer condition.

Our findings identify frost exposure as an important constraint on tropical montane forest restoration, potentially acting as a bottleneck to seedling establishment, and show that microclimatic buffering, even through artificial shade nets, reduces frost impacts on seedlings, thereby improving restoration success.

Abstracts

361 | Understanding the Drivers and Mechanisms of Water Scarcity through an Integrated Water–Energy–Food–Ecosystem Nexus Framework

G E, Nagashree[1]; Saroj, Chapagain[3]; Daniel, Karthe[3, 4, 5]; Ashutosh, Sharma[1, 2]

[1] Department of Hydrology, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, 247667, India

[2] International Centre of Excellence for Dams (ICED), Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, 247667, India.

[3] Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES), United Nations University, 01067, Dresden, Germany

[4] Faculty of Environmental Sciences, TUD Dresden University of Technology, 01187, Dresden, Germany.

[5] Faculty of Raw Materials and Environmental Engineering, German-Mongolian Institute for Resources and Technology (GMIT), Nalaikh District, Ulaanbaatar, 12800, Mongolia

Water scarcity has emerged as a critical global concern resulting from the combined influence of hydrological and human-induced pressures. Developing effective mitigation strategies requires a comprehensive understanding of these interactions, yet their interconnected, nonlinear, and dynamic behaviour across multiple sectors remains difficult to capture. In this study, the Water-Energy-Food-Ecosystem nexus was systematically developed as an integrated conceptual framework and coupled with a Simultaneous Equation Model (SEM) to quantify the causal relationships governing water scarcity. Rather than analysing individual factors independently, the proposed framework reveals interdependencies among key drivers, traces their cascading effects, and identifies causal pathways whose influence changes under different system conditions. The framework was applied to the Mahi River Basin (MRB), India, to evaluate the dominant processes shaping water scarcity. Results showed that anthropogenic factors, particularly urban population growth, agricultural expansion, and urban development, exert a stronger influence on water scarcity than climatic and hydrological drivers, including precipitation and river discharge. Furthermore, the same leverage factors generated demand-induced water scarcity in the upper sub-basin but hydrologically controlled scarcity in the lower sub-basin. Uncertainty analysis confirmed the robustness of the framework, while system dynamics simulations demonstrated that coordinated, cross-sectoral interventions are necessary to effectively alleviate water scarcity. Overall, the proposed methodology offers a transferable framework for analysing coupled human–water systems and supporting integrated decision-making for sustainable water resource management.

371 | Assessing the impact of agricultural virtual water exports on water security in the Indian Indus River Basin (I-IRB): A Resource Nexus perspective on food-water-trade

Aakash Kumar, Subramaniyan[1,2]; Daniel, Karthe[1,2,3]; Serena, Coetzee[1,2,4]

[1] United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES), Dresden, Germany

[2] Technische Universität Dresden, Dresden, Germany

[3] Faculty of Engineering, German-Mongolian Institute for Resources and Technology (GMIT), Nalaikh, Mongolia

[4] Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Pretoria, South Africa

The interaction between crop production, water use, and agricultural trade plays a critical role in shaping a region's water security. In water scarce regions, such as the Indian Indus River Basin, export of water-intensive crops may boost local economies but exacerbate hydrological stress, threatening water security. Virtual water estimates quantify the volumes of embedded water trade but do not capture their impact on regional water security. This study assessed the magnitude and geospatial distribution of agricultural virtual water exports and their impact on regional water security in the Indian Indus River Basin. A multidimensional water security assessment based on DPSIR (drivers, pressures, state, impact and response) framework was conducted at the district level and integrated with virtual water export accounting based on crop water estimates from FAO's CROPWAT 8.0. A geospatial analysis of agricultural and socio-hydrological datasets from 2015-2025, with a particular focus on export-oriented water intensive crops such as rice, identified hotspots of red virtual water exports, revealing districts where such exports are not sustainable. The study reexamined water security under alternative management and policy interventions like crop diversification, improved irrigation efficiency, and modified trade policies, by studying the potential synergies and trade-offs. The findings provide insights into the role of export-oriented crop production in regional water insecurity and suggest strategies for sustainable management of environmental resources in the basin. By assessing water, food and trade from a Resource Nexus perspective, this study supports the development of evidence-based policies for the balanced and sustainable use of environmental resources.

Abstracts

387 | From Network Design to Community Action: Operationalizing a Health-Driven Groundwater Monitoring Network Through Citizen Science in the Comarca Lagunera, Mexico

Heriberto, González-Sánchez[1]; Antonio, Cardona-Benavides[2]; Jorge, Aceves-de Alba[2]; Javier, Castro-Larragoitia[2]; Silvia, Romero-Contreras[3]

[1] Autonomous University of San Luis Potosi, Multidisciplinary Graduate Program in Environmental Sciences, San Luis Potosi, Mexico

[2] Autonomous University of San Luis Potosi, Engineering Faculty, Earth Science Department, San Luis Potosi, Mexico

[3] Autonomous University of San Luis Potosi, Psychology Faculty, San Luis Potosi, Mexico

As climate change intensifies reliance on groundwater in semi-arid regions, chronic exposure to geogenic arsenic and fluoride — the primary drinking water source for 1.6 million residents of the Comarca Lagunera in North-Central Mexico — remains a serious public health concern requiring community-driven strategies beyond conventional monitoring. This study presents a citizen science protocol designed as a participatory complement to a previously developed, health-driven priority network of 39 core wells. It demonstrates how this complementarity can be operationalized through capacity-building across two academic cycles (2025–2026) at a local university, training 30 students. Co-managed with a regional water-rights NGO and a research partner, the protocol unfolds through four sequential phases — technical diagnosis, stakeholder engagement, integration, and implementation — instructing volunteers, researchers, and policymakers in field-based sampling and analysis. Coursework paired hands-on rapid arsenic screening with confirmatory laboratory analysis, embedded within 96 hours of academic credit requirements. By deliberately mixing early- and final-semester students, the protocol built a self-replicating cohort: graduates have already sampled public supply wells independently, testing their skills under real operating conditions. The next phase will extend citizen-led sampling to those priority wells, treating participation itself as a governance indicator. These results show how participatory monitoring can operationalize and complement a health-driven network design, yielding a transferable framework for geogenically contaminated semi-arid regions of Latin America facing climate uncertainty, and advancing SDG 6 and SDG 3.

389 | Morphometric characterization and multifractal analysis of the river basins of the Colombian Orinoquia using SRTM digital elevation models and automated geospatial processing

William A., León-Rueda[1]; Douglas A., Gómez-Latorre[1, 2]; Nelson, Obregón Neira[3]

[1] Facultad de Ciencias Agrarias, Universidad Nacional de Colombia, Bogotá, Colombia

[2] Corporación Colombiana de Investigación Agropecuaria - AGROSAVIA, Mosquera, Colombia

[3] Facultad de Ingeniería, Pontificia Universidad Javeriana, Bogotá, Colombia

This study presents an automated and scalable process for morphometric characterization and multifractal analysis of 73 sub-basins in the river network of the Colombian Orinoquia. Digital elevation models (DEMs) with a resolution of 30 m were obtained from the Shuttle Radar Topography Mission (SRTM) via the Google Earth Engine cloud processing service and processed using the WhiteboxTools geospatial library. For each basin, Horton's morphometric laws were calculated—including the bifurcation ratio (R_B), the stream length ratio (R_L), and the drainage area ratio (R_A)—derived directly from the Strahler stream order grid and connected-component analysis. For the width function of each basin, mass exponents and the multifractal spectrum were estimated. The results reveal systematic variations in network complexity across the biogeophysical sub-basins of the Orinoquía. The automated, iterative framework enables reproducible geomorphological characterization at the sub-basin scale at a regional level. These results support the conceptualization process of different modeling approaches, both physically based and data-driven, for future studies of climate-risk resilience.

Abstracts

391 | Hydroclimatic Drivers of Agricultural Water Demand in a Brazilian Semiarid Region: Insights from Water Footprint Assessment

Jocimar, Coutinho Rodrigues Junior[1]; Bruna, Scandolara Magnus[2]; Mario Takayuki, Kato[2]; Maria de Lourdes, Florencio dos Santos[2]

[1] Federal University of Southern Bahia, Rodovia Ilhéus/Itabuna, km 22, 45604-811 Ilhéus-BA, Brazil

[2] Federal University of Pernambuco, Av. Helio Ramos s/n , 507540-530 Recie-PE, Brazil

Climate variability poses challenges to agricultural water security in semiarid regions by altering the balance between rainfall availability and irrigation demand. Identifying the hydroclimatic drivers of agricultural water use is essential for climate adaptation and sustainable water management. This study investigated the influence of hydroclimatic variables on the water footprint (WF) of sweet potato cultivation in the Ipojuca Valley, northeastern Brazil, during 2010–2019. The WF was estimated following the methodology proposed by Hoekstra et al. (2011), distinguishing Green (rainfall-derived) and Blue (irrigation-derived) water use, as well as the Total Water Footprint. Pearson correlation analysis evaluated relationships between WF components and precipitation, surface runoff, crop evapotranspiration, mean air temperature, relative humidity, and mean daily sunshine duration. The Green Water Footprint was positively correlated with precipitation ($r = 0.557$) and, particularly, surface runoff ($r = 0.931$), reflecting its direct dependence on natural water availability. In contrast, the Blue Water Footprint showed negative correlations with precipitation ($r = –0.635$), surface runoff ($r = –0.626$), and relative humidity ($r = –0.676$), and a positive correlation with sunshine duration ($r = 0.599$), indicating increased irrigation demand under drier hydroclimatic conditions. The Total Water Footprint was most strongly associated with mean air temperature ($r = 0.457$) and crop evapotranspiration ($r = 0.357$). These findings demonstrate that hydroclimatic variability is a key driver of agricultural water demand and highlight the Water Footprint as an effective decision-support tool for climate-resilient irrigation management and strengthening water security in semiarid regions.

397 | Integrating Water Quality Modeling and Multi-Criteria Decision Analysis for Climate-Resilient Watershed Management: A Case Study from Northeastern Brazil

Jocimar, Coutinho Rodrigues Junior[1]; Simone, Machado Santos[2]; Mario Takayuki, Kato[2]; Maria de Lourdes, Florencio dos Santos[2]

[1] Federal University of Southern Bahia, Rodovia Ilhéus/Itabuna, km 22, 45604-811 Ilhéus-BA, Brazil

[2] Federal University of Pernambuco, Av. Helio Ramos s/n , 507540-530 Recie-PE, Brazil

Water quality degradation caused by untreated wastewater discharges and inadequate sanitation services poses a major challenge to water security in the Ipojuca River Basin in northeastern Brazil. Decision-support tools that integrate pollution control, environmental targets, and investment priorities are therefore essential for climate-resilient watershed management. This study combined the Total Maximum Daily Load (TMDL) approach with Multi-Criteria Decision Analysis (MCDA) to evaluate pollution reduction scenarios and prioritize municipalities for sanitation interventions. The TMDL model simulated progressive reductions in organic matter and nutrient loads from domestic, industrial, agricultural, and livestock sources, while the MCDA incorporated indicators related to sanitation coverage, operational performance, financial capacity, and water quality. Results showed that isolated reductions from individual pollution sources were insufficient to restore water quality. In contrast, integrated mitigation scenarios involving reductions greater than 75% across all pollution sources achieved more than 70% compliance with dissolved oxygen and biochemical oxygen demand targets, supporting the feasibility of progressive water quality goals. Phosphorus remained the most critical parameter, particularly during the rainy season, indicating the need for complementary nutrient management strategies. The MCDA also identified municipalities requiring priority investments in sanitation infrastructure, with São Caetano and Bezerros ranking among the highest priorities. The proposed framework provides a practical basis for prioritizing sanitation investments, supporting progressive water quality restoration, and strengthening climate-resilient watershed governance.

Abstracts

398 | Hydroclimatic Vulnerability of Rainfed Sugarcane Cultivation Across a Humid-to-Semiarid Gradient in Northeastern Brazil

Barbara, Albuquerque Branco de Moraes[1]; Jocimar, Coutinho Rodrigues Junior[2]; Mario Takayuki, Kato[1]; Maria de Lourdes, Florencio dos Santos[1]

[1] Federal University of Pernambuco, Av. Helio Ramos s/n , 507540-530 Recie-PE, Brazil

[2] Federal University of Southern Bahia, Rodovia Ilhéus/Itabuna, km 22, 45604-811 Ilhéus-BA, Brazil

Hydroclimatic variability poses major challenges to agricultural production and water security in tropical regions, highlighting the need for climate adaptation strategies based on local water availability. This study assessed the hydroclimatic vulnerability of sugarcane cultivation across a humid-to-semiarid gradient in the Ipojuca River Basin, northeastern Brazil, encompassing the humid Zona da Mata and transitional Agreste regions. Monthly meteorological data (2010–2019), including precipitation, air temperature, sunshine duration, wind speed, and relative humidity, were analyzed. Potential evapotranspiration was estimated using the Thornthwaite–Mather method, and the climatological water balance assumed a soil water storage capacity of 100 mm. Hydroclimatic suitability was evaluated using water, aridity, and humidity indices from the Brazilian Agroclimatic Zoning. The Agreste exhibited a pronounced water deficit, with annual precipitation (604 mm) substantially lower than potential evapotranspiration (1,440 mm), resulting in persistent dry conditions and classification as unsuitable (C5) for rainfed sugarcane. In contrast, the humid Zona da Mata received 2,050 mm of annual rainfall, exceeding potential evapotranspiration (1,558 mm), generating seasonal water surpluses and a C2 classification, indicating favorable conditions for sugarcane production. Evapopluviograms corroborated the contrasting seasonal water balance patterns across the basin. These findings identify water availability as the main driver of hydroclimatic vulnerability and provide scientific support for climate-resilient agricultural planning, indicating the need for irrigation in the Agreste and improved drainage in the Zona da Mata, to strengthen water security under increasing climate variability.

399 | Spatial Analysis of Climate Risk for Water Security in the Colombian Orinoco Basin

William Alfonso, Leon Rueda[1]; Jesús Efrén, Ospina Noreña[1]; Victor Orlando, Rincon Romero[1]; Juan Carlos, Barrientos Fuentes[1]

[1] Universidad Nacional de Colombia, Facultad de Ciencias Agrarias, Departamento de Agronomía, Bogotá, Colombia.

Increasing climate variability and changes in hydrometeorological patterns pose significant challenges to water security in complex socioecological systems. Understanding these interactions requires quantitative approaches integrating spatial data within reproducible frameworks. This study develops a spatial assessment of climate risk in the Colombian Orinoco basin, aiming to identify priority areas for adaptation and territorial planning.

The analysis is based on the IPCC AR6 conceptual framework, in which risk arises from the interaction between climate hazard, exposure, and vulnerability. Hazard is represented through climate variables related to precipitation, temperature, and climate variability. Exposure incorporates potentially affected territorial elements, such as agricultural land cover, strategic ecosystems, and areas of interest for the provision of water-related ecosystem services. Vulnerability is estimated using biophysical indicators derived from remote sensing and geospatial data, including land cover, vegetation indices, slope, and adaptive-capacity variables.

The indicators are standardized and integrated through a multi-criteria approach to build spatial indices of hazard, exposure, vulnerability, and climate risk. The results allow the identification of spatial risk patterns and the pinpointing of areas where the convergence of high hazard, elevated exposure, and greater vulnerability could compromise regional water security.

The study contributes to water-climate-territory nexus approaches through a reproducible methodology based on open-access geospatial data, providing spatial evidence to support planning processes, the prioritization of adaptation measures, and the strengthening of resilience to climate change in the Colombian Orinoco basin.

Abstracts

406 | Linking Forms of Power with Actor-Centred Mechanisms in Polycentric Water Governance: Evidence from Mount Kilimanjaro

Manuel Francisco Diaz[1]; Andreas Thiel[1]

[1] University of Kassel, Steinstraße 19, 37213 Witzenhausen, Germany

Water security requires coordination among interdependent users, but this process is neither politically neutral nor inherently equitable. While polycentric systems disperse authority, how power concentrates and translates into practice remains poorly understood. To open this 'black box,' we develop a framework bridging Morrison's macro-typology of power with the micro-foundations of the Actor-Centred Power (ACP) approach. While Morrison locates power within rule-setting (by design), implementation (pragmatic), and discourse (framing), ACP empirically tracks their relational enforcement via coercion, incentives, and dominant information. We apply this framework in the Karanga subcatchment, Tanzania, combining 52 surveys mapping 71 actors with qualitative interviews. The analysis reveals that actor-centred mechanisms cross-cut governance functions: While basin authorities wield legal coercion and dominant information to shape power by design through permits, village authorities and furrow leaders exercise pragmatic power through selective enforcement. ACP metrics show an "equality of weakness" in incentives, indicating the absence of a dominant potentate. Crucially, pragmatic coercive power is highly concentrated upstream but becomes significantly more dispersed downstream. By exposing these localised discrepancies, the framework provides a transferable diagnostic of where dispersed authority masks concentrated power, which actors enable or obstruct water-security goals, and how institutional redesign can strengthen equity and accountability across nexus settings.

426 | Supporting Water Security through Forest Transformation: Quantifying Soil Water Availability in Climate-Adapted Forests

Camila Zamora[1]; Katja Skibbe[3]; Romy Rehschuh[4]; Goddert von Oheimb[4]; Sven Wagner[3]; Karsten Kalbitz[2]; Natalie Orlowski[1]

[1] Chair of Forest Sites and Hydrology, Institute of Soil Science and Site Ecology, TU, Dresden, Tharandt, Germany

[2] Chair of Soil Resources and Land Use, Institute of Soil Science and Site Ecology, TU Dresden, Tharandt, Germany

[3] Chair of Silviculture, Institute of Silviculture and Forest Protection, TU Dresden, Tharandt, Germany

[4] Chair of Biodiversity and Nature Conservation, Institute of General Ecology and Environmental Protection, TU Dresden, Tharandt, Germany

Climate change is increasing droughts across Central Europe, threatening forest resilience and water-related ecosystem services. Forest transformation has emerged as a nature-based solution; however, the extent to which forest structure, site conditions, and soil properties jointly regulate soil water availability remains poorly quantified. This knowledge is essential for developing strategies that strengthen long-term water security for forests in central Europe.

This study presents results from the "Waiklim project", a monitoring network across 14 forest sites in Saxony, Germany, including beech, pine, and pioneer forests representing different degrees of stand opening created by thinning. High-resolution measurements of soil water availability, precipitation, canopy cover, site and stand characteristics, and soil properties were integrated to evaluate whether forest transformation through thinning enhances soil water availability under heterogeneous conditions.

Results indicate that canopy cover is a primary driver of soil water availability. Stands with larger canopy openings showed higher water availability due to reduced interception losses and less transpiration. The interaction between canopy cover and soil properties explained much of the observed spatial variability, while contrasting responses between pine and beech forests revealed species-specific hydrological functioning. Overall, stands with larger canopy openings were most effective in maximising soil water availability.

These findings demonstrate that forest management can guide thinning practices to improve soil water availability, contributing to climate-smart forest management and strengthening water security through nature-based solutions.

Abstracts

429 | Linking Surface Energy fluxes to Flash Drought and Terrestrial Water Storage Dynamics in the Humid Tropics

Linitha, Nair[1]; Ajithkumar, Balakrishnan[2]; Suzanne, Robin Jacobs[3, 4]; Ajaykumar, Vayalvadi Chandran[1]; Archana, Raghavan Sathyan[5]; Lutz, Breuer[3, 4]

[1] Department of Agricultural Meteorology, College of Agriculture, Vellayani, Kerala Agricultural University

[2] Department of Agricultural Meteorology, College of Agriculture, Vellanikkara, Kerala Agricultural University

[3] Institute for Landscape Ecology and Resources Management (ILR), Research Centre for BioSystems, Land Use and Nutrition (iFZ), Justus Liebig University Giessen, Germany

[4] Center for International Development and Environmental Research, Justus Liebig University Giessen, Germany

[5] Department of Agricultural Extension Education, College of Agriculture, Vellayani, Kerala Agricultural University

Conventional drought indicators often fail to capture rapid flash drought onset. In humid tropics, the progression from land atmosphere energy imbalance to deep regional water storage depletion is poorly understood. This study aims to trace flash drought across humid tropics of Kerala, Southwest India (2003–2024) using a multi-layer hydroclimatic framework. Weekly Bowen ratio anomalies(ß') derived from ERA5-Land heat fluxes were merged into a master dataset alongside the 4-week Evaporative Stress Index (ESI), GLDAS-2.1 Noah volumetric water content (VWC at 0–10 and 10–100 cm), and GRACE-FO terrestrial water storage (TWS) anomalies. Flash drought onset defined by 4-week ESI change≤–1.5 and surface soil moisture Z score≤–0.5, identified 308 flash drought onset events across 7968 weekly gridded observations of hydroclimatic variables, which could validate the predictive power of the Bowen ratio. Bowen ratio spikes sustained for two consecutive weeks (Δß ≥ 0.05 and ß' ≥0.15) served as early surface energy precursors of flash drought onsets within three week predictive window successfully flagging 118 out of 713 warning windows preceding onset. Though sensitivity(16.5%) shows thermal anomalies precede only a specific subset of rapid drought transitions, the low false alarm rate(7.9%) establishes it as a dependable, early-warning signal of surface drying. Downstream monthly macro-scale analysis revealed tight coupling between the drought footprint and deep groundwater depletion, peaking at same month (r= –0.28) than later months. Months exceeding 10% drought coverage exhibited mean TWS anomaly of –9.67 ± 0.58 cm. This study proves that global gridded datasets can diagnose onset and progression of flash drought in data-scarce regions making it ideal for macroscale monitoring.

435 | Nature-Based Solutions for Water Security and Climate Resilience: Integrating Land-Use Change, Ecosystem Services and Carbon Storage in a Tropical Coastal Zone

Jocimar Coutinho Rodrigues Junior[1]; Simone Machado Santos[2]; Elvis Carissimi[3]; Mário Takayuki Kato[2]; Lourdinha Florencio[2]

[1] Federal University of Southern Bahia, Rodovia Ilhéus/Itabuna, km 22, 45604-811 Ilhéus-BA, Brazil

[2] Federal University of Pernambuco, Av. Helio Ramos s/n , 507540-530 Recie-PE, Brazil

[3] Federal University of Santa Maria, Av. Roraima, 1000 - 97105-700 Santa Maria-RS, Brazil

Coastal ecosystems are essential for water security and climate resilience by regulating hydrological processes, storing carbon, and providing critical ecosystem services. However, rapid urban expansion threatens these functions in tropical coastal regions. This study evaluated the effects of land-use change on ecosystem services and carbon storage in Pernambuco's coastal zone, northeastern Brazil, to support nature-based solutions for climate adaptation and sustainable management. Land-use and cover dynamics were assessed using MapBiomas data for 1985, 1995, 2005, 2015, and 2023, with 2050 projections generated via the MOLUSCE module in QGIS. Ecosystem service potential was evaluated using the Ecosystem Service Potentials, Flows and Demands framework, while carbon storage was estimated with the InVEST Carbon Storage and Sequestration model. Results revealed substantial urban expansion and a marked reduction in agricultural land, while forest cover expanded in parts of the study area. Despite rapid urban growth, total carbon storage increased from 59.30 to 61.52 million tons between 1985 and 2023 and is projected to reach 61.85 million tons by 2050, indicating that conserving natural ecosystems helped maintain carbon storage despite urbanization. Mangroves, forests, and wetlands exhibited the highest potential for climate regulation, water retention, and biodiversity conservation, highlighting co-benefits between ecosystem conservation, water security, and climate mitigation, reinforcing their role as nature-based solutions. These findings demonstrate that integrating spatial analysis, ecosystem service assessment, and carbon modeling provides a framework for resilient coastal planning and ecosystem-based management under increasing urbanization and climate change.

Abstracts

437 | Long-Term Assessment of Water Quality in the Ipojuca River Basin (Brazil) Using the Water Standards Compliance Index (WSCI)

Jocimar Coutinho Rodrigues Junior[1]; Anderson Luiz Ribeiro de Paiva[2]; Mario Takayuki Kato[2]; Lourdinha Florencio[2]

[1] Federal University of Southern Bahia, Rodovia Ilhéus/Itabuna, km 22, 45604-811 Ilhéus-BA, Brazil
[2] Federal University of Pernambuco, Av. Helio Ramos s/n , 507540-530 Recie-PE, Brazil

Agricultural, industrial, and urban expansion has progressively impaired water quality in the Ipojuca River Basin, northeastern Brazil, highlighting the need for integrated tools to assess compliance with environmental standards and support watershed management. This study applied the Water Standards Compliance Index (WSCI), an adaptation of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI), to evaluate long-term compliance with Brazilian freshwater quality standards at 12 monitoring stations along the Ipojuca River. A total of 480 water samples collected between 2010 and 2019, covering both dry and wet seasons, were evaluated using eight water quality parameters: dissolved oxygen, biochemical oxygen demand, total phosphorus, ammonia, total solids, pH, turbidity, and chlorophyll-a. Land-use data available for the watershed was used to provide contextual interpretation of the WSCI results. Only three of the twelve monitoring stations fully complied with the applicable water quality standards throughout the study period, while five met the standards in about 80% of the monitoring campaigns and four consistently failed to achieve compliance. The lowest WSCI values were observed in river reaches characterized by intensive agro-industrial activities and higher urban occupation, a spatial pattern consistent with the expected effects of anthropogenic pressures on water quality, particularly during the dry season when reduced streamflow limits pollutant dilution. This adaptation of the CCME WQI provides a practical framework for assessing long-term compliance with water quality standards, identifying priority river reaches for management, and supporting evidence-based decision-making in watersheds subjected to multiple anthropogenic pressures.

438 | Integrating Water Quality and Watershed Sustainability Assessments to Support Water Security in a Tropical River Basin

Laura Gomes da Costa[2]; Jocimar Coutinho Rodrigues Junior[1]; Mário Takayuki Kato[2]; Lourdinha Florencio[2]

[1] Federal University of Southern Bahia, Rodovia Ilhéus/Itabuna, km 22, 45604-811 Ilhéus-BA, Brazil
[2] Federal University of Pernambuco, Av. Helio Ramos s/n , 507540-530 Recie-PE, Brazil

Achieving water security requires integrated assessment frameworks that link water quality, environmental pressures, and watershed governance. This study evaluated the sustainability of the Ipojuca River Basin in northeastern Brazil by integrating multivariate water-quality analysis with the Watershed Sustainability Index (WSI). Water quality data collected between 2006 and 2019, including water temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total phosphorus, ammonia, salinity, conductivity, and fecal coliforms, were analyzed using exploratory factor analysis after preprocessing and imputation of missing values. The adequacy of the analysis was confirmed by the Kaiser–Meyer–Olkin index (0.70). The WSI was calculated for 2018–2022 based on the Pressure–State–Response framework, considering hydrological, environmental, socioeconomic, and governance dimensions. Three major drivers of water quality degradation were identified: urban and industrial wastewater pollution; mineralization associated with agricultural pressures; and the combined influence of temperature and ammonia. Water quality assessment revealed severe impairment, characterized by low DO and high concentrations of BOD, phosphorus, and coliforms. The WSI score of 0.52 indicated intermediate watershed sustainability, constrained by low per capita water availability, limited wastewater treatment coverage, and increasing deforestation in protected areas. Integrating multivariate analysis with sustainability indicators enabled the identification of key drivers of degradation and management weaknesses, providing an effective framework for prioritizing sanitation investments, watershed restoration, and governance actions to strengthen water security amid increasing environmental pressures.

Abstracts

439 | Spatiotemporal analysis of extreme indices derived from daily precipitation and temperature for climate change detection over the Kashkadarya River Basin, Uzbekistan

Erali Abdumajidov[1]; Swatantra Kumar Dubey[1]; Abdulkhakim Salokhiddinov[1]

[1] Tashkent Institute of Irrigation and Agricultural Mechanization Engineers - National Research University, Kari Niyazi-39, Tashkent 100000, Uzbekistan

Climate change has altered the frequency and intensity of temperature and precipitation extremes, affecting water resources and agricultural systems in arid regions. Assessing these changes at the basin scale is essential for understanding regional climate variability and supporting adaptation strategies. This study evaluates spatiotemporal changes in climate extremes across the Kashkadarya River Basin using ETCCDI climate indices generated from the ClimPACT2 platform for 23 representative grid points. Long-term trends were identified using the Mann–Kendall test, while pivot analysis and comparison between the periods 2001–2012 and 2012–2023 were applied to quantify recent changes. The results indicate predominantly positive trends in warm-related indices (SU, TX90p, WSDI, TXx, and TNx) and negative trends in cold-related indices (FD and TN10p), confirming a basin-wide warming pattern. Mean maximum temperature increased by 0.07–2.52°C, whereas mean minimum temperature increased by 0.43–2.64°C, indicating stronger nighttime warming. Annual precipitation exhibited pronounced spatial variability, decreasing by 6–33 mm across most western and central areas but increasing by 4–57 mm in several eastern mountainous locations. Extreme precipitation indices (R95P, R99P, RX3day, and RX5day) also showed increasing tendencies mainly in the eastern basin. These findings demonstrate significant warming accompanied by spatially heterogeneous precipitation changes, providing important evidence for climate adaptation, water-resource management, and agricultural planning in the Kashkadarya River Basin.

453 | Hidden Water Losses in Irrigation Systems: Remote Sensing Evidence and Economic Implications for Agricultural Water Use in Kazakhstan

Rustam, Rakhmetov[1]

[1] Center for Natural Resources and Sustainability, Kazakh-German University, Almaty, Kazakhstan

Water security in Central Asia is heavily threatened by climate change, aging infrastructure, and misgovernance. In Kazakhstan's Kyzylorda region, in the Aral Sea basin, over 40% of agricultural water is lost during transportation, yet the underlying local institutional drivers of the losses and their economic implications remain poorly understood. This study addresses these gaps by implementing unique data and an innovative, interdisciplinary framework that couples institutional analysis, machine learning-based remote sensing, and economic modeling.

First, we mapped agricultural fields and classified crops (rice, wheat, alfalfa) using Sentinel-1 and Sentinel-2 time-series data and identify water consumption by each field and crop type. Second, we compared de facto satellite-measured water consumption against 2,042 de jure Kazvodhoz water contracts (2023–2025). Finally, actual water-use and loss parameters were integrated into an agricultural Partial Equilibrium model to simulate the economic impacts of tariff reforms and physical land caps.

The empirical analysis reveals that actual de facto water use exceeds de jure contracted allocations by 20%, confirming substantial system-wide losses. Policy simulations demonstrate that current 15% annual flat-rate price increases (2023–2025) fail to reduce consumption or incentivize water-saving technologies, rendering regulatory land caps a binding administrative constraint. Conversely, simulating transitioning to volumetric pricing establishes a positive marginal cost, making the land cap non-binding. This volumetric signal shifts water-use to an economically efficient equilibrium, naturally incentivizing technology adoption and reducing system-wide conveyance waste by penalizing inefficiency.

Abstracts

460 | Menstrual Health at the Water–Health–Gender Nexus: Unequal Preparedness in Flood-Prone Bihar, India

Ashutosh, Singh[1]

[1] University of Glasgow, Glasgow, United Kingdom

Menstrual health is rarely treated as a water-security concern in climate adaptation, although recurrent floods disrupt the water, sanitation, mobility and household arrangements through which menstruation is managed. This paper examines these interdependencies in two flood-prone villages in Bihar, India.

The study draws on qualitative in-depth interviews with women, male household members and community gatekeepers. Reflexive thematic analysis combined inductive coding with intersectional and stigma-informed sensitising concepts, followed by constant comparison across participant groups and negative-case analysis. Current cross-case analysis identifies three linked mechanisms. First, flood-related water insecurity is experienced through loss of privacy, difficulties washing and drying materials, unsafe disposal, and constrained mobility, rather than through water scarcity alone. Second, recurrent exposure generates anticipatory practices, including storing menstrual materials and preparing separate emergency supplies, but the capacity to prepare depends on income, housing, sanitation and household support. Third, infrastructure failures operate cumulatively: damaged roads, electricity loss and disrupted communication can reduce access to health workers, markets and relief.

The paper argues that menstrual health reveals an intimate and neglected dimension of the water-health-gender nexus. It proposes that local flood preparedness should integrate menstrual materials with safe water, private changing and disposal facilities, accessible communication, and frontline-worker coordination, while recognising that households have unequal capacities to act on preparedness advice.

461 | Robust decision-making for emergency water supply planning under parametric, structural, and deep uncertainty

Steins, Ella[1]; Cominola, Andrea[1]

[1] Technical University Berlin, Straße des 17. Junis 135, 10623 Berlin, Germany

Emergency water supply planning is central to critical infrastructure resilience against hazards such as droughts, contamination, power outages, cyberattacks, and floods. In Germany, infrastructure planning is largely expert-based and semi-quantitative, relying on guidance provided, for instance, by the Federal Office of Civil Protection and Disaster Assistance (BBK). While accessible to practitioners, these frameworks rely on deterministic, simplified assumptions, potentially leading to overconfident preparedness decisions in deeply uncertain scenarios.

Pairing the BBK approach with uncertainty quantification, we introduce an uncertainty-aware decision framework based on a two-step model, and demonstrate it in a case study near Frankfurt (Germany). Upstream, a fuzzy analytical hierarchy process captures deep and structural uncertainty, turning expert knowledge into probabilistic emergency scenarios; downstream, a dynamical model reacts to each state, optimizing measures such as mobile pipes and transportation via linear programming under parametric uncertainty. Using a two-stage pre-positioning robust optimization formulation, we assess how preparedness decisions vary among different uncertainty representations and show that the expected value of partial perfect information reveals the most decision-relevant sources of uncertainty.

Preliminary results show that preparedness is sensitive to the robustness criterion and structural uncertainty, both of which lie outside the scope of deterministic frameworks such as BBK's. Our framework assesses which sources — parametric, structural, or deep uncertainty — can improve expert-based emergency water planning and adds to the broader discussion on uncertainty-aware decisions in critical water infrastructure.

Abstracts

474 | Integrated Water Resources Management in the Southern Ecuadorian Andes: Addressing Emerging Water Challenges using the Nexus approach

Rolando, Célleri[1]

[1] Universidad de Cuenca, Av. 12 de Abril, Cuenca, Ecuador

Andean cities and communities are situated at headwaters and as a result, they rely on water sourced from small to medium size catchments, making them particularly vulnerable to changes in the hydrological cycle and changes in land use. Tropical Andean ecosystems, including páramos and cloud forests, have historically provided a reliable and sustained water supply for downstream populations. However, ongoing land cover change, unsustainable land use practices, and increasingly erratic weather patterns are placing this vital resource under growing pressure. This study presents the experience of the Machángara River Watershed Management Council, which, after more than 20 years of operation, represents one of the most successful examples of integrated water resources management in southern Ecuador. Within this framework, multipurpose reservoirs are managed to support hydropower generation, drinking water supply, and irrigation while addressing water and land use challenges through an interinstitutional and interdisciplinary governance approach. This has ensured water supply to the different users even during drought conditions. However, deforestation, wetland drainage, rainfall-induced landslides, and extreme events will severely compromise water availability; thus new approaches to manage uncertain conditions are needed.

475 | Quantifying Hydrological Functioning across Tropical Environments: From Observations to Integrated Assessments

Alicia Correa[1]

[1] Centre for International Development and Environmental Research (ZEU), Justus Liebig University, 35390 Giessen, Germany

Tropical environments sustain water resources, ecosystem services, and climate resilience, yet their hydrological functioning remains insufficiently understood because of limited observations and environmental heterogeneity. Advancing quantitative hydrology requires integrating observations and modelling across tropical settings.

This contribution presents a framework developed across humid rainforests, tropical mountains, glacier-influenced catchments, and seasonally dry landscapes. It combines hydrometric observations, environmental tracers, hydrochemical information, spatially distributed hydrological models, and cross-site comparison. The analyses identified near-surface flowpaths and hydrological connectivity as dominant controls of runoff generation, demonstrated the disproportionate influence of headwaters on downstream streamflow, quantified variability in storage dynamics and water ages, and revealed recurring controls on water storage, mixing, and release despite contrasting hydroclimatic conditions. These findings improve process identification beyond discharge-based analyses and strengthen the representation of hydrological functioning in data-scarce tropical environments.

Building on this improved understanding of hydrological functioning, hydrological evidence was integrated into ecosystem-service assessments, Water-Energy-Land-Food nexus analyses, nature-based solution planning, and climate-change impact assessments. This progression demonstrates how hydrological understanding can inform interdisciplinary assessments and support sustainable water-resource management under global environmental change.

Abstracts

476 | Satellite - Based Modelling of Agricultural Exposure, Recovery Recovery and Reslience to Floods and Droughts in Andhra Pradesh, India

Gayathry Damarla[1]; Dr. Lanka Lakshmikanth[2]; Dr. Naga Chaithanya Kavuri[3]

[1] Justus Liebig University
[2] Ananth National University
[3] Ananth National University

Agriculture in semi-arid India is increasingly exposed to alternating floods and droughts, yet hazard extent alone does not reveal crop damage or recovery capacity. This study developed a satellite-based framework to quantify agricultural exposure, vegetation response and resilience in Andhra Pradesh. Floods were assessed in Prakasam District for 2019, 2020, 2022, 2024 and 2025, while droughts were evaluated across Rayalaseema for 2016, 2017, 2018, 2019 and 2024. Sentinel-1 radar, Sentinel-2 vegetation indices, land-surface temperature and environmental datasets were processed in Google Earth Engine. Flood mapping integrated inundation, active cropland, vegetation damage and post-event recovery. Drought severity was derived from the Vegetation Condition Index, Temperature Condition Index and Vegetation Health Index. Terrain, soil, drainage and surface-water variables supported resilience, vulnerability and hotspot assessment. Flood extent ranged from 12,352 ha in 2022 to 21,733 ha in 2025. Between 66.10% and 92.69% of flooded cropland showed measurable damage, whereas substantial recovery ranged from 11.74% to 38.25%. Low environmental recovery suitability characterized 68.20–86.82% of affected cropland. In Rayalaseema, drought affected 33.87% of cropland in 2016, peaked at 91.23% in 2018 and declined to 0.69% in 2024. During 2018, 65.40% of cropland experienced severe or extreme drought, and 27.40% of the region was identified as a moderate-to-persistent hotspot. The framework demonstrates how Earth observation and spatial modelling can distinguish hazard exposure from agricultural impact and identify priority areas for climate-resilient land management.

487 | Contesting livestock transition pathways: A Neo-Gramscian analysis of power, institutions and environmental governance

Zainab Oyetunde-Usman[1, 2]; Darren Clarke[3]; Alice Brawley-Chesworth[3]; Mosunmola Toluse Adeoye[4]; Kehinde Oluseyi Olagunju[5]; Danny Marks[3]

[1] Rothamsted Research, United Kingdom
[2] AgriFood Lens, United Kingdom
[3] Dublin City University, Ireland
[4] Brunel University, United Kingdom
[5] Department of Agriculture, Environment and Rural Affairs (DAERA), Northern Ireland, United Kingdom.

Livestock production is central to rural livelihoods and food security across the UK and Europe while shaping net-zero transitions, freshwater resources and environmental sustainability. Intensifying climate risks require understanding institutional, political and social processes influencing decisions across the agriculture, water, food and climate nexus, not only technological interventions. Despite livestock's central role in climate risks, resource use and agricultural emissions, governance shaping transition pathways remains underexplored. Using a Neo-Gramscian framework, this paper examines how hegemonic power relations, competing interests and institutional dynamics shape sustainable livestock transitions under pressure on water and land resources. Evidence comes from stakeholder workshops in England and interviews in Ireland with policymakers, researchers, industry and farmers. This transdisciplinary approach explores how diverse knowledge shapes governance. Four governance mechanisms constrain transitions: belief formation, organisational inertia, veto-playing and lost-in-translation between policy design and farm implementation. Findings show responsibility is disproportionately placed on farmers, while dominant agrifood actors shape policy through technological optimism, rural identity framings and resistance to structural change. Path dependencies and policy translation gaps limit transformation. The paper argues resilient livestock systems require institutional and ideological change alongside innovation. A Neo-Gramscian perspective shows contested power relations determine whose knowledge, priorities shape environmental policy, contributing a transdisciplinary perspective on equitable pathways towards climate-resilient agricultural systems.

Abstracts

493 | An Integrated Socio-Hydrological Framework for Urban Water Demand: Combining Machine Learning and Agent-Based Modelling

María Inés, Coronel-Ordoñez[1]; David, Córdova[1]; Esteban, Samaniego[1]

[1] Departamento de Recursos Hídricos y Ciencias Ambientales & Facultad de Ingeniería, Universidad de Cuenca, Av. 12 de Abril, Cuenca, Ecuador

Growing uncertainty driven by climate change and urban expansion calls for tools that capture the interactions between hydrological processes and human decisions shaping water demand. This study presents an integrated socio-hydrological framework that combines machine learning and agent-based modelling to quantify urban water demand and support the evaluation of future scenarios.

A Gradient Boosting model was developed as the first component of the framework to estimate monthly water consumption for urban blocks in Cuenca, an intermediate-sized Andean city in Ecuador. The model used data from 2009–2025, including housing typologies, physical characteristics, demographic information, and socioeconomic variables. Principal Component Analysis (PCA) was applied to reduce data dimensionality and identify the main drivers of water consumption. Seven principal components retained 85.2% of the total variance, with only a slight reduction in predictive performance (R2 = 0.627 compared with 0.664 for the original model). Housing typology, particularly the proportion of detached houses, together with built-up area, were identified as the main determinants of domestic water consumption.

These findings provide the behavioral component of the proposed framework. As a next step, they will be integrated into an agent-based model in which urban blocks interact with the water utility, the municipality, and the real estate sector to represent feedbacks among water demand, urban planning, and water management. This integrated framework will support the evaluation of urban growth, hydrological extremes, and management strategies to strengthen water security in intermediate-sized cities under uncertain conditions.

494 | The Resilient Spring: Indigenous Stewardship, Water Security, and Landscape Governance among the Gujar Community in Swat Valley, Pakistan

Mohsin, Ullah[1]; Sunbal, Ali[1]

[1] Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

[2] Sarhad University of Science and Information Technology, Peshawar, Pakistan

This study explores, how the traditional ecological knowledge and land-management practices of the Gujar pastoralist community contribute to water security and ecological resilience in Pakistan. Our research investigates the relationship between indigenous resource governance, watershed protection, and the sustainability of mountain springs under conditions of climate change. Drawing on ethnographic fieldwork and semi-structured interviews, the study explores the social organization of seasonal migration, grazing patterns, and community-based stewardship of spring sites. The practices of Gujjar community are understood not merely as livelihood strategies but as forms of collective environmental governance embedded in local knowledge systems, cultural values, and social institutions. The findings indicate that Gujar communities play a significant role in maintaining ecological balance by protecting recharge zones, reducing landscape degradation, and sustaining hydrological functions. Areas where indigenous institutions remain active demonstrate greater resilience in water availability and quality despite increasing climatic variability. Conversely, processes of land dispossession, marginalization, and institutional neglect weaken community stewardship mechanisms, contributing to environmental degradation and increasing regionalwater insecurity. The study argues that effective water governance requires recognition of indigenous communities as active environmental actors rather than passive beneficiaries of development interventions. Integrating local knowledge and stewardship practices into formal policy frameworks canstrengthen adaptive capacity, enhance socio-ecological resilience,resilience, and promote more equitable and sustainable resource management in Pakistan.

Abstracts

496 | The Groundwater Recharge Paradox on Climate Change Adaptation in Peri-urban Agriculture in the Andean Valleys of Bolivia

Benjamin, Salas Garcia[1, 2]; Ivan Alexis, Chavez Flores[1, 3]; Galo, Muñoz Vasquez[1]; Andres, Gonzales Amaya[1]; Daniel, Vega Barbato[2]; Anne, Gobin[3]

[1] Laboratorio de Hidráulica, Departamento de Ingeniería Civil, Universidad Mayor de San Simón, Cochabamba, Bolivia

[2] Centro Agua, Universidad Mayor de San Simón, Cochabamba Bolivia

[3] Soil and Water Management Division, Department of Earth and Environmental Sciences, KU Leuven, Leuven, Belgium

Peri-urban agriculture in the Bolivian Andean valleys faces increasing water insecurity owing to climate vulnerability and aquifer overexploitation. This study evaluates the efficacy of different adaptation scenarios for the Huerta Mayu agricultural system in the Cochabamba valley, by modeling water demand and net aquifer recharge using HYDRUS-1D. To integrate climate projections (SSP1-2.6 and SSP3-7.0), statistical downscaling methods based on Quantile Perturbation and Delta Change were applied, allowing the analysis of local typical years (normal, wet and dry) using the SPEI index. Based on this, three scenarios were analyzed: i) drip irrigation (grey adaptive technology), ii) phenological adjustments (green adaptive management), iii) a hybrid approach. Results revealed a critical "recharge paradox": although technological interventions optimize efficiency at plot level reducing gross water demand by 44% to 67%, it simultaneously suppress net aquifer recharge by 40% to 60%, compromising the structural integrity of this water source under future projections. Conversely, optimized phenological planning consisting of delaying maize sowing (+45 to +60 days) and advancing planting dates for potatoes, broad beans, and lettuce (-60 days), as well as radish and onion (-15 to -30 days) proves to be a more effective adaptation strategy towards recharge. Aligning crop phenology with projected periods of effective precipitation reduced demand by 5–25%, while maintaining aquifer recharge. These findings highlight the need to strengthen adaptation in peri-urban agriculture. Water-saving technologies must be integrated with local hydrogeological dynamics, showcasing adaptive phenological planning as a Nature Based Solution ensuring water-food security without depleting the aquifer.

500 | Natural Hydrogeochemical Constraints on Water Security in High-Andean Páramo Catchments

Juan Pesántez[1, 2]; Verónica Guaman[1, 3]; Christian Birkel[4, 5]; Rolando Celleri[1]; Enma Mora[1]; Patricio Crespo[1, 6]

[1] Departamento de Recursos Hídricos y Ciencias Ambientales & Facultad de Ingeniería, Universidad de Cuenca, Cuenca, Ecuador

[2] Facultad de Ciencias Agropecuarias, Universidad de Cuenca, Cuenca, Ecuador

[3] Fideicomiso Mercantil Fondo Ambiental para la Protección de Cuencas y Agua-FONAG, Quito, Ecuador

[4] Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany

[5] Department of Geography and Water and Global Change Observatory, University of Costa Rica, San José, Costa Rica

[6] Regional Initiative for Hydrological Monitoring of Andean Ecosystems (iMHEA), Lima, Peru

Water security is constantly challenged by a complex system in which anthropogenic demands and ecosystem degradation constantly pressure water quality and quantity. In this context, high-Andean tropical páramo streams, which are vital to downstream populations, are often overlooked by conventional management approaches. To address these underlying dynamics, this study quantifies the background hydrochemistry of 28 peri-urban páramo rivers using long-term water quality data (2008–2021) to assess major solutes and heavy metals. We identified three distinct hydrogeochemical stream types, revealing a general downstream enrichment of major ions. Results indicate that certain near-pristine páramo landscapes show geogenically elevated concentrations of Al, As, Cd, Fe, Mn, Pb, and Zn that naturally exceed national and international water quality standards. Elevated concentrations of these water quality-important solutes result from the region's volcanic origins and hydrothermally altered formations rather than from human activity. In the context of water security and nexus-driven solutions, it is essential to first establish that natural background levels inherently limit the assimilative capacity of these water bodies to accommodate additional anthropogenic inputs from agricultural, industrial, or mining activities. Therefore, these findings provide a critical foundation for drafting new, context-specific environmental policies. Addressing the practical challenges of integrated management requires moving beyond theoretical frameworks to implement rigorous baseline monitoring. By doing so, policymakers can translate these hydrochemical realities into evidence-based legislation, targeted land-use zoning, and updated discharge regulations that genuinely safeguard water security.

Abstracts

503 | Developing Indicators of water security from Indigenous Knowledge perspective in the Amazon Indigenous communities

Juan Carlos, Cueva Orjuela[1, 3]; Clara Ines, Villegas Palacio[1]; Ignasi, Rodriguez-Roda[2]; Antonina, Torrens[3]

[1] Universidad Nacional de Colombia - Sede Medellin, Carrera 80 No 65-223, Medellin, Colombia
[2] LEQUIA - University of Girona, Campus Montilivi, 17003, Girona, Spain.
[3] University of Barcelona, Joan XXIII, 27, 08028, Barcelona, Spain.

In the Amazon River Basin, access to water is limited by natural and social barriers, while climate change and human activities increasingly affect water sources. Indigenous communities are among the most affected, which may contribute to the loss of Indigenous knowledge. Understanding water security from an Indigenous perspective can complement Western science approaches, but few studies have explored these perspectives in depth or examined their applicability in other regional contexts. This study develops a water security framework for Indigenous communities in the Amazon River Basin that incorporates the Indigenous knowledge perspective. A modified version of the Process Analysis Method was applied, including the co-design, co-creation, and co-dissemination steps. Qualitative methods were used, including interviews, gender-focused focus groups, and workshops with Indigenous communities, academics, public officials, and private sector actors. Thematic analysis was used to examine and interpret data. The study identified, developed, and validated a context-specific definition, topics, dimensions, and indicators of water security for Indigenous communities in the Amazon River Basin. Among the main findings, important differences were identified between the water security literature and the Indigenous knowledge perspective, particularly in the Amazonian context. Additionally, differences were found in perceptions of water security among Indigenous communities, reflecting their different relationships with the environment. These differences reflect diverse worldviews and cultural practices. Indigenous knowledge of water security includes spiritual and ecological connections, in contrast to global frameworks that primarily emphasise access, availability, and quality.

506 | From Exposure to Impact: Estimating the Welfare Losses from Climate-Driven Water Shocks in Nigerian Agriculture

Kehinde Oluseyi Olagunju[1]; Zainab Oyetunde-Usman[2]

[1] DEARA, UK
[2] Rothamsted, UK

Agri-food systems in developing countries are increasingly exposed to climate-driven water shocks such as droughts, floods, and erratic rainfall, with serious consequences for food and water security, nutrition, and rural livelihoods. Nigeria's agri-food system is especially vulnerable due to overreliance on irrigation-fed agriculture. Yet, empirical evidence of these impacts at the household level remains limited, particularly in relation to income, food consumption, and access to clean water. Using nationally representative data from 1,356 rural agricultural households in the 2023/2024 production season, combined with spatial precipitation data, this study examines the welfare effects of climate-induced water shocks. We employ a two-stage least squares (2SLS) regression model to estimate the impact of exposure on farm revenues, Household Dietary Diversity Scores (HDDS), Household Food Insecurity Access Scores (HFIAS), and access to safe water. Findings show that water shocks significantly reduce household income, dietary diversity, food access, and water security, with disproportionate effects on poorer and female-headed households. However, adoption of climate-resilient practices and access to agricultural extension services are found to mitigate these impacts. These findings underscore the need for targeted interventions to strengthen climate resilience in agri-food systems. Specifically, the promotion of climate-smart irrigation technologies can reduce dependence on vulnerable systems; gender-sensitive extension services can better support female-headed households; and financial mechanisms such as microinsurance can help buffer poorer households against shocks.