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BOOK OF ABSTRACTS
ORAL PRESENTATIONS

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Day 1 | 19 April 2023 | Hydroclimatic risk, monitoring and vulnerability: state-of-the-art solutions for climate risk management

Technical session 1: Monitoring the impacts of hydroclimatic risks and EWS – Part 1

ROBIN - A Reference Observatory of Basins for International hydrological climate change detection

Jamie Hannaford[1], Lucy Barker[1], Stephen Turner[1], Harry Dixon[1], Adam Griffin[1] and Gayatri Suman[1]

[1] UK Centre for Ecology & Hydrology, United Kingdom, jaha@ceh.ac.uk

Floods and droughts are expected to become more severe in a warming world, furthering the significant impacts they cause to lives and livelihoods, infrastructure, and economies. To adapt to future changes in water quantity, we need to detect and attribute emerging trends in hydrological variables such as river flow, and we require projections of future flood and drought occurrence. Climate and hydrological modelling chains are used to provide such scenarios, but they are complex and highly uncertain. We can use long records of past hydrological observations to better understand and constrain these model-based projections; river flows are especially useful because they integrate climate processes over the large areas covered by drainage basins.

There have been many studies of long-term changes in river flows around the world although, at a global scale (as represented by successive IPCC (Intergovernmental Panel on Climate Change) reports), confidence in observed trends remains very low. This is primarily due to the modification of river flows by human activities (e.g., presence of dams and the abstraction of water for public water supplies, industry, agriculture, etc.). These human disturbances can obscure climate change signals and distort trends in river flows and in cases lead to a complete a reversal of the climate change trends. It is also challenging to integrate the results of various regional- and national-scale studies due to the many different methods used, hampering continental and global-scale assessments.

Therefore, to detect climate-driven trends we need to analyse river basins that are relatively undisturbed by human impacts. Recognising this, many countries have 'Reference Hydrometric Networks' (RHNs) consisting of catchments where river flows are measured, and where human impacts are absent or minimal. Globally however, these are sparse and there is a need for an integrated approach to advance international assessments of hydrological change on a consistent basis, such that they can provide a robust foundation for international assessments such as IPCC Reports.

Here we introduce the ROBIN initiative, where we are advancing a worldwide effort to bring together a global RHN. With a growing network of partners from >30 countries spanning a broad range of climates and geographies, on all inhabited continents, ROBIN will develop a consistently defined network of near-natural catchments across the world, sharing knowledge from countries with established RHNs to enable other countries to define similar networks. ROBIN will use this network to undertake the first, truly global scale analysis of trends in river flows using undisturbed catchments. With the support of international organisations, including WMO, UNESCO and IPCC, ROBIN will lay the foundations for an enduring network of catchments, and scientists, to support global assessments of climate-driven trends in future.

In this presentation we will introduce the ROBIN network and its current global extent and coverage. We will introduce the criteria and protocols behind selection of RHN status catchments, including quality control. We will introduce the framework for the first global-scale analysis of climate-driven trends in RHN catchments, and we will show preliminary results from this analysis. We will conclude with a forward look to the next stage of network expansion and analysis – and an open invitation to partners from other countries to join the network!

Unlocking Flood Resilience With Remote Sensing Approaches to Early Alerting and Financing

Annalee Tai[1], Colin Doyle[1]

1 Floodbase, annalee@floodbase.com

In a climate-changed world, governments need new tools to cope with flooding and its impact on communities, assets, and livelihoods. A country's flood resilience depends on its ability to prepare for, respond, and adapt to flooding. Early alerting and financing systems that allow communities to take actions have been shown to minimize downstream losses. Early, direct, cash transfers or insurance payouts allow individuals to avoid negative coping mechanisms, and protect their livelihoods. However, alerting with accuracy and immediacy has proven a challenge to flood modelers, forecasters, and hydrologists alike, in large part due to the dynamic, complex nature of flood hazards.

We present a novel approach for remote, near real-time flood monitoring for effective disaster response. This monitoring system is rooted in historical analysis of flood risk to enable resource planning and financial risk transfer in areas where Disaster Risk Financing (DRF) has been impossible. We demonstrate the use of satellite-observed flooded areas to create parametric flood financing at scale. When coupled with daily monitoring, this data source triggers insurance payments and early actions, co-designed with local actors. This approach has been operational in Colombia, supporting small-holder farmers with debt relief flood insurance. It has been launched in the Republic of Congo supporting the World Food Program to respond to flood shocks. And it is supported by NASA in a project with Give Directly, where the alerts trigger donations and payouts to flood-vulnerable communities in Mozambique.

To design the index, we use a Convolutional Neural Network (CNN) to extract flood footprints from every daily Aqua and Terra MODIS image collected from the 20+ year record. Next, we divide the area into spatial units, either watersheds or administrative boundaries, depending on the policy design. We then use the MODIS water record to quantify the annual maximum flooded area in each spatial unit. By fitting these measurements of flooded areas to a probability distribution, we can estimate the probability — and return period — of a certain size of flood happening. Using these probabilities, we set thresholds to pay out at the desired frequency, and monitor the location on a daily basis to identify units that trigger. If a threshold is crossed in a given spatial unit, all policies within that unit are paid. Lastly, we develop a CNN for water detection for the VIIRS sensor designed to map water consistently with the MODIS CNN in order to ensure future continuity of the product when MODIS is decommissioned. We validate the approach in multiple locations using historical event and loss data. The history of satellite observations with the continued record of VIIRS makes possible parametric flood insurance and action in areas with large flooding for the first time.

Bridging science, policy and decision making gap through co-creating next generation of climate services

Ilyas Masih[1], Nora van Cauwenbergh[1], Schalk Jan van Andel[1], Micha Werner[1] Alexandros Ziogas[2], Annelies Broekman[3] Ester Prat[3] Lluís Pesquer[3], Béla Mihalik[4] Veronika Fabók[4] Györgyi Bela[4] Megi Gamtkitsulashvili[5] , Miranda Apakidze[5], Nino Tevzadze[5], Vakho Chitishvil[5] , Marc van den Homberg[6] Orla Canavan[6] Francesca Moschini[7] Rebecca Emerton[7] Lucia De Stefano[8] Nuria Hernández-Mora[8], Nikoletta Ropero[8] Apostolos Tzimas[9] Marije Schaafsma[10], Francesca Renzi[11], Paolo Mazzoli[11], Stefano Bagli[11], Sebongile Hlubi[12]

[1] IHE Delft Institute for Water Education, i.masih@un-ihe.org

[2] EMVIS

[3] GREAF

[4] IDEAS

[5] **CENN**

[6] **510**

[7] **ECMWF**

[8] **UCM**

[9] **EMVIS**

[10] **VUA**

[11] **GECOsistema**

[12] **Lesotho RC**

While advances in climate services (CS) have contributed to addressing extreme events to some extent, there are still multiple challenges, such as the lack of human centred approaches in the design of CS, that hinder achieving of their full value proposition. This contribution reflects on the approach and preliminary results from the I-CISK project, which aims to address these challenges by co-creating next generation of CS together with multiple actors representing the full CS value chain (providers, purveyors and end-users). Seven Multi-Actor Platforms (MAP) are established in the I-CISK Living Labs (LL) located in the Netherlands, Spain, Italy, Hungary, Greece, Georgia and Lesotho, with members representing some 100 different actors; including policy makers, academia and research, industry and business community, and citizens. End-users involved in the LL represent multiple sectors such as management, agriculture, environment, tourism and energy. The participation of such a diverse and highly relevant group of actors will ensure that a transdisciplinary approach will be used throughout the process of co-creating next generation CS.

In this paper, we reflect on the experience from the establishing and operationalising of the LL in these early stages of the project. These highlight the need to address the multiple hazards (e.g., droughts, water scarcity, floods, heatwaves, and wildfires) that are faced by end-users. While CS availability, use and barriers to effective use greatly differ across the LL, we find there is a general need to address barriers related to limited lead time provided by available CS if any, lack of access, unsuitability in terms of required spatial and temporal resolution, and uncertainty of the forecasts. The next generation CS co-created through integration of scientific and local knowledge should improve spatio-temporal resolution; cover sub-seasonal, seasonal and climate projections; innovate multi hazard forecasting and early warning systems; and provide sector-tailored information. The active participation of CS providers, purveyors and end-users in different stages of co-creation process will help meet these expectations, and a continuous engagement with MAP in the LLs will contribute in closing the science, policy and decision making gaps in the development and use of the CS. The process will also contribute in building a culture of proactive decision making, based on up-to-date evidence-based information that seamlessly integrates science, policy and decision-making process throughout the full CS value chain.

High Mountain Climate, Snow, Glacier and Water Risk and Vulnerability

John Pomeroy[1]

[1] **University of Saskatchewan,** john.pomeroy@usask.ca

High mountains supply freshwater for over half of humanity and mountain water supplies are strongly governed by the accumulation and melt of seasonal snowpacks and melt of perennial snowfields and glaciers. Methods to estimate the impact of changing climate on mountain water supplies have been impeded by inadequate observations and knowledge of mountain snow and ice processes that control streamflow. Most hydrological models do not include the key high-mountain snow and ice processes and therefore have limited reliability and prediction capability when applied to extreme events and future climates. Here, advances in headwater and major river basin hydrological models are detailed along with their applications to operational flood forecasting, land use planning, diagnosis of hydrological

vulnerability, and risk management under climate change. Examples are chosen from high mountains around the world that are subject to study by the UNESCO Chair in Mountain Water Sustainability.

Climate resiliency for our habitat through immersive technologies

Yétindranathsingh (Vipin) Dhunnoo[1]

[1] Bond University, vipindhunnoo@gmail.com

Climate Change will impact key aspects of our lives, most notably our living environment. With 68% of the world's population expected to live in cities by 2050 (United Nations, 2018), the effects of Climate Change will lead to adverse repercussions such as soil erosion, flooding and coastal displacement.

At a macro scale, it is evident that our living spaces must be made resilient and a key starting point for exploration is at the meso scale of built form, which is our homes. With the detrimental effects of Climate Change not yet fully appreciated, as it is simply too abstract a concept for many to comprehend, there is an urgent need to create adequate tools to illustrate and communicate such impacts on the environment we inhabit. Furthermore, people living in vulnerable regions and coastal areas are at the ones at greater risk of Climate Change. Exposed places such as Small Island Developing States (SIDs) and coastal areas ideally require real-time mechanisms to understand climate ramifications on the built environment, in order to help mitigate and adapt. As such visualisation and efficient information dissemination is essential for their safeguard.

Advancements in Cross Reality (XR) technologies, such as Virtual Reality (VR) and Augmented Reality (AR), have led to promising multi-disciplinary applications. With their unique interactive propensities, these technologies can be powerful aids at bridging the gap of theoretical understanding of impending climate impacts with experimental psychology and environmental research. This novel medium of visualisation can be utilised to strengthening communication of what is likely to occur and what needs to be done to provide resiliency to those future scenarios. By leveraging the benefits of immersive technologies, knowhow of climate impacts on our environment and infrastructure can be enhanced, as this novel communication medium transcends traditional language and accessibility barriers. This paper investigates the development of XR media as an innovative visualisation and effectively communication instrument for climate resilience.

Technical session 2: Adaptation strategies and NBS – Part 1

Climate risk analysis for value chains in mountain ecosystems

Aracely Salazar-Antón[1] Patrick Reuter[2] Gabriela Banegas[2]

[1] GIZ, aracely.salazar@giz.de

[2] Independent consultant

Andean mountain ecosystems are of outstanding importance for biodiversity, as well as for the provision of environmental services such as the regulation of hydrologic balance. The Andean mountains ensure the supply of drinking water to rural and urban communities and irrigation for agricultural production areas.

In the Andean highlands of Ecuador there are protection mechanisms such as the National Protected Areas, as well as private initiatives like Water Funds which conserve these mountain ecosystems. Nevertheless, the "páramo" highlands requires the application of large-scale protection measures inside and outside of those areas. The local population live mostly from agriculture and livestock activities although they recognize the need of protecting the mountain ecosystems through the application of innovative incentives for conservation and sustainable use, even though, the lack of alternative sources of income, the economic situation of the country, the impacts delivered by the pandemic force local communities to expand agricultural production in sensitive and fragile natural areas.

The “Conservation and Sustainable Use of Mountain Ecosystems” Programme of the Ministry of Environment, Water and Ecological Transition of Ecuador (MAATE), financed by the Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), aims to improve the restoration of high Andean Mountain ecosystems impacted by climate change through strengthening local capacities in territorial planning issues, creating alternative and sustainable sources of income for the population together with facilitating knowledge exchange on the sustainable management of mountain ecosystems. All these actions will contribute to restore degraded areas and promote a green recovery. The programme's target group is the high mountain Andean rural population, especially small farmers, indigenous people, and mestizos, who apply land management practices.

Outcome 1 of the programme works to promote identified value chains (quinoa, fresh milk, alpaca, rural tourism, and honey) with sustainable, profitable and climate change-resilient approaches; thus, there is a need to develop a climate risk analysis, the results of which will support the strategy to promote value chains and the implementation of adaptation measures.

Whit all the above in mind, these abstracts explain the development of the climate risk analysis for the identified value chains in two regions of Ecuador. The objectives of the process were 1) Analyse climate risks as a function of climate hazard, exposure, and vulnerability, 2) Evaluate whether or not a specific dimension for the inclusion of gender could be included, 3) Explore the vulnerability of women and men to climate risks, 3) Define adaptation measures based on the risks identified, 4) Generate the strategy for each value chains which includes climate lens.

Adaptation to Impacts of Climate and Demographic Changes on Water Supply and Demand in Nairobi, Kenya

Lydia Munene[1], Eunice Maina[1]

[1] Nairobi City Water & Sewerage Company, Lydia.Nmunene@gmail.com

Decision making in the management of water resources under changing environment full of uncertainties of climate and demographic factors, pose a challenge in the cities. It is therefore, of importance to comprehend the impacts on the system to establish adaptation strategies. In the case of Nairobi City, where an intermittent water distribution system is in operation, climate change coupled with increasing population growth has led to a widening of the supply-demand gap. Different approaches have been employed to understand the climate change impacts without considering the contribution of non-climate factors to a given water system thus developing inflexible adaptation measures. With the dynamic nature of both climate and demographic changes, proper planning ought to be considered while developing adaptation strategies. Collaborative Risk Informed Decision Analysis (CRIDA) is an iterative process that gives a guideline on decision making for planning while putting into consideration the dynamic changes of the environment through the decision context, bottom-up vulnerability assessment, development of robust and flexible adaptations, evaluation of plan alternative, and institutionalize decision. The objective of this study was to develop adaptation pathways using CRIDA approach to enhance the system performance of urban water supply. Decision context was done to understand the current performance of water system for Nairobi city by use of time series and stakeholder engagement. To investigate the suitability of water supply from the existing catchment, a Hydrological model for the Thika-Chania Sub catchment was done which informed on the prediction of future flows for a 30-year period using 4 Regional Climate Models (RCMs) under both Representative Concentration Pathways (RCPs) 4.5 and 8.5. A multivariate econometric approach was used to investigate the effect of climatic, socio-economic, and management instrument factors on water use in Nairobi City to forecast on future water demand. Based on the results, water demand was found to be highly influenced by the availability of water from the catchment and population. Hence, demand scenarios were based on different population growth patterns, exponential growth, and decreasing rate of increase growth, with per capita consumption scenarios of 85 and 170 litres per day (lpd). The water system performance was evaluated through bottom-up vulnerability to determine its behavior under

different scenarios of water demand and climate based on Regional Climate Models. The results revealed an increasing supply-demand gap due to the impacts of climate and demographic changes through varied flows and increased population growth respectively, with the system at high risk of failure under climate change and the exponential demand scenario. Both structural and non-structural adaptation strategies were identified, and their tipping points were established through vulnerability test in the water system models at different scenarios. By use of adaptation tipping points, adaptation pathways were developed using a pathway generator tool indicating the timelines for the implementation of the proposed strategies and their effects on the water system. The sustainability of the water system based on the results, was achieved when a combination of structural and non-structural strategies are implemented.

Data-based decision making for climate risk: defining a flood adaptation portfolio for coastal cities in Vietnam

Maxime Souvignet[1]

[1] **United Nations University (UNU-EHS), souvignet@ehs.unu.edu**

Storms, floods, and other extreme weather events can threaten urban and rural areas, from small regions to entire nations. Along with growing populations and economies, losses from natural hazards are rising in the World's most exposed areas as our climate continues to change. The Economics of Climate Adaptation (ECA) is a unique decision-making support framework that integrates climate vulnerability and risk assessments with economic and sustainability impact studies to determine the portfolio of optimal adaptation measures for various climate risks.

The United Nations University - Institute for Environment and Human Security (UNU-EHS) is collaborating with the FloodAdapt Vietnam project funded by the German BMBF and with other partners to implement the ECA framework in several cities in Vietnam, to identify the most cost-efficient measures to address the negative impacts of floods. The ECA framework supports decision-makers in developing their adaptation strategy and prioritizing investments in climate change adaptation (CCA), including risk transfer. It offers a systematic and transparent approach that fosters trust and initiates in-depth inter-sectoral stakeholder discussions. ECA can be flexibly applied from the national down to the local level to different stakeholder groups and hazards. It further provides key to supporting National Adaptation Plans (NAPs) development.

We present here a summary of the different stages of the process of implementation of the ECA study and the final recommendations for adaptation measures to flood in Can Tho and Hue cities in Vietnam. Stakeholders were asked to provide input and feedback on the assumptions, decisions, data, and adaptation options assessed. For example, in Can Tho, 17 adaptation measures for flood and heat waves were identified and validated, including technological and engineering solutions, ecosystem-based (nature-based) approaches, maintenance/operational measures, instruments and tools that improve baseline data, and risk transfer solutions.

Making Room for Our Forthcoming Rivers

Andrea Gianni Cristoforo Nardini[1]

[1] **Fundación CREACUA, nardiniok@gmail.com**

A new climate implies that present rivers will change because of a different hydrological regime, sediment supply and transport, vegetation dynamics, and even uses. This fact implies, of course, a corresponding different morphological configuration and geomorphic dynamics with an impact on flooding.

The main thesis of this presentation is that accordingly a rethinking of rivers configuration is unavoidable and It requires redesigning the rural and urban territories. The socio-political-economic difficulties involved in such a demanding change are undoubtedly extremely challenging and an enormous dose of courage is required. But ignoring this reality will definitely bring us all towards unprecedented flood

severe damages. (Other related issues, such as water quality, water regime, and biodiversity are not touched here, although they certainly deserve similar considerations and are strongly related.)

To support this thesis, several paradigms and associated approaches that can be (and indeed still are) adopted to design flood control actions, and the associated river setting, are schematically reviewed. On this basis, a conceptual-technical framework and operational methodology that can support the design of a forthcoming socially desirable river setting, and its associated fluvial space, under a changing climate, is progressively delineated.

Most of what is presented here is well known, but key concepts are presented in a new way, while linking them together in a structured and robust discourse, and offering a pathway for an improved, clearly stated approach.

The discourse starts with a very synthetic presentation of what can be denominated as the classic engineering paradigm of flood control, pointing out its principles and weaknesses. It is then shown how more evolved paradigms derive from it, spontaneously calling into play Cost–Benefit Analysis (CBA).

Climate change is then explicitly considered to point out that two facts are clear: i) flood (and drought) events will be harsher and more frequent; ii) although predictions are improving, we are in reality ignorant about the probability distribution of future events. One of the consequences is that we need to learn to make decisions under a strict uncertainty framework to design robust systems, according to the CRIDA approach (Climate Risk Informed Decision Analysis). The backbone of the envisaged strategy is to restitute space for the rivers by defining an appropriate river setting within a wide corridor. But this must be accompanied by complex measures that ensure a viable transition.

The role of the CBA as a tool to explore candidate river-setting alternatives at a preliminary level is illustrated. It is however stressed that even the extended version of the CBA cannot be considered the panacea: it is necessary to broaden the view to directly address people's quality of life—of which risk is just one of the relevant components—so achieving a further evolved multicriteria paradigm.

This effort is of the utmost urgency because significant changes in land use and infrastructure setting require long planning time and even longer implementation horizons, while the climate has already changed.

These ideas are presented in Nardini, A.G.C. (2022). Making Room for Our Forthcoming Rivers. Water 2022, 14, 1220.https://doi.org/10.3390/w14081220.

IMWR Water Planning Based on the PAMIC Ecosystem Based Adaptation (EBA) Tool

Sergio Marcelo Villa Gomez Gironda[1], Luise-Katharina, Richter[1] Carlos, Saavedra[1] Andrea, Salinas[1] Carlos, Arteaga[2]

[1] PROCUENCA-GIZ, nardiniok@gmail.com

[2] AKUT

Climate vulnerability and the increase and recurrence of hydrometeorological disasters have an acute incidence in water planning processes, mainly towards achieving long term resilient and sustainable water resources management.

Bolivia, within the framework of national hydric regulations, uses the Integrated Water Resources Management (IWRM) and Integrated Watershed Management (IWM) approaches to applies a programmatic framework of structural measures and capacity development (based on strengthening communities) to deal with the water insecurity in the country. Integrated Watershed Management (IWM) at micro-basins and sub-basins are the main technical implementing mechanisms developed to respond to the water user needs, mainly answering to sociocultural and environmental conflicts.

IWRM, through IWM projects, has made significant progress in general but is still present insufficient results to tackle de problem, both due to its high dependence on climate change and the increasing growing of water demand for users to which they must adapt. Thus, a large part of the IWM projects is affected by operational problems, such as lack of maintenance, loss of operability and damage, and insufficient mechanisms to adapt to extreme climate. Issues that not only concern water users, but also generate greater pressure on municipal and departmental authorities and that require large economic investments. For this reason, there is a need to strengthen the sectoral water planning capacities through sound integration of alternative adaptation mechanisms in IWM projects, from which arises the opportunity to couple water planning at watershed level to an ecosystem-based adaptation (EbA) approach.

PAMIC is a regional water planning tool, developed in Mexico by CONANP, which uses ecosystem-based adaptation (EbA) to strengthen the country's water-environmental management. This article assessed the potential application of the PAMIC tool in Bolivia, to integrate climate, ecosystem and anthropic resilience on IWM projects. It is evaluated if through the PAMIC application on national context it would be possible to improve water planning in micro-basins and sub-basins, by integrating ecosystem vulnerability within IWRM. For this purpose, a normative and institutional analysis of the watershed and river basin planning process was developed from which indicators on vulnerability and adaptation were obtained, framed in the IWM project cycle with EbA measures.

As a result, a qualitative assessment of the IWRM planning mechanisms existing in Mexico and Bolivia was obtained, emphasizing in a comparative analysis between them, and providing recommendations for mainstreaming EbA effectively on IWRM and IWM planning. Finally, the roadmap for its application at sectoral level is presented together with some guidelines for sustainability, scalability, and replicability of EbA measures within IWRM water planning.

Technical session 3: State of the Art: tools for flood monitoring – Part 1

Development of a real-time flash flood prediction system using data assimilation for small and medium-sized rivers

Daiki Kakinuma[1] Shingo, NUMATA[1], Takafumi, MOCHIZUKI[1] Keijiro, KUBOTA[1] Masaki, YASUKAWA[1] Toshio, KOIKE[1], Toshihiro, NEMOTO[2] Koji, IKEUCHI[2], Yosuke, NAKAMURA[3],

[1] International Centre for Water Hazard and Risk Management(ICHARM), Public Works Research Institute(PWRI), kakinuma@icharm.org

[2] The University of Tokyo

[3] Mitsui Consultants Co., Ltd

Recently, many people have died from delays in evacuation during flash floods especially in small and medium-sized rivers for which flood forecasts have not been implemented. Damage caused by such flash floods occurs not only in Japan but also all over the world, and countermeasures are needed. For these reasons, this study aims to develop flood prediction system that is fast in calculation, low-cost, simple, and adequately accurate and then standardize the provision of water-level prediction information for small and medium-sized rivers. Specifically, to improve the accuracy of the water-level prediction model, the particle filter which one of the data assimilation method was applied to continuously calibrate the RRI (Rainfall-Runoff-Inundation) model using real-time observed water levels. Furthermore, the SCE-UA of model parameter optimization method was also installed into the model to calibrate parameters for flood prediction.

The models were built for 120 rivers and tested to confirm if they would run properly on a real-time automatic flood prediction system. As a result, the system was verified for 216 events on 120 rivers, and obtained a target lead time of 2 hours for approximately 75% of the floods (Consider a permissible range

of ±50 cm). Additionally, the target events included small basins with flood arrival times of less than 2 hours, and obtaining the target lead time depended on the accuracy of rainfall forecasts. Therefore, using the required accuracy as the arrival of hazardous water levels within the flood arrival time for each basin, the system satisfied the target lead time for about 88% of the floods. We could develop a flash flood prediction system that can be implemented in small and medium-sized rivers.

Levels of risk and vulnerability associated with floods and adaptation to climate change in urban and peri-urban areas of the Binational Basin Puyango - Tumbes

Bertha Cecilia Garcia Cienfuegos[1], Felix Enrique Alcoser Torres[1]

[1] National University of Tumbes, goodall@virginia.edu

Basin Binational Transboundary Puyango - Tumbes, covering territories of northern Peru and southern Ecuador, is the center of the impacts El Niño, specifically the Tumbes Region, presents critical conditions of vulnerability that permanently expose its people and production systems to natural events. The research was conducted with the aim of reducing vulnerabilities and prevent disaster risks; It was identified and defined the study area, determining the possible risk scenarios (rain, storms and floods). To do so, risk index was applied by flooding, this model allowed from a holistic perspective assess the level of risk of flooding in the Tumbes region and marginal urban localities. It was established the relative size of threat (T), being of size 3 (high), establishing that it is representative flooding also ability to damage (D) of threat in locations of Aguas Verdes (Zarumilla) and Barrio San Jose (Tumbes), since the peri- urban flooding in this area cause a strong impact, determining a matrix of significance for threats, being very significant selection criteria. Levels of risk and vulnerability, were determined by the model of risk indices, being the highest (0,58), corresponding to stratum 1 (Sector San Jose, Bellavista,Aguas Verdes) and the low (0,35) , layer 2 corresponding to (center of the city of Tumbes, top). With regard to the consequences, economic losses, operational involvement (collapse of water and sewage system), environmental pollution (presence of sewage, propelling epidemics) was determined. It was determined that the driving factors that increase the risk level are climate, the geographical location of the study area, the proximity to the equator and the mangrove area, the depth of groundwater level and soil salinization . At the urban level, vulnerability as intrinsic factor of the risk was associated with not only exposure of the material context and / or physical susceptibility of the elements exposed to be affected, but also weaknesses, social fragility and lack of capacity community response study areas.

Hydrometry from Space: the solution for early information on hydrological risks in ungauged and/or transboundary basins

Stéphane Calmant[1], Sylvain Biancamaria[2], Adrien Paris[3], Jean-Francois Cretaux[4], Fabrice Papa[1]

[1] IRD, stephane.calmant@ird.fr

[2] CNRS

[3] Hydro-Matters

[4] CNES

After about 3 decades of R&D in public labs across the world, and significant technological and algorithmic improvements pushed by Space Agencies, satellite altimetry is now a mature technology that can monitor the water levels on most rivers on Earth larger than 50m. This technology is thus particularly well adapted to monitor ungauged and/or transboundary basins.

For users, continuous delivery of the altimetry data and quality control are guaranteed. Same is guaranteed the free delivery of the data, whatever the mission, as long as the mission is funded by public, national or international, institutions.

We present existing applications of Hydrometry from Space in South basins including the early monitoring of the Ubangui flood, support for humanitarian action in the inundated South Sudan or basinwide monitoring of the Niger basin.

The limitation of the current altimetry missions is the time sampling: at best one measurement every 10 days. Such a coarse sampling limits its use for some applications in risk assessment which may require higher temporal sampling. Therefore, we -partnership between French research Institutions and Space Agency- develloped a concept of constellation of µ satellites, SMASH, that could monitor tens of thousands river reaches spread all over the world 1) daily 2) in NRT 3) at competitive costs

Critical evaluation of Integrated Community-Based Flood Early Warning System for Disaster Risk Reduction and Resilience in Malawi

Leman Ngwena[1], Calvince Wara[2], Hasting Mbale[3], Chikondi Mbemba[3], Samuel Gama[4], Yobu Kachiwanda[5], Ted Nyekanyeka[6], James Nyaga[2], Fedson Chikuse[4], Hel Kumar Shreshtha[7], Shailendra Shakya[7]

[1] Ministry of Water Development (Malawi), lemanngwena@gmail.com

[2] Regional Centre for Mapping of Resources for Development (Kenya)

[3] Department of Water Resources (Malawi)

[4] Department of Disaster Management Affairs (Malawi)

[5] Department of Climate Change and Meteorological Services (Malawi)

[6] United Development Programme

[7] Sustainable Eco Engineering Pvt (Nepal)

Floods are the major climate-induced natural hazards that threaten the lives and livelihoods of many communities in Malawi. During the rainy season, displacement of people, considerable loss of lives, livelihood and damage to property and public infrastructures are common annual occurrences due to sporadic flooding in the low-laying areas of several river basins. This has imposed substantial economic, social and environmental cost hence reversing the recent economic gains. With increasing population growth, urbanization and environmental degradation, climate change and variability has exacerbated the situation hence the increased severity and magnitude of occurrence. In response, the government and development partners have adopted and supported four mechanisms for flood forecasting and early warning for disaster risk reduction and resilience of the vulnerable communities; telemetric community-based flood early warning system (CBFEWS), Operational Decision Support System, (ODSS) and Earth Observation and satellite forecast technologies. Recent effort and investment have been focused on integration of satellite and telemetric technologies for the community-based flood early warning to enhance community preparedness and resilience to flood disasters. However, the effectiveness of the integrated system has not been critically evaluated. Therefore, this paper provides a critical evaluation of the effectiveness and the performance of the recently established integrated systems in the provision of flood early warning information for disaster risk reduction and resilience, their accuracy and reliability as well as community perceptions. It highlights and existing operational and technological gaps in the generation of the much needed accurate, timely and reliable flood early warning information for the vulnerable communities and their livelihood in the flood plain. The findings demonstrate that despite the significant investment and challenges, the integrated system has immense potential in the region with remarkable performance in the two years of operations.

Smart Stormwater Management for Reducing Flood Impacts in Coastal Urban Communities

Jonathan Goodall[1] Brad, Campbell[1], Donna, Chen[1] Madhur Behl[1]

[1] **University of Virginia, goodall@virginia.edu**

Effective stormwater management is critical for reducing flood impacts within urban communities. Often, stormwater systems are passive, gravity-driven systems. This approach has worked well in the past, but climate change is placing increased stress on such systems. This is playing out for cities worldwide but is being felt most acutely in coastal communities because they are experiencing both sea level rise and more frequent intense storms. In this presentation, I will describe research to bring concepts and approaches from the field of cyber-physical systems (CPS) to stormwater management. The goal of this research is to understand and mitigate the impacts of flooding in urban coastal communities more effectively. I will present modeling work to predict high-resolution flooding impacts on transportation systems, crowdsourced data analysis for understanding flooding impacts on road networks, and the application of machine learning algorithms for controlling stormwater infrastructure assets. This research is in partnership with Norfolk, Virginia, USA, a coastal community experiencing increased flooding impacts due to relative sea level rise and storm events, which serves as the research tested.

Technical session 4: Adaptation strategies and NBS – Part 2

Climate risk and adaptation assessment for water security in support of the NAP in Bhutan

Ad Jeuken[1] Mark Hegnauer[1], Laurène Bouaziz[1] Ümit Taner[1] Chhimi Dorji[2]

[1] **DELTARES, ad.jeuken@deltares.nl**

[2] **ChhimiD consultants**

With the changing climate, water sources in Bhutan are dwindling and drying up, with experiences of wetter summer months and drier winter months and increased melting of glaciers. This has multiples effects on various sectors, in particular those that are primarily dependent on water. Therefore, based upon a bottom up vulnerability assessment and a top down climate impact assessment, priorities for adaptation to climate change in Bhutan have been identified for disaster risk management, rural and urban water supply and hydropower. Proxy variables for droughts/water shortages, extreme precipitation/ flooding, landslides, glacial lake outburst floods and hydropower were calculated under different scenarios for climate variability and change. Relative differences between a reference and multiple future climate projections were presented at district level and for different time horizons as part of the top down analysis. Regional consultations were held to collect bottom up vulnerabilities.

Next pathways for adaptation, in terms of short term actions and long term options, have been formulated based on 7 key overarching strategic goals: 1) Strengthening ecosystems, 2) Improved flood risk management and planning, 3) Protect critical infrastructures and settlements, 4) Develop more resilient infrastructure, 5) Improve early warning and response & recovery capacity, 6) Increase robustness of sectoral water supply and demand and 7) Increase the climate resilience of the Hydropower sector. Recommendations for monitoring and implementation are complementing the identified actions for the NAP.

The presentation will highlight how a high level multi hazard impact assessment can be executed using open source weather, climate and other data and hydrological modeling to inform indicators for water security. In addition, we will provide insight in how national water resources and adaptation planning can be applied in a structured stepwise manner following a climate risk informed decision analysis (CRIDA) approach.

Building climate resilience capacity in rural India through integrated CWRM approach

Parthasarathy Radhapriya[1], Sowmithri V.R[2], Krishnan Tyagi[2], Rengalakshmi R[2], Ramachandran A[3], Kurian Joseph[3], Anushiya J[4],

[1] **GIZ, radhapriya.cc@gmail.com**

[2] **MSSRF**

[3] **Anna University**

[4] **Consultant & C-STEP**

Increasing hydro meteorological hazards - floods and droughts in recent decades have more significant impacts on physical, environmental, economic and social consequences in Rural India. This urges an evidence based decentralized scientific framework to increase its resilience from planning, implementation, impact & monitoring at all levels. In this context, Indo German bilateral project's Water Security and Climate Adaptation (WASCA) in rural areas of India developed a framework to address climate risks for water security, integrating with existing mechanisms in rural development and water resources combining IPCC vulnerability assessment methodology.

Composite water resource management (CWRM) tool is developed with integrating water, agriculture, socio economic and climate concerns in order to identify the key water challenges. This tool is being piloted in two climate impact of water vulnerable districts of Ramanathapuram and Tiruvannamalai in the state of Tamil Nadu between 2020 to 2022. The tool (http://65.1.201.178/cwrmwebapp/) is designed to adopt bottom-up approach in planning, science-based inputs to identify water security risks, hazards and evolve locally relevant climate resilient development measures and participatory approach in the whole developmental process. Further, appropriate adaptation and mitigation actions were planned in accordance with rural development and other central and state government programme convergence schemes.

The CWRM approach is complemented by an adaptation planning and monitoring tool. It also includes a component to map with the national goals of Nationally Determined Contributions (NDCs) and Sustainable development goals (SDGs). The work implemented through this approach enabled communities to reduce vulnerability by building assets that improved climate resilience.

Spatio-temporal changes in social vulnerability and socioeconomic variability in Canada

Liton Chakraborty[1]

[1] **University of Waterloo, liton.chakraborty@uwaterloo.ca**

The socioeconomic status index, created by Chakraborty et al. (2020), assessed the spatial patterns of social vulnerability at the census tract level to deconstruct the social liability of risk across Canadian neighbourhoods. Research shows that varying scales of aggregating census-based population data can produce different results and conclusions in different geographical contexts. As social vulnerability changes over space and time, understanding the variability of vulnerable populations exposed to climatic hazards helps develop equitable and sustainable climate change adaptation plans and disaster risk management programs. This study presents the first nationwide evidence of the spatial and temporal patterns in social vulnerability to flood hazards across Canada by incorporating the impact of scalar, variables, and temporal changes on the index construction. This exploratory study uses a subset of the 2016 and 2021 national census variables representing racial/ethnic, demographic, and socioeconomic characteristics of Canadians to calculate social vulnerability indices at two geographic scales, including dissemination areas and census subdivisions that cover Canada's all provinces and three territories. The study compared the results from the variant of vulnerability indices over time and across Indigenous vs non-Indigenous communities, most remote vs least remote areas based on the 2021 index of remoteness, large urban centres, province/territory, and national levels. Consistent with the contemporary US-based literature, the study shows considerable variability of the social vulnerability of Canadians over time and space, reflecting transformations in population size, economic conditions, and sociodemographic characteristics across communities and places. These results would help improve user confidence in understanding the utility of social vulnerability indices in designing effective

adaptation, disaster mitigation, and emergency management plans in high-risk and priority areas that foster social resilience to hazards and disasters in Canada.

A participatory systems approach to understand the impacts of nature-based solutions on water security

Clara Gimeno Jesús[1], Wouter Buytaert[1]

[1] Imperial College London, clara.gimeno-jesus17@imperial.ac.uk

Nature-based solutions (NbS) are increasingly being recognised as sustainable solutions to tackle water security issues. NbS cover a large range of interventions that utilize natural processes to enhance the benefits provided by watersheds such as increased water availability, reduced flood risk, and better water quality. These solutions are attracting increased interest due to the multitude of benefits and co-benefits they can simultaneously provide, ranging from hydrological and environmental benefits to societal and economic benefits. Due to their dynamic and variable nature, NbS benefits are difficult to quantify and monetise, which generally results in investments in more traditional solutions. In addition to hydrological uncertainties and a limited evidence base to assess their effectiveness, the implementation of NbS faces other unknowns such as human behaviour, institutional decisions and human-water dynamics.

The work presented here explores the use of a systems approach to the implementation of NbS to better understand the complex interactions in these coupled human-water systems and identify trade-offs to evaluate their effectiveness. A participatory approach is explored through stakeholder elicitation and interactions with local communities to inform and develop a systems model. We use Lima, Peru, as a case study. Lima is the second largest desert city in the world, facing increasing water shortages amidst a growing population and changing climate. Facing water security issues, city and water authorities have been experimenting with NbS such as wetlands, ecosystem restoration and ancestral practices to secure lowland water needs. Through this work, we explore how a systems approach can be a useful tool to understand and analyse the multi-dimensional nature of NbS in a complex catchment system. We show how this can aid the identification of trade-offs and feedback mechanisms such as potential sources of conflict between actors, assist in balancing total runoff and baseflow generation, and help to optimise the full portfolio of ecosystem services. This exercise of capturing the benefits and disbenefits that NbS interventions can trigger in the system provides valuable insights for assessing their effectiveness and inform decision-making.

Understanding climate change impacts on the availability of groundwater resources in the Transboundary Aquifers: Case Study for Selected Shared Groundwater Bodies in the Nile Basin Country (ies): Burundi; Ethiopia; Kenya; Rwanda; Sudan; Tanzania; Uganda

Maha Ismail[1]

[1] Nile Basin Initiative, mabdelraheem@nilebasin.org

Along the Nile basin countries, reliance on groundwater is rapidly increasing due to the increased demand over water supply. There is ample evidence that groundwater recharge in the Nile basin is under threat. This is partly attributed to climate change, high rainfall variability, and land use/land cover changes leading to declining amount of surface/ground water interaction in different areas. With the financial support of the Global Environment Facility (GEF) and in collaboration with the United Nations Development Program (UNDP), Nile Basin Initiative (NBI) is implementing its first groundwater study project with the objective of enhancing knowledge and capacity for sustainable use and management of trans-boundary aquifers and aquifers of regional significance in the Nile Basin. Three aquifer areas have been chosen for the current intervention, namely the Kagera aquifer shared among Burundi, Rwanda, Tanzania, and Uganda; the Mt Elgon aquifer shared between Kenya and Uganda, the Gedaref-Adigrat aquifer shared between Ethiopia and Sudan. The aquifers are in diverse ecological zones

ranging between arid, semi-arid and tropical. Groundwater Modelling System (GMS) was applied. A monthly stress period each with 3-time steps was used with the aquifer hydraulic heads generated from 2022 to 2051 period. Due to poor or inexistent hydraulic properties (e.g. K, T), the calibration of the observed to the simulated groundwater levels, was manually accomplished, with controlled parameter boundaries based on elevation/empirical value ranges. The model sensitivity of each of these parameters (e.g. recharge, aquifer bottom, K and groundwater discharge) was evaluated individually and in couples against the aquifer heads. The three models indicated no change in the current situation with minor drop down in water levels ranging from 5meters in the fluvial deposits of the kagera aquifers and the sandstone aquifers in Gedaref – Adegrat aquifers to 20 meters drop in the fractured basement aquifers of Mount Elgon. The groundwater models indicated sharp drop of water levels when compared to population growth in 2051 and beyond. At present the three shared aquifer areas are experiencing shortage of water supply to satisfy the basic needs for domestic water requirements due to increased displaced population from already climate impacted nearby areas in east Africa. It is recommended that more investigations are required to identify potential sites and techniques for management of aquifer recharge (MAR) as an important step towards maximizing water availability and mitigating climate change future impacts.

Technical session 5: State of the Art: tools for flood monitoring – Part 2

Building flood resilience by incorporating dynamic adaptive behavior into agent-based modeling of ice-jam flood prone Nordic communities

Mohammad Ghoreishi[1], Apurba Das[1], Karl-Erich Lindenschmidt [1]

[1] Global Institute for Water Security - University of Saskatchewan, mohammad.ghoreishi@usask.ca

Human behaviors have changed as ice-jam flooding have become more prevalent, impacting both flood hazard and vulnerability as a function of flood risk. These dynamic adaptations can be developed by both governments (e.g., artificial breakup and dike installation) and individuals (e.g., flood-proofing and elevating houses). The interaction between these top-down and bottom-up measures provides a complex socio-hydrological system. However, the traditional assessment of ice-jam flood risk lacks an appropriate consideration of evolving human behaviors and their interactions with static assumptions on human adaptations. We build an agent-based model to assess the ice-jam flood risk with top-down and bottom-up adaptive strategies (artificial breakup and flood-proofing). The individuals' behaviors are influenced by the possible reduction in flood risk at the individual level by artificial breakage over time. Also, the government's behavior is influenced by the possible reduction in total flood risk by the dynamic adaptive behavior of individuals (flood-proofing). Thus, micro levels' behavior can dynamically lead to macro phenomena, and macro phenomena define micro levels' behavior over time. This model is applied to Fort McMurray along the Athabasca River, Canada, with a long history of ice-jam flooding. Also, we perform a variance-based global sensitivity analysis to investigate the individual effect of model factors and their joint effects on ice-jam flood risk. The results show that although the artificial breakage by the government lead to a regime shift and a considerable decrease in the ice-jam flood risk, it decreases the number of the newly adapted residents to flood-proofing and the role of residents in ice-jam flood risk. This study can provide a good understanding of the important role of dynamic adaptive behavior in ice-jam flood risk and pave the way for better Building flood resilience.

Role of Hydrometeorological Services in the Risk Management of Dangerous Hydrological Phenomena: Case Study of Ukraine

Viacheslav Manukalo[1]

[1] Ukrainian Hydrometeorological Institute, manukalo@ukr.net

The natural conditions of Ukraine are favorable for formation of such dangerous hydrological phenomena as river floods of various origins and long periods of low flow on rivers, which cause water - related disasters - innundations and droughts. Researches of Ukrainian scientists show that a climate change anticipates increasing an occurrence of dangerous meteorological and related hydrological phenomena. Taking this fact into account, a development of measures to reduce negative consequences of natural hydrometeorological disasters is the important task of national policy in the field of prevention of emergency situations. The national information and analytical system "Prevention of Emergencies of Natural and Man-Made Origin" is intended to support a management of decision-making to solve this problem. The functional component of this System is the Hydrometeorological Risk Management Subsystem (HMRMS), which allows recognize dangerous situations in the weather- and water - depended sectors of economy. The purpose of the presentation is to provide information about: 1) the main task of HMRMS; 2) organizational and technological principles of HMRMS construction; 3) problematic issues that should have been resolved to ensure reliable functioning of HMRMS. The main objective of this Subsystem is to help decision-makers to identify a level of disaster risk and to indicate the best prevention (mitigation) measures on the basis of continuous monitoring and forecasts of evolution of hydrometeorological conditions. The Subsystem is based on the following approaches: a) the transition from the principle ‘protection of disasters' to the principle ‘disaster risks management’; b) the reconsideration of existing conception of separate development of each component of HMRMS and using the integrated approach ‘from sensors to decision-making’; c) application of modern information technologies (Internet of Things, Big Data, Cloud Computing) for data collection and processing, model calculations and customer service. According to these approaches, the disaster risk management is based on using the comprehensive end-to-end service delivery which includes many stakeholders. The HMRMS includes following components: 1) an assessment of probability of occurrence of dangerous hydrometeorological phenomena, taking into account an impact of expected climate change; 2) monitoring situation development; 3) predict and warn about reaching dangerous levels of phenomena; 4) communicate information, forecasts and warnings to decision – makers. Observational data, as well as forecasts and warnings of the State Hydrometeorological Service of Ukraine are the core of HMRMS. The report: 1) considered organizational, scientific and technological principles of HMRMS functioning; 2) examples of HMRMS application are given and existing problems in its work are analyzed; 3) a number of measures to improve its functioning are proposed. The article will provide information on the damage caused by Russia's military aggression to the infrastructure of the Hydrometeorological Service of Ukraine.

The Interaction between human and water and its effect on the intensification of flood in Iran

Sara Attaran[1], Abolfazl, Mosaedi[1]

[1] Ferdowsi University of Mashhad, sara.attaran95@gmail.com

The most destructive floods in the history of the world have occurred in the last millennium in third-world or developing countries, especially in Asia. Cities have been formed along rivers due to economic reasons, which caused human affect by floods. Humans developed flood control structures to safeguard towns and maintain their economic interests; This caused a change in the river's regime, and larger floods with long return periods increased. The change in land use, an increase in impervious surfaces, and the change in the river's main path have caused destructive and harmful floods. With the expansion of urbanization, human involvement in the hydrological system has increased. Destructive floods are nature's response to human encroachment on river watersheds and the destruction of vegetation. In order to reduce flood risks and damages, communities often apply two approaches: structural approach and non-structural approach. Many communities build levees along rivers to protect cities. Also, non-structural factors have an effect on the co-evolutionary relationships of the social and hydrological systems. Human and hydrological systems are interconnected. To examine the interaction between society and water, humans should be considered as an internal component in the water cycle. To understand human-water interactions, the science of social-hydrology was proposed, which has two aspects of research in a social system (human) and the hydrological system (water). It effectively deals

with the comprehensive integration of social, economic, environmental, and hydrological elements. We studied the effect of changing precipitation patterns and urbanization on floods in Kalat city (Iran). Kalat is situated in a semi-arid mountainous area. In this study, the influence of rainfall on the amount of flood was estimated according to the amount of equivalent runoff. The change in curve number was used to evaluate the impact of urbanization. On the other hand, we collected some questionnaires from specialists. The factors affecting the intensification of flooding in the city, include the factors inside the city and the factors upstream. These questionnaires examined cultural, social, structural, climatic, and managerial factors. The results showed that the effect of changes in curve number (by human activities) on the peak discharge is 20 times more than changes in the precipitation. Also, the results of the questionnaires show that people's non-participation in the restoration and preservation of natural resources and encroachment on the river's path are the most significant factors that have caused floods in Kalat city in the last few decades. Consequently, in this regard, it is suggested to provide platforms for proper education about floods for all people. These platforms can supply appropriate training for all sections of society about the role of humans in flood reduction as well as methods of sustainable coexistence with nature and resilience.

Seasonal variability of precipitation and temperature over Egypt during 2014 using Climate Monitoring Tool (CMT)

Awatif Mostafa[1]

[1] **Egyptian Meteorological Authority,** awatif.ebrahim2013@yahoo.com

Climate Monitoring Tool (CMT) is used to generate time series and spatial analysis of both rainfall and temperature at different time scales for 12 Egyptian climate stations. The daily mean observations and monthly mean reanalysis data during the period 1974-2014 are used to discuss climatic distribution of precipitation and temperature over Egypt. This article aims at detecting the behavior of winter and summer season in 2014 with respect to climate base period of 1981-2010 for observations. The study also investigates correlations between the NAO, ONI and precipitation, temperature in both north and south of Egypt during the winter and summer seasons. The results showed that, 2014 was characterized by a sequence of warm waves during the winter and summer seasons. Precipitation was marked by a strong regional disparity with a rainfall deficit in the south and surplus in the north. Finally, Overall, precipitation was below normal and the temperature was above-normal in 2014 based on climatology period (1981-2010).

An end to end framework for flood resilience in the Grand River North West Basin, Mauritius under a changing climate

Akshay Kowlesser[1]

[1] **Land Drainage Authority,** akowlesser.lda@gmail.com

Mauritius, an island nation in the Indian Ocean, experiences frequent flood damage due to high variation in rainfall patterns and urbanization. In response to these challenges, an end-to-end framework was implemented to address flood disaster management in the Grand River North West (GRNW) catchment area (114 km2). This study aimed to investigate the implementation of this framework through three main components: climatology analysis, hydrological modeling, and GIS-based flood risk modeling.

The climatology analysis examined trends in floods for the past (2003-2018) and future climate (2025-2040) to assess the impact of climate change on flood risks. The analysis revealed an increasing trend in extreme rainfall, which is likely to continue in the future. The hydrological model was developed to study the hydrological responses of the basin to extreme flooding events. The WEB-RRI model was used to simulate the impacts of flooding within the basin, and the model was validated with a satisfactory NSE = 0.41, MBE = -0.08 m3/s, and RMSE = 2.06 m3/s for 2015-2016. The resulting inundation map was then used to calculate the damage caused by future extreme events.

Given the high level of confidence in an increase in extreme precipitation and high certainty in an increase in urbanization, the flood risks in the GRNW Basin are likely to worsen. Therefore, a GIS-based risk model was employed to identify the areas in the catchment most vulnerable to flooding. The model calculated the vulnerability index at a village council area (VCA) scale, which was calculated using the formula Vulnerability = Exposure + Susceptibility – Resilience. Indicators were used to evaluate the exposure, susceptibility, and resiliency of each VCA. The indicators for exposure included risk to loss of life, access to highways and metro lines, and economic damages. The indicators for susceptibility were new developments within the catchment, velocity of flow, the number of flood-prone areas, and environmentally sensitive areas. The indicators for assessing resiliency were the presence of shelters and evacuation centers and drainage projects and flood control measures. A weighted score was assigned to the indicators based on their relative importance, and a vulnerability map was developed.

Through the WEB-RRI model and the GIS-based risk model, and the depth damage curve methodology, the simulated direct damages incurred were seen to double compared to the worst recent flood event in the basin (March 2013). This study has provided valuable insights into flood disaster management in Mauritius and could serve as a useful reference for policymakers and stakeholders in addressing the challenges posed by increasing flood risks at a local level. The findings underscore the need for effective flood risk management strategies to mitigate the adverse impacts of climate change and urbanization on flood risks. Furthermore, the vulnerability index and the GIS-based risk model can serve as powerful tools to guide decision-making and prioritize investment in flood risk management measures. Ultimately, this study provides a roadmap for effective flood disaster management in Mauritius, which could be scaled to other catchments.

Technical session 6: Monitoring the impacts of hydroclimatic risks and EWS – Part 2

Reproducibility and uncertainty for national Canadian hydrometric stations

Shervan Gharari[1], Paul H. Whitfield[1], Alain Pietroniro[1], Hongli Liu[1], Jim Freer[1], Martyn P. Clark[1],

[1] University of Saskatchewan, shervan.gharari@usask.ca

Reliable and accurate river streamflow or discharge measurement and reporting are essential for engineering, economic, and social decision-making. Discharge values are often perceived as true and deterministic by users, modelers, and decision-makers. In this study, the processes of discharge estimation by the Water Survey of Canada, WSC, are presented. The process of inferring the discharge (water volume over time) based on stage (water level) through stage-discharge relationships or “rating curves” including related terminologies is described. Multiple practices of rating curve construction and discharge estimation across WSC hydrometric stations are explored. Major processes of "override" and "temporary shift" which significantly affect the discharge estimation are elaborated. The reproducibility of the published discharge data using data from the production process for approximately 1750 active hydrometric stations operated by WSC is examined. Other impacts of temporary shift and override have been evaluated on the properties such as discharge residuals or performance metrics. Recommendations are made for wider access to metadata and measurements that are essential to quantify the reproducibility and uncertainty of reported discharge values. Open science, particularly Earth system modeling, demands clear communication of reproducibility, and uncertainty of published discharge.

Strengthening the Resilience of Vulnerable Communities of Caribbean SIDS Through Education and Communication Project (Ranfo Kariyib)

Marcelo Gaviño Novillo[1], Zelmira May[2]

[1] UNESCO Advisory Group in Disaster Risk Management for Latin America and the Caribbean (GERM)-Member, magavino@gmail.com

[2] **UNESCO Regional Bureau for Sciences in Latin America and the Caribbean**

Small Island Developing States of the Caribbean (SIDs) are one of the region of the world that face a unique set of increasing stressors, both climatic and non-climatic, which are pushing on people's livelihoods, threatening the well-being and sustainability of communities. Quick-onset events, such as tropical storms and hurricanes showed a gradual increase between 1980 and 2009, however a noticeable increase was registered between 2010 and 2022, for which risk management and resilience building constitute a growing challenge for decision makers and society as a whole.

Early warning systems are one of the major elements of disaster-risk reduction, saving effectively lives by providing information before the occurrence of a disaster, then, it is important that messages allow the population to know the true magnitude of the associated risks, being key to this will to build a "communication bridge" so that policy makers can implement the best ways to "reach" communities and individuals to ensure that they take the most appropriate measures to preserve life in the most critical time: during an event.

As a specific UN organization, UNESCO is closely involved in the conceptual change to build less vulnerable and more resilient societies through strong preventive actions against disasters operating at the interface between natural and social sciences, education, culture, communication, and information.

Considering that citizen science and open science can significantly contribute to an effective adaptation to the impacts of those hazards, UNESCO is developing the project Strengthening of local and community capacities in the face of natural disasters in Small Island Developing States of the Caribbean (SIDS), which aims to strengthen the capacities of communities and individuals in order to improve their preparation through formal and non-formal education, as well innovative communication in The Bahamas, Haiti, Dominican Republic, Saint Lucia and Saint Vincent and the Grenadines, helping the most vulnerable population to take the most necessary actions. The project basis includes a 1) Multi Sectoral Approach, 2) South-South and North-South cooperation and 3) Dissemination of the output through a MOOC so that this project could be implemented appropriately, broadly and effectively, and acquire sustainability.

The project is financed by the Japanese government and has been formulated in such a way as to involve the participation of several UNESCO offices, the authorities of the selected countries, as well as other UN agencies, multilateral organizations as well as organizations with concrete experience in community strengthening in the Caribbean setting.

Be Resilient - Building the resilience of Southern African countries to climate change and disasters a case of Chimanimani Post Cyclone Idai

Tawanda Gijima[1], Muchaneta Munamati[1], Martiale Zebaze Kana[1], Guy Broucke[1], Koen Verbist[2]

[1] UNESCO Regional Office for Southern Africa, t.gijima@unesco.org

[2] UNESCO Headquarters

Climate change impacts are being observed across the Southern African region, with water-related hazards causing massive flooding, landslides and severe droughts, significantly affecting natural resources and posing a direct threat to human security. While climate change is driven by global processes, the solutions to offset the negative effects of climate risks are particularly dependent on local conditions. In this respect, through the Be-Resilient Initiative, UNESCO Biosphere Reserves (BRs) have become observatories for climate change adaptation and mitigation. The Be-Resilient Initiative aims to strengthen Biosphere Reserves and their communities to address climate change challenges and associated water-related hazards. It engages the BRs in the region to pilot effective pathways towards climate change adaptation, using a multidisciplinary approach. To solicit the communities' understanding of climate change related challenges in the Biosphere Reserve a bottom up 5 step Climate Risk Informed Decision Analysis is being implemented. The methodology has been successfully

implemented in the newly established Chimanimani Biosphere Reserve resulting in an improved understanding of the local context and establishing adaptation pathways for the communities. In addition to understanding the problems in the area technical flood risk assessments were carried out. 30 meter flood hazard maps were developed showing areas prone to flooding for different return periods. Using an open source Delft Flood Impact Assessment Tool (FIAT), detailed floodwater depth information was combined with the exposure of the infrastructure and livelihoods of communities to these flood events, to provide insight into the physical exposure of communities to these flood hazards resulting in detailed flood impact maps used for decision making. Furthermore, landslide susceptibility assessments were carried out in the Chimanimani BR. The Be-Resilient initiative also led to the development of high-resolution (30 m) flood and drought monitoring and early warning system for two transboundary basins between Mozambique and Zimbabwe. This was building further on the Zimbabwe national Flood and Drought Monitor (5km resolution) to support early action and increase early warning capacities. To ensure early warning communication, community radios were set up.

Modeling the impacts of climate change on resources in water from the Bafing watershed (Upper Senegal River Basin)

Ibrahiam Thiam Gaye[1], Mamadou Lamine[1]

[1] Assane Seck University of Ziguinchor, thiamgaye08@gmail.com

The flow records of the upper basin of the Senegal River and its Guinean part are often incomplete, discontinuous, of short duration, and therefore difficult to use for a reliable hydrological analysis. Indeed, it is not always possible to have long chronological series of observed flows allowing an adequate evaluation of surface water resources. Rainfall-runoff modeling is mainly interested in the functioning of the hydrological cycle at the level of a catchment area at different spatio-temporal scales. The objective of our work is to model the impacts of climate change on the water resources of the Bafing watershed based on the hydrological model GR4J (Agricultural Engineering 4 Daily Parameters). The methodology applied consists in calibrating and validating the GR4J model before simulating the future evolution of flows in the Bafing catchment area under the SSP245 and SSP585 climate scenarios. The GR4J calibration and validation procedures were carried out with rainfall, ETP and flow data observed over the period from 1981 to 2010. The outputs of six global climate models from the CMIP6 project (CanESM5, CNRM, IPSL, NESM3, INM_CM4 and FGOALS) were corrected before being used as a forcing of the GR4J model to simulate future flows. The results show that the GR4J model satisfactorily reproduces the shape of the observed hydrographs. The calculated peak flows are well located in time even if they are sometimes underestimated or overestimated. Climate projections reveal a rise in temperature and ETP, which will further strengthen in the future under SSP245 and SSP585. For rainfall, some models predict an increase and others a decrease and the overall average of these models predicts a decrease in precipitation under the SSP585 scenario and a slight increase under the SSP245 scenario for the 2050 and 2090 horizons. As for future flows, a downward trend in average annual and monthly flows is expected at the level of the two Bafing sub-basins (Daka Saidou and Bafing Makana) under the two scenarios. This decline is more pronounced in Daka Saidou than in Bafing Makana. These results could help decision-makers, farmers and herders to better plan and direct socio-economic activities in order to reduce the risks associated with the negative impacts of climate change and increase their resilience.

Status of metrological drought in South Asia: Spatial and Temporal Analysis 2000-2020

Hemu Kafle[1]

[1] Kathmandu Institute of Applied Sciences, hkafle@kias.org.np

Every year, South Asian countries suffer from a decline in agricultural output due to climate extremes such as floods and droughts. Recurrent droughts have depressed rural economies and enhanced widespread hunger and human migration to South Asian cities (Miyan, 2015). Due to climate change,

the region is projected to experience rising temperatures and more frequent extreme weather events in the long term (Trenberth et.al., 2014). Accurate determination of drought, its impact and early detection facilities are not present in most South Asian countries due to a lack of sufficient hydro-meteorological datasets, poor access to satellite products and shortages of well-trained staff. This study seeks to address these deficiencies in a scientific manner by analysing past meteorological droughts on a regional scale using freely available satellite data products. The Drought Severity Index (DSI) has been used for assessing meteorological droughts from 2000 to 2020. The long-term trend of drought and its occurrence in the region is shown via monthly drought severity maps, individually on a country basis for Nepal, Bangladesh, Pakistan and the northern part of India. Results from DSI were further compared with the Standardized precipitation index (SPI) in Nepal and Bangladesh. Our result identified pre-monsoon months as the driest period in South Asian countries experiencing severe to moderate drought.

Day 2 | 20 April 2023 | Next level of participatory water management: Citizen and open science and the role of indigenous and local knowledge systems

Technical session 1: Innovative participatory approaches, tools and methodologies supporting citizen science

Tidal River Water Custodian: An approach to link local communities to decision making

Myisha Ahmad[1], Willem van Deursen[2]

[1] BRAC, myisha.ahmad@brac.net

[2] Carthago consultancy

Livelihoods in the South-West Delta of Bangladesh are under increasing pressure from changes in the physical environment, compounded by socio-economic dynamics such as population growth and a decreasing income from traditional agriculture. Over the last 50 years experts and engineers have been trying to deal with these adverse trends by developing optimized, rationalized polders following the Dutch examples. This approach however, resulted in ambiguous impacts. An increased salinity, accelerated soil subsidence and deteriorating drainage congestion seems to be the adverse effects of these interventions. The unfavorable consequences have forced the locals to be less and less content with the intended solutions that were promised by the development of the polders. This further has led to some recent events of local farmers breaching the embankments around the polders in an attempt to increase the drainage situation of their inundated lands. Farmers are increasingly resorting to shrimp farming as an alternative way to make a living in these regions. These dramatic dynamics are further enhanced by a top-down approach to water management. However, communication and exchange of ideas between experts and local communities seems to be almost absent.

The real challenge in improving livelihoods is in handling the complex interaction between many diverse actors. Agriculture is recognized as one of the important stakeholder sectors, but the agricultural sector itself is heterogeneous, consisting of diverse groups ranging from large landowners to subsistence farmers and landless seasonal laborers. All these actors have individual stakes, incentives and thus individual perspectives and behavior towards the dynamic changes in land use and water management.

The 'Tidal River Water Custodian (TWC)' decision making framework is a bottom-up approach to create a pathway towards resilient livelihoods in changing deltas. Decision making is a process that needs careful design and a strong focus on the inclusion of all relevant stakeholders in the decision making process. The current limited focus on the geo-physical environment and an optimization of infrastructure and control structure misses the ultimate goal of defining adaptation strategies to improve the livelihoods of the local communities. The TWC framework is developed with a set of tools and concepts based on the life stories of the local families-that serves as the evaluation background, against which proposed interventions by government or the community will be analysed. We present a case study in the South West Bengal Delta, where drainage congestion is a major challenge, but the technical solutions fails address real livelihood consequences. Incorporating life stories to the decision making process is therefore a crucial requirement. TWC paves a way of resilience through science to communities and vice versa.

Development of Integrated System and Multi-layered Governance for Flood Resilience Enhancement

Mamoru Miyamoto[1], Daiki Kakinuma[1], Tomoki Ushiyama[1], Abdul Wahid Mohamed Rasmy[1], Della Grace Bacaltos[2], Anthony, C. Sales[3], Toshio Koike[1]

[1] ICHARM, mmiyamoto@pwri.go.jp

[2] Davao del Sur State College

[3] Department of Science and Technology XI

To cope with the external force of unexpected water-related disasters and intensification due to climate change, the concept of disaster resilience is indispensable in addition to suppressing hazards. This manuscript presents an operational methodology and practice case for enhancing flood resilience and bridging the gap between local society and science community.

The Platform on Water Resilience and Disasters in the Philippines, which is an interagency framework among all relevant stakeholders on water-related disasters, has been enhancing flood resilience with the support from the International Flood Initiative (IFI)* by developing an Online Synthesis System for Sustainability and Resilience (OSS-SR) and fostering Facilitators who can interlink between local society and science community. The primary contents of OSS-SR for Davao City have emphasized real-time flood forecasting and climate change impact assessment according to local needs. The OSS-SR has also been used as a tool to engage stakeholders and communities through the visualized system for flood inundation information, the accumulating database of indigenous knowledge, and the e-learning function to foster Facilitators.

Through the cooperation of practitioners and academia for the open science in e-learning workshops and training, the Platform was able to come up with and implement a design of a robust flood forecasting system and four criteria to gather various types of facilitators. A robust flood forecasting system is one that has succeeded in continuing to provide flood risk information in spite of poor data availability due to missing data. It has been realized by synthesizing different types of rainfall inputs such as satellite-based rainfall and ground gauge. Four criteria realized a governance building for comprehensively coping with extreme water-related disasters by effectively gathering candidates of Facilitators from multiple disciplines and sectors in the local society.

Hence, the study clarified that simultaneous developments of an integrated system e.g. OSS-SR, and the multi-layered governance enabling effective capacity building, can enhance the flood resilience of local society based on stakeholders' and community's literacy improvement regarding water-related disasters.

*International Flood Initiative (IFI) is a joint initiative in collaboration among international organizations such as UNESCO-IHP, WMO, UNDRR, UNU, ICLR, IAHS, and IAHR.

Rapid Games Designing; a participatory format to unpack and discuss concepts like resilience building

Bruce Lankford[1]

[1] **University of East Anglia, b.lankford@uea.ac.uk**

A participatory technique for understanding and discussing complex or abstract socio-ecological concepts called 'rapid games designing' will be presented. Initiated by a recent research project examining agricultural and water/catchment resilience in South Africa, and tested in three workshops, 'games designing' is a format for constructing dynamic metaphors of complex systems and related concepts (e.g. the resilience of a catchment-agricultural-marketing system). The workshops support participants to design, compare and discuss their games, and to explore the ideas and meanings of a given complex system, even if the latter is initially deemed by participants to be abstract and 'academic'. The abridged term for short-format games designing is 'rapid games designing' (RGD). Key benefits to participants, the whole group and workshop organizers include: a) the highly productive and creative use of limited time; b) an inclusive group exercise that draws everyone into the process; c) rich discussion of pluralist viewpoints through the comparison of the remarkable variety of games generated including differences in purpose, players and rules; and, d) observations on how the games construct a dynamic metaphor of the system and its properties, leading to deeper insights and knowledge-building regarding system concepts and components. In conclusion RGD offers an option to the on-going evolution of games and other participatory knowledge tools about complex human, natural and socio-technical systems, and that it generates considerable creativity, learning, discussion and insights amongst all participants. The presentation explains the format, and presents feedback and photographs

taken from South Africa that ‘game-designed’ catchment and drought resilience. A short video from a RGD workshop on 'Build Back Better' will also be shown. The presentation is supported by this journal paper:- https://doi.org/10.3390/su12177200

Water management actions towards more climate resilient business parks

Wim Schiettecatte[1]

[1] **VITO, wim.schiettecatte@vito.be**

WaterProof (www.vlaanderenwaterproof.be) is a 4-years Flemish Blue Deal project to demonstrate at large scale how to deal, within the built environment, with future droughts and intensive rainfall, both related to climate change. One of the three demonstrators is located at the business park of Tielt Noord, in the west of Belgium, where ‘water gains’ are pursued through i. Greening and infiltration, ii. Innovative road building, iii. Activation of existing and new buffer volumes and iv. Unlocking new local water sources.

Partners within Tielt Noord demonstrator of the WaterProof project are the VITO (Flemish institute for technological development) as coordinator, public wastewater company Aquafin and drinking water company De Watergroep, strengthened by the active support of local government entities.

The first two years of the project have been dedicated to stakeholder consultations (industry, farmers, fire department), a thorough analysis of the water network, starting from public data and valuable local knowledge and finally a co-created and modelled set of water gains to be further implemented in the upcoming two final project years.

The presentation will zoom in on two specific building blocks to make business parks more climate resilient. The first solution is the activation of existing water buffers, both private and public. Through the implementation of water sensors (level, flows, quality) and controlled pumps and valves, the static operation of buffers can be optimized to a more intelligent and flexible one. The second (linked) solution is unlocking the newly buffered water volumes as an alternative water source towards local users, being on one hand large industrial production sites and on the other hand neighboring farmers. Buffered rainwater runoffs of business parks might contain (historical) contaminations with emerging contaminants, as for instance PFAS. An analysis campaign provides insight in the magnitude of the problem and in the possible remediation or treatment solutions. Both WaterProof solutions will be presented, based on analysis results, modelled water balances, scenario analysis, technology selection and (social) cost benefit analysis.

VITO is member of the Water4All partnership and proposed the Business Park Tielt Noord as a Water Oriented Living Lab, to become a powerful instrument in the European open innovation context. Furthermore, Tielt Noord is part of the Flemish case study within the Horizon Europe project RETOUCH Nexus, on resilient water governance under climate change and will identify business models for decentralized water use schemes.

Designing a SMART flood early warning system for a lesser Himalayan urban region

Tahmina Yasmin[1], Sudhanshu Dixit[2], Kieran Khamis[3], Anthony Ross[4], Subir Sen[2], Debashish Sen[5], Sumit Sen[2], Wouter Buytaert[6], David M. Hannah[3]

[1] **University of Birmingham, t.yasmin@bham.ac.uk**

[2] **Centre of Excellence in Disaster Mitigation and Management, Indian Institute of Technology Roorkee**

[3] **School of Geography, Earth & Environmental Sciences, University of Birmingham**

[4] **Department of Civil and Environmental Engineering, Imperial College London**

[5] **People's Science Institute**

[6] **Department of Civil and Environmental Engineering, Imperial College London**

Since the beginning of 21st-century, floods and heavy rainfall events are becoming frequent, sudden and destructive. In the mountainous regions, flash floods are becoming devastating and significantly damaging to the lives and property of vulnerable people. There are no alternatives than to engage with local community and better understand the risks posed by these hydrometeorological extremes and watershed characteristics to pre-plan flood response, and mitigation. In response, we adopted a SMART-approach for designing an inclusive early warning system by deploying a low-cost sensor-based-network to produce information on hydrological variability and runoff-response in the Bindal-river catchment in Dehradun, India. The SMART-approach refers to developing a Shared understanding, Monitoring, and Awareness of the associated risks for preplanning Response action on Time. Inclusiveness in this context refers to integrate science, policy and local community-led approaches to connect engaged stakeholders and generate knowledge for guiding environmental decisions that fit the local context.

The Bindal-river lies in the Doon-valley in the Himalayan-region with an elevation difference from 450m to 44.4km2. With a series of consultations with communities, three appropriate elevation points were found to place the sensors and rain-gauges. The preliminary data (September 2022 rainfall data with 15mins intervals) showcased a significant variability at both spatial and temporal scales. The correlation coefficient (p value<0.05) between the rainfall observations at different stations varied from 0.82 to 0.20 with a distance between their locations ranging from 2.74 to 8.24km. The difference in total monthly rainfall recorded in two rain-gauges 8.24 km apart is 187 mm. This means that the unplanned urban settlements downstream receive heavy rainfall within a short duration, while upper-catchment regions receive low-intensity rainfall for a longer duration. Future work includes mapping of the areas that are likely to get affected by flash floods and requires a dense network of sensors for monitoring and measurement.

Technical session 2: Participatory approaches involving Indigenous and Local Knowledge

Value of the river for improving participation on water governance facing drought in the Chota valley

Sandra Megens[1], Jeroen Warner[1]

[1] **Social Science Group, Wageningen University, sandra.megens@wur.nl**

In the face of climate extremes, such as flooding, earthquake, and droughts, Ecuador has made significant progress in structuring government organizations for alerts and risk management. Nevertheless, due to the lack of a disaster risk reduction law and weak institutional strategies, it is difficult to establish adequate protection, adaptation, mitigation, and restoration measures. Moreover, it is important to consider that droughts tend to be slow and/or progressive, accompanied by secondary economic, social, and environmental effects. Also, when water is scarce, it can lead to conflict among people because they can't get enough water to drink or irrigated their crops. Therefore, the impact of climate change and variability has resulted in major social-environmental transformations, as in the ancestral afro-territory in the northern part of the country, over the last few decades. This study explains how the historical transition, struggles, practices, and political participation surrounding irrigation water governance-related ethnic minorities have resulted in the redefinition of hydrosocial territories in the dry Chota Valley of the Mira River Basin. To understand the collective identity of the Afro-descendants, as a society, this study examines collective property rights and heritage theory and concepts with a particular focus on the cultural heritage of water. These ancestral territories of Salinas, Concepción, and the Chota Valley are multicultural and multiethnic regions where people of different identities belong. In recent years, the growth of the Ecuadorian agro-export sector has brought with it significant

transformations in these territories. Based on a case study, this research responds to the general objective of recovering memory through the process of its ancestral experience, and collective rights, and as a critical opportunity to protect the intrinsic value of the Chota River and to recognize the intangible national heritage of the Chota valley, against water scarcity scenarios. Utilizing qualitative research methods, including bibliographical review, ethnographic information, and results validation. Findings show that mapping is not a neutral political process; it is a political practice that reflects upon how we perceive territories, and how they organize themselves within them. They coexist with other diverse groups (such as the Indigenous communities) in the rest of the Mira Basin of which the Chota sub-basin is part, with sometimes similar disagreement over the water management and services in the areas, and all together form the multispecies resistance to this water policy. We agree on the relevance that knowing the human-water system at the Chota river basin interactions, helps to understand the value of the rivers, thus we can anticipate how it works. These aspects are incorporated into a conceptual model aimed not at replacing, but at expanding and enhancing, existing framework systems on the semi-arid watershed of this ancestral hydro-social territories. We can conclude that may not be able to predict everything, but we can look for and reduce these uncertainties.

Net Zero: Heritage for Climate Action

Aparna Tandon[1], Mohona Chakraburtty[1], Jui Ambani[1]

[1] ICCrom, aparna.tandon@iccrom.org

This presentation will outline heritage-based mitigation and adaptation strategies for water effects of climate change. It is based on the findings of an ICCROM-led capacity development project, Net Zero: Heritage for Climate Action, which uses Indigenous knowledge and traditional practices to mitigate water scarcity, food insecurity, environmental degradation, carbon emissions, forced migration and conflict over resources, in five climate hot-spots.

The project is founded on the idea that every place has a climate-culture story that is shaped by humans living in a place and their interactions with the specific natural environment of that place.

In the ongoing research phase of the project, multidisciplinary teams in Ubatuba (Brazil), Rosetta

(Egypt), Jodhpur (India), Rwenzori National Park (Uganda) and Tutti Island (Sudan) are collecting place-specific oral histories to identify root causes of the prevalent climate risks in their sites and build climate-culture stories. The emerging results of this ongoing research underscore that water and its management play a central role in adapting to and mitigating the effects of climate change, as well as reducing the risks of conflict.

With an aim to build a globally applicable foundation for engaging culture and heritage in climate action,this paper will showcase approaches and conditions in which community held heritage can become a vector for climate action and sustainable development.

Investigating the Potential of Indigenous-led Conservation Finance for Climate Mitigation

Audrey Popa[1], Ana Maria Peredo[2],

[1] University of Victoria, audreympopa@uvic.ca

[2] University of Ottawa

Healthy ecosystems are vital to addressing the global climate crisis. When intact, they play an essential role in regulating and reducing risks associated with climate-related hazards, such as floods and sea level rise (Pimentel et al., 1997; Barbier, 2017; Uhlmann & Ross, 2018; Sothe et al., 2021). However, a majority of the world's land and oceans remain unprotected and underfunded, leaving them at risk of degradation (Waldron et al., 2020). Conservation financing, generally defined as mechanisms that generate, manage, and deploy financial resources for environmental conservation, has recently

emerged as an alternative to insufficient traditional conservation funding resources (Conservation Finance Alliance, 2021). Conservation financing initiatives vary greatly in size, mechanisms type, and degree to which Indigenous knowledge and values are included in their development. Importantly, the level of involvement of Indigenous communities greatly impacts the design and implementation of these mechanisms. However, conservation financing discourse largely ignores components of community economic development, cultural resurgence, and sovereignty, which are integral to Indigenous-led conservation financing initiatives. This presentation will explore the current landscape of Indigenous-led and collaborative conservation financing initiatives in Canada, alongside an overview of Indigenous stakeholders' perceptions on conservation financing as a tool for environmental and economic resiliency. This research aims to emphasize the need for Indigenous ownership and management of conservation financing opportunities, and highlight the financing models, governance structures, and related experiences of present-day conservation financing initiatives.

Contribution of citizen participation, open science and indigenous knowledge forward to action for water

Haydee Villalta Rojas[1]

[1] **SAGUAPAC, haydeevillaltarojas@gmail.com**

In this presentation I want to show the experience of the citizens' participation in the management of the provision of the water service, which inspires inter-institutional action in Santa Cruz de la Sierra and moves public policies that are favorable to the care of the environment in general and of water in particular.

The open dialogue with different knowledge systems allows effective social participation, this participation in the integral management of water is key, both because it incorporates new ways of seeing nature, that other point of view that is decisive when making decisions in public policies.

It is another point of view that values nature and is important in advocacy actions, if Mother Earth has no one to manage for her, she dies in the midst of deforestation and ecosystem degradation. Faced with the system of political representation without speakers who defend integral water management. The cooperative model that exists in SAGUAPAC allows popular groups and indigenous people with a high presence of young people and teenagers to ensure water management in Santa Cruz.

Currently there is a system of participation in decision-making in the provision of water service where representatives are elected to take directive actions every 2 years. Likewise, the compilation of myths began, stories about the water of indigenous people of the lowlands of Bolivia where values and principles that guide the care of water in indigenous cultures are rescued.

This care is oriented for a different epistemology, for indigenous people water is not only a resource. Water has life, it is part of life and it gives life. We can speak of water's breeding, as well as water's mother.

The Ayoreo people believed that there was a time in which only humans existed and they progressively transformed into animals, geographical features or plants. This transformation was made both by their own decision and by some fortuitous event. There were no differences between the human world and that of nature. From this principle, what exists in nature has a direct and close relationship with the human, therefore, there is a mandate to care for and respect it.

Another example, the Guarani people trusted, water in the form of mist was the first thing that existed, there are myths in which underground waters and water springs were where life is created and regenerated. There even the gods would regenerate. Everything that exists is created from water. The water is a connector for the planet and a fundamental element for its subsistence.

Another fundamental and necessary element to explore is to make technical and technological advances in water management available to the population, guaranteeing the nexus: water, energy and food, in order to seriously think about sustainable models that are part of families daily lives.

This process began with the implementation of technology, but also with dissemination and interactive dialogues, making the dialogues available on the web platform.

There remains a challenge to take on and it is Collective Financing for open science and knowledge management for comprehensive water management.

The valorization of citizen science in water management. The Touareg population in Southern Algeria - A study example

Hachelafi Hamid[1]

[1] **University Oran1, hachelafih@hotmail.fr**

Introduction: The movement of sub-Saharan populations from the southern to the northern shores has been very marked over the last few decades, with multiple socio-economic factors agreeing on the extent of clandestine migration.

However, observation of the South-North migratory flow shows that the indigenous populations of the southern shore, such as the Touareg population, have not been affected by this demographic transition.

The nomadism of the Touareg in the large area of the Sahel keeps its authenticity despite natural (drought and climate change) or human (armed conflicts) hazards.

The ancestral heritage of the indigenous populations deserves to be re-read in the light of technological upheaval (satellite geo-localization of water tables, hydraulic engineering, etc.) in the face of mutating know-how, but resistant to climate change for the sake of survival.

Objectives: The study focuses on the adaptation behaviors of the Touareg population to the climate changes that have affected their way of life and to extract the experiences with social and economic impact of the indigenous population.

Methodology: Our study is based on the collection of climatic data on rainfall, the rate of migration of the sub-Saharan population transiting through the city of Tamanrasset (a city in southern Algeria and the crossroads of clandestine sub-Saharan migration) and the inventory of water management methods and related activities among the Tuareg population in southern Algeria.

Results: The Touareg have maintained themselves for a long time in the mountainous geographical areas between the countries of Algeria, Libya, Mali, Niger and Burkina Faso. In these arid environments, rainfall is scarce and irregular, with extreme temperatures where the wind further stresses the aridity and drought.

The Touareg have regulated their way of life according to perennial climatic changes, notably through rainfall indicators. They have divided the year into four seasons (Awelen (the hot season), Akassa (the rainy season), Gharatte (the equivalent of autumn in the West) and Tedjrest (the cold season)) which reflect the annual cycle and its rhythm. They know the signs announcing the changes of the season.

The shepherds use animal traction to draw water. Although all the navigable areas are cultivated, yields remain low because the soil is poor. This temporal organization of space is based on a thorough knowledge of seasonal characteristics and vegetation over considerable distances. It shows the example of the sorghum plant by the scientific literature in biology, which reports that the adaptation of sorghum comes from the shifting of the cycles on the dates of the beginning and end of the rainy seasons. This characteristic of photoperiodism ensures that flowering is synchronized with the end of the rainy season regardless of the sowing date (Falalou, et al., 2005).

The Touareg community's world is built around a tradition of transhumance that follows a seasonal shift; during the dry season, which lasts over six months of the year, pastoralists migrate south with their livestock in search of grazing land and water.

Technical session 3: Stakeholders engagement through new approaches — Part 1

Use of a mobile app based on biological indicators for monitoring water quality in rural communities in the Cordillera Blanca (Peru): a citizen science approach

Raúl Loayza-Muro[1], Vanessa, Arévalo Seijas[1], Fiorella La Matta Romero[1]

[1] Universidad Peruana Cayetano Heredia, raul.loayza@upch.pe

The Cordillera Blanca (CB) in the Northern Peruvian Andes holds 40% of the world's tropical glaciers and represents one of the most important freshwater sources in the country. Its rivers and streams drain the Santa River, within the Huascarán National Park, in the Áncash region. The geology of the CB is characterized by the pyrite-rich Chicama formation, which produces naturally acid rock drainage and the consequent mobilization of toxic metals, such as aluminium, arsenic, manganese, cadmium, lead and zinc after rock weathering and oxidation. In many cases, the concentration of these elements exceed national and international environmental quality standards, thus posing a standing threat for economic activities and ecosystem health. Hence, climate change increasing glacier retreat is accelerating the acidification of headwaters through exposure of metal-rich mineralized rocks, which impacts on water quality and livelihoods and health of rural communities in the Peruvian Andes. Although this is a serious hazard, most communities do not have access to reliable water quality monitoring tools to face this rapidly changing scenario and to take decisions on water resource management and adaptation.

The aim of this study was to train stakeholders in a rural community in Canrey Chico (Recuay, Áncash) in the CB to perform river quality monitoring using the mobile app "Aqua Biosmart" based on the Andean Biotic Index (ABI). This index has been adapted for the Andean region and relies on the responses of aquatic macroinvertebrates (mostly insect larvae living in freshwater ecosystems) assemblages to changes in water and environmental conditions. Along four training and field workshops, the members of the Water Research Committee "Alli Yacu, Alli Pastu" of the community successfully identified up to 94% of the macroinvertebrates using standard sampling methods and identification guides, and calculated the quality of 12 sample points in rivers and streams using the mobile app. Surveys were applied to participants to identify skills and motivations gained from their experience: 62% mentioned that the app was easy to use, 57% found larvae identification as very easy, 72% gained skills in water quality monitoring, and 57% in water management and decision-making. Interestingly, after this experience they were able to train undergraduate students from the Environmental Engineering Program at the Universidad Nacional Santiago Antúnez de Mayolo (Huaraz, Áncash) in sampling methods and how to use of the app.

A citizen science approach in vulnerable regions, such as communities in the tropical Andes, promotes social participation, and provides knowledge, changes in attitudes towards environmental problems, and tools that allow autonomy in policy generation and decision-making to ensure a sustainable use of water resources. In this case, mobile applications and an adequate training and scientific support have demonstrated a great potential for water quality assessment. Moreover, understanding the perceptions, motivations and benefits for participants will help in the recruitment and retention of volunteers.

Cliamte Variability and Agricultural Changes in Tamou (Periphery of "W" Park) in Niger

Amadou Abdou Bagna[1]

[1] Department of Geography, Abdou Moumouni University, amadoubagna@gmail.com

Located on the periphery of the 'W' biosphere reserve in Niger and well known for its agricultural vocation, the Tamou area is affected by climate variability observed since the late 1970s. The objective of this study is to analyze the agricultural changes induced by rainfall variability since the end of the great drought of 1972-1973. The methodological approach used combines criticism of rainfall data observed from the stations of Tamou, Tapoa and Say (1983-2019) and field surveys of producers. All these data are supplemented by field information collected from 96 producers on perceptions of climatic deterioration and the responses provided. The results reveal a marked rainfall variability, characterized by a drop in rainfall and sudden alternation between dry and wet periods. These events have resulted in land pressure on limited agropastoral areas, in addition to very complex practices. Thus, producers have a good understanding of climate variability and are developing a typology of responses to cope with it. Among these are the appropriation of new agricultural orientations, modification of the calendar and cultivation options (85%), development of new land resources, particularly lowlands (78%), dissemination of irrigation technologies (30%) and adoption by producers of new seed varieties better adapted to intra-seasonal climatic disturbances (79%).

Predictors of Stakeholders' Willingness to Participate in Payment for Ecosystem Services among Urban Water Users in Accra, Ghana

Roland Apambilla[1], Opoku Pabi[1], Daniel Nukpezah[1], Erasmus H. Owusu[1],

[1] University of Ghana, aapambilla001@st.ug.edu.gh

Ecosystem services are the benefits that people receive from nature. They play an important role in the socioeconomic well-being of local communities. Climate change, urbanization, population increase, and land degradation all contribute to severe ecosystem degradation with increasing risks and vulnerability to local communities in face of climate threats to water availability and quality. Wider stakeholder participation in ecosystem conservation is becoming increasingly important. The purpose of this study was to explore how socioeconomic characteristics influenced stakeholders' willingness to participate in payment for ecosystem services for long-term water supply in places where water supply instability is already a major developmental concern. We quantitatively surveyed 400 downstream water users of the Densu basin in the city of Accra, Ghana. Our results show that only 39.3% of the total respondent surveyed were willing to pay for ecosystem services with the majority not willing. A chi-square test further revealed that respondents' age, education, kind of work and income levels were all significant factors in their willingness to participate in the payment for ecosystem services at a 0.05 significant level. Respondents' willingness to pay for ecosystem services was prioritized on the availability and quality of water urban water supply, as well as ensuring efficient resource management. The majority's hesitancy was however fuelled by a lack of trust in the management of such funds, a high cost of living, and a lack of alternative sources of income. This necessitates increasing the credibility of resource management institutions and ensuring a broader range of stakeholders' engagement in the development of inclusive community co-management initiatives. These can contribute to a win-win situation for ecosystems and build community resilience and improve livelihoods in driving the sustainable development goals agenda.

DecisionMentor as Climate Smart Decision Making tool to Individuals

Shashi Bhattarai[1], Sovit Poudel[2]

[1] Development Dynamics Pvt. Ltd., ShashiBhattarai@gmail.com

[2] Truneary Solutions

The DecisionMentor mobile application was created to provide access to multiple criteria decision making (MCDM) tool to individuals, helping them use systematic approach to make personal decisions. DecisionMentor is based on well-known and widely used MCDM theory called the Analytic Hierarchy Process (AHP). The theory of AHP is combination of psychology and mathematics (Saaty, 1980), It uses psychology in the process of deriving priority and mathematics while processing to get results of human judgements.

As smartphone have become obvious lifestyle component. DecisionMentor be the touchpoint to provide decision insights on the critical decision junctures. Individual decision makers in dilemma needing support to choose among available options, with due consideration of their criteria of concern are the target customers of DecisionMentor. Decision that have positive impact on the climate are often conflicting with criteria Climate, Cost and Comfort, such as deciding Which vehicle to buy ? or What kind of food to eat ?, among lifestyle related decisions.

The work will showcase the academic endorsement of DecisionMentor including by (Mu, 2022) and (MCDM Society, 2021) and will be presenting potential Climate Smart Decision (CSD) application cases. The case includes, adaptation on farming (Banarjee et al., 2020) to demonstrate potential for facilitating local level decisions. The DecisionMentor, personal MCDM (PMCDM) mobile application is available for free on the app stores of Google, GooglePlay and Apple, AppStore. We are working to come out with improved version of DecisionMentor with artificial intelligence (AI) integration.

Assesing the complementarity of soil moisture monitoring and remote sensing data based on the Citizen participation in the Irrigated Area of Lakhmass (Siliana, Northern Tunisia)

Amani Belhaj Kilani[1], Slaheddine Khlifi[2], Marnik Vanclooster[3]

[1] UCLouvain, amani.belhaj@uclouvain.be

[2] Higher School of Engineers of Medjez El Bab

[3] ELI

The optimization of water management in climate-constrained irrigation perimeters in Tunisia requires a detailed understanding of the space-time dynamics of soil water. The specific objective of this study is to evaluate the performance of low-cost soil water (SW) sensors operated by informed citizens and to combine these data with remote sensing-based soil water products to provide an extensive data product of soil water observations.

The data relating to soil water content (%) at 10 cm and 20 cm depths by the TMS sensors jointly using satellite images by considering diverse environmental variables such as the normalized difference vegetation index (NDVI), land surface temperature, actual evapotranspiration, topographic parameters (elevation and aspect) and soil texture (clay, loam, and silt). Crop irrigation data is collected from December to March.

Exploratory data analysis and pre-processing were performed and their statistical models were constructed for time series forecasting based on the set of available data preliminary results showed good prediction accuracy and good interpretability results.

Technical session 4: Stakeholders engagement through new approaches — Part 2

Making Resilience Building Work for Hydroclimatic Risk, Monitoring and Vulnerability: Strategies for Resource Constrained Metropolitan City of India

Shailendra Mandal[1]

[1] National Institute of Technology Patna, shailendra@fulbrightmail.org

Enticing on the theories of ‘resilience building as development’ and in-depth examines of rolling development initiatives in the metropolitan city of India, this study explores the factors that promote or hamper successful resilience building action for the hydroclimatic risk and vulnerability. The city of Patna is located in the central part of the Gangetic plains. The city (1.68 million) is one of the fastest growing urban centres in India. It falls in the risk zone of floods and the problem is aggravated in the

rainy season. Based on the interviews, primary documents, direct opinion, and three emblematic, developmentally oriented project case studies that address the city' most urgent hydroclimatic risks in sewage, drainage and solid waste management, it recommends a contingent resilience building approach as most-suited to such resource-constrained environments. Such an approach has the ability to overcome intrinsic local resource constraints, institutional limitations, while increasing the likelihood of adoption of resilience building-oriented projects. The climate fragility statements were prioritized through a participatory assessment based on the degree of risk that each expected climate impact poses for the identified fragile systems. This study identifies several factors-among them, developing collective partnerships to conduit technical deficits, taming local organizational structures to create internal resources, and constructing political consensus for climate action-as crucial for successful resilience building. Such contingent resilience building approaches may thereby deliver a blueprint for instant, realistic, and cost-effective feasible applications in similar cities in India and in comparable developing regions of the world. This study concludes that these rudimentary resilience building measures, which are needed just to address the city's development, management, risk and vulnerability concerns, are necessary as a stepping-stone to transformative pathways for addressing the uncertainties associated with hydroclimatic risk for sustainable and resilient development of the city.

Andean Water Towers Knowledge Centre for Climate Change Adaptation (AKCC)

Paula Lady Pacheco Mollinedo[1], Jaime Quispe[1], Marcela Bustillos[1]

[1] Centro de Apoyo a la Gestion del Agua y el Medio Ambiente: "Agua Sustentable", paulis.pacheco@gmail.com

The acknowledge that mountains are fragile ecosystems and their global importance for sustainable development is growing. Mountains are recognized as sources of most of the world's fresh water and home of biological and cultural diversity, therefore custodians of knowledge and heritage.

Among the numerous impacts of climate change such as floods and the increasing unpredictability of drought episodes, glacier retreat is already evident. An unknown number of low and medium-altitude glaciers have already disappeared and projections indicate major losses in the decades to come that will impact discharges of springs and rivers and hence, the availability of water upstream and downstream.

The Andean Water Towers Knowledge Centre for Climate Change Adaptation (AKCC) implemented by Agua Sustentable and financed by IKI (The International Climate Initiative –German government) has worked on citizen science, open information, and local knowledge to contribute to strengthening the climate change resilience at the Sajama National Park.

The major results worked with the participation of the indigenous communities are listed below:

- The project left a comprehensive public information system based on GIS with data from the region that contributes to open science and will be mainly used by local and regional governments for project design, investments, decision-making, and promotion of tourist attractions. The information system shows also climate change adaptation strategies around water towers that are based on technological tools such as drones, combined with local knowledge including rainwater harvesting, improved irrigation, water storage, etc.

- People in the region, have recognized the importance of the conservation of bofedales (high-altitude Andean wetlands) as water reservoirs and are prioritizing actions to preserve these unique ecosystems. Work has been done on the participatory monitoring of water resources and bofedales with the National Protected Areas Service, municipalities, and schools in the area, showing that participation and open science are of great importance in generating knowledge.

- The Center “Yatin Uta” (Aymara: Knowledge house) has been implemented as a community center to receive researchers from around the world and study climate change in this unique and special region and it is being promoted on the web page.

- To contribute to the construction of knowledge, two seasons of a course called "Mountain Courses" have been organized, both in coordination with the Bolivian Catholic University. The two continuous training courses were highly successful as a contribution to knowledge about mountain ecosystems, climate change, adaptation, high altitude wetlands “bofedales” and management of water resources from water towers. In addition to contributing to the training of more than 30 professionals in the field, the courses also stimulated the interest of other institutions and universities for the organization of academic activities at the Center.

The Yatin Uta Center has already formed many people and the current community leader are willing to keep the place (virtual and physical) as a gathering point for the generation and dissemination of data. The contribution made will also be a seed to continue working on open science and knowledge generation in the mountains.

Citizen Science for Mapping Urban Flooding Hazard in Villa Paez, Cordoba, Argentina

Sebastian Lopez[1], Leandro Massó[1], Andrés Portigliatti[1], Leandro Kazimierski[2], José Manuel Diaz Lozada[2], Antoine Patalano[1], Mariano Re[2], Carlos Marcelo Garcia[1]

[1] IDIT-CONICET, slopez@mi.unc.edu.ar

[2] National Institute of Water (Argentina)

Floods are one of the most dangerous natural disasters, causing mayor damage requiring special attention, specially under the context of climate change and its effect on the frequency of occurrence of extreme flood events. The Urban floods represent a significant topic since more than half of world’s population lives in urban areas. The impact of extreme events is intensified by the vulnerability of civil society, due to their lack of awareness of the threat to which they are exposed. The Sendai Framework for Disaster Risk Reduction proposes, within a series of public policies, empowering communities, ensuring behavior change through science, evidence and effective communication and increasing understanding of management of natural disasters and climate risk.

There are few experiences in Argentina of urban floods hazards mapping projects in which the affected community is involved in different phases of the research process. For that reason, a different approach for mapping urban flood´s hazards is needed, in which the inhabitants of the affected catchment area play an important role in the study of the problem. The community might increase the awareness of the hazards they are expose to and reduce their vulnerability to it through understanding the hydrological system, collecting data, and working along with hydrological researchers. Thus, the community also empowers itself for during the communications with local authorities and claiming for better conditions.

This paper presents the results of a co-creative project of citizen science performed with the goal of characterizing urban flooding´s hazard of a vulnerable community in the city of Córdoba, Argentina called Villa Páez. In this work, an urban hydrology model validated with data and experiences provided by the affected community is used. In addition, a criterion for the level of threat is defined based on the probability of occurrence of a hydro-meteorological event and the level of risk according to the type of person affected. Finally, a mapping is developed of the pluvial threats to which the community is exposed. The mapping of the urban flood hazards is transferred to the community through oral presentations in NGOs and schools located in the affected territory seeking to increase the resilience of the community. This information is also transferred to the local authorities as a tool for the design of public policies.

Day 3 | 21 April 2023 | Water as a climate connector: The central role of water-energy-food nexus in cross-sectorial adaptation

Technical session 1: Assessing climate change impacts and adaptation through climate stress testing — Part 1

Climate Vulnerability Assessment of Hydropower Sector in the Ivory Coast

Kristin Gilroy[1], Anne-Marie Sfeir[1], Nicolas Avisse[1]

1 Tractebel France, kristin.gilroy@gmail.com

As climate change becomes increasingly relevant to water resources and energy projects, the demand for vulnerability analyses and adaptation plans is growing. This presentation will highlight Tractebel FRANCE's work in both of these subject areas as applied to the project: "Climate Change Vulnerability Study for the Hydropower Sector in the Ivory Coast", funded by the French Development Agency. The results identify both climate risks and opportunities for the hydropower and flood security sectors of the Bandama and Sassandra watersheds. Proposed climate adaptation measures, including the development of a real-time water management tool, will be presented as well as lessons learned and next steps.

Characterising and addressing interdependencies in two river basins in Africa

Declan Conway[1]

[1] Grantham Research Institute, London School of Economics, d.conway@lse.ac.uk

Climate change will bring serious cross-cutting consequences for present and future ambitious development plans in many river basins in Africa due to the strong interdependencies between the water-energy-food nexus sectors. However, climate impacts and their cross-sectoral transmission pathways are poorly understood and rarely considered in development planning. This presentation profiles insights from detailed analysis of climate variability and change impacts in two major river basins of southern Africa (Siderius et al., 2021), the Rufiji in Tanzania and the Lake Malawi Shire River system. River basin development plans are stress-tested with climate projections focusing on the risk of failure to meet stakeholder prioritised multi-sector performance metrics.

Results show for the Rufiji that projected risks for the mid-21st century are similar to those of the present day, but for the Lake Malawi-Shire River system, future risk exceeds that experienced during the 20th century. In both basins repeat of an early-20th century multi-year drought would challenge the viability of proposed irrigation and hydropower infrastructure. Exposure to future risk differs between the two basins. Storage in Lake Malawi buffers single-year extremes, so that future risk is mainly associated with projections of reduced rainfall. In the Rufiji, increasing interannual variability in rainfall extends the climate risk profiles for hydropower and environmental flow performance.

The impacts highlight the need to develop contingency plans for the worst-case extremes (in the past and future), for example, the design of drought management plans in both basins to handle multi-year dry conditions. Moreover, the multi-sector nature of the impacts underscores the need for greater horizontal governance and coordinated management structures which are nascent at present. Innovative modelling and visualisation techniques can provide opportunities to convey the complex outcomes of impacts and responses, capturing alternative perspectives and values and in so doing address some of the many barriers to enhanced coordination.

Siderius, C. et al. (2021) Climate variability affects water-energy-food infrastructure performance in East Africa. One Earth, 4(3), 397-410.

An integrated approach for risks and impacts assessment to inform flood risks adaptation in urban regions

Dominic Sett[1], Michael Hagenlocher[1], Thao Phuong[1], Andrea Ortiz-Vargas[1], Florian Waldschmidt[1], Eike Behre[1], Felix Bachofer[2], Nguyen Hoang Khanh Linh[3], Nguyen Dang Giang Chau[4]

[1] **United Nations University - Institute for Environment and Human Security [UNU-EHS],** sett@ehs.unu.edu

[2] **German Aerospace Center [DLR]**

[3] **International School of Hue University [HUIS]**

[4] **Hue University of Sciences [HUSC]**

Exacerbated by climate, socio-economic, political, and environmental change, flood risks are increasing in many parts of the world, often leading to devastating impacts, particularly affecting the most vulnerable. Therefore, enhanced flood risk adaptation is vital to reduce adverse impacts.

To best design adaptation measures, comprehensive risk and impact information is crucial as it helps to determine where adaptation is needed, by whom, and why. Unfortunately, this information is often incomplete or even missing. In many cases, this proved to hamper adaptation effectiveness and caused maladaptive outcomes. Therefore, advanced risk and impact assessments considering multiple risks for people, sectors, and systems as well as their underlying drivers are needed to better adapt while leaving no one behind.

Based on extensive stakeholder consultations and desk studies as part of the FloodAdaptVN project, we developed an integrated risks and impact assessment concept that was applied in the highly flood-prone urban region of Hue, Vietnam. It aims at providing actionable information on flood risks, impacts, and underlying root causes, thereby supporting local agencies in their adaptation efforts.

In an initial step, four key impacts were identified by local stakeholders in a co-development workshop in July 2022 in Hue. Fatalities, disrupted agricultural livelihoods, disrupted transportation, and water contamination were rated as most relevant flood impacts for Hue. Second, an impact chain approach has been applied to capture interlinkages within and across these four key impacts and their underlying risks and drivers.

Results of the application of this comprehensive flood risks and impact assessment approach in Hue underline the interconnection between risks and impacts and the potential harm of impact cascades. For example, impact linkages were identified between damaged infrastructures (such as damaged or blocked roads and sewerage systems), hampered service provision (such as interrupted water and sanitation supply and interrupted waste collection), subsequent environmental impacts (such as decreased water quality and contamination), health impacts (such as water-borne diseases and injuries), and eventually livelihood impacts (such as disruption of livelihood activities and subsequent income losses).

In addition, similar root causes of risk were identified. For example, rapid urbanization proved to increase all subcomponents of risk, namely flood hazard levels (e.g. through increased sealing and subsequent increase of runoff), exposure (e.g. through increased number of people, physical assets and economic activities, often in flood prone areas), and vulnerability (e.g. through increased marginalization).

The identification of cross-sectoral, interconnected risks and impacts helps to avoid blind spots and maladaptive outcomes when designing adaptation measures. It also helps to identify entry points for interventions that can tackle multiple underlying risk factors and thereby avoid direct and cascading impacts. For example, enhanced risk-informed urban planning could help to reduce urban flood hazard, exposure, and vulnerability levels, thereby contributing to effective adaptation to urban flood risks.

This presentation will discuss results of the applied risks and impact assessment for Hue in more depth. In addition, insights into the development of the applied integrated risks and impact assessment approach as well its potential for transferability to other risk-prone urban areas will be provided.

Leveraging collaborative modeling to build a more equitable and resilient future: The Guayubin Pilot, Dominican Republic

Rosanna Vasquez[1], Inmaculada Adames[1], Raul Perez[1,2], Jennifer Olszewski[3], Aneliya Nikolova[4], Guillermo Mendoza[3], Will Logan[3]

[1] Comisión Presidencial para el Ordenamiento y Manejo de la Cuenca del Rio Yaqué del Norte (CRYN), rvasquez@plansierra.org

[2] Instituto Nacional de Recursos Hídricos (INDRHI), Dominican Republic

[3] United States Army Corps of Engineers (USACE)

[4] United States Agency for International Development (USAID) Dominican Republic Office

The River Basin Commission of the Yaque del Norte in Dominican Republic (CRYN) is interested in how investments in watershed planning can enhance resilience to droughts and floods in the context of climate change. This work will showcase current efforts being made towards the development of a system model for the collaborative modeling and planning of the Guayubin subbasin of the Yaque Del Norte. It will also detail how Guayubin stakeholder input is being integrated into the design of the system model interface so that it aligns with how they evaluate success and failure. To do this, CRYN is currently leading a Shared Vision Planning (SVP) pilot to evaluate and prioritize investments in watershed planning and water resources development based on their expected impacts to desired performance across sectors and interests. SVP is a planning process that incorporates structured collaboration with stakeholders and system modeling. The objective is to align planning with the specific indicators for success or failure by a sector. We will discuss how the system model will be used with a Climate Risk-Informed Decision Analysis (CRIDA) process to develop watershed climate adaptation plans. This means that states of chronic unacceptable failure for various sectors will be identified and then the model will be stressed to determine what stressors lead to failure. Once this is done, watershed plans can be evaluated for their impact to immediate benefits and with respect to their resilience to deep uncertainty. This effort includes quantifying and evaluating investment tradeoffs between hydropower energy, agriculture, ecosystems, and flood risk.

Bridging the gap between top-down and bottom-up approaches for climate impact assessements

John Kucharski[1], Scott Steinschneider[2], Jonathan Herman[3], Jennifer Olszewski[1]

[1] USACE Engineer Research and Development Center, johnkucharski@gmail.com

[2] Cornell University

[3] UC Davis

The threat of climate change to water resource systems has led to a substantial and growing number of impact studies. These studies follow two general methodological approaches: (1) top-down, process-based studies are driven by projections of future climate change supplied by downscaled general circulation models (GCMs), while (2) bottom-up, vulnerability-based studies are driven by exploratory scenarios. Top-down studies generate realistic climate scenarios, but computational burdens can limit the size of the ensemble, which may not encapsulate all the plausible states of concern. Bottom-up approaches make it possible to assess a wider range of scenarios, but a lack of process-based insight can limit their utility in adaptive planning. This paper evaluates process-informed exploratory scenarios that bridge the gap between top-down and bottom-up methods. The resulting hybrid approach yields several advantages. First, emerging vulnerabilities are explicitly linked to thermodynamic and dynamic climate variables modeled in the GCMs with differential likelihoods and plausible ranges of change. This provides a more transparent link between vulnerability and likelihood than in most bottom-up studies. Second, the systematic perturbation of process-informed parameters links climate drivers to vulnerabilities more clearly than is possible in most top-down studies. These points are demonstrated

through a case study in which process-informed variables most closely linked to thermodynamic and dynamical change have the largest impact on system performance; their non-linear impacts are revealed through systematic perturbation of these parameters. Finally, this hybrid approach to impact assessment has implications for the development of dynamic adaptation plans through process-informed monitoring of climate variables.

Technical session 2: WEF-nexus impacts of Climate Change: Challenges and solutions at national and regional scales — Part 1

Hazard Risk and Vulnerability to Climate Change among Coastal Communities on the Southwestern Indian Coast: The Case of the State of Kerala

Aravindh Panikkaveettil[1], Nivedya V S[1], Arya C M[1]

[1] Cochin University of Science and Technology, aravind.gopinathan08@gmail.com

India's southwestern coast, particularly the state of Kerala, has been noted to be quite vulnerable to severe cyclonic storms in recent years. Kerala is home to an estimated 8,00,000 individuals dependent on the sea for their livelihood, and the region's changing climate considerably threatens their assets and livelihoods. The study examines the vulnerability of coastal communities to climate change in the state, focusing on households who live along the eroding sections of the Kerala coast. A total of 221 marine fishing households belonging to six villages in Central Kerala have been chosen for the study. The villages are spread across the districts of Ernakulam and Thrissur. Both districts have severely eroded coastlines and were devastated by cyclones recently. The study employs a climate vulnerability index (CVI), following the IPCC framework, which incorporates the three axes of exposure, sensitivity, and adaptive capacity. Exposure is determined by the incidence of natural disasters and climate variability, while sensitivity includes the dimensions of health, food, and water. Adaptive capacity looks at the socio-economic status of the households, livelihood diversity, and social networks at play. Vulnerability is a positive function of the community's exposure and sensitivity to climate change-induced crises, and a negative function of its adaptive capacity. The value of the CVI ranges from zero (low) to one (high). The CVI was adopted from previous studies and modified to suit the Kerala context. Qualitative data was also collected through in-depth interviews and focus group discussions among the fisherfolk to learn their perceptions toward climate change. The study results indicated marked differences between villages in terms of settlement patterns along the coastline, level of intra-community linkages, and access to food and water. Households in Thrissur were more vulnerable, with a CVI of 0.676, due to lower adaptive capacity and higher sensitivity, although they were less exposed to disasters. The CVI for Ernakulam was only 0.485 despite the higher risk of exposure to natural hazards. Going deeper into the analysis for individual fishing settlements at the panchayat level revealed that local differences were also sharp within the villages. The study concludes that the situation in Ernakulam demands strengthening of the coast to protect against hazards since fisherfolk lived close to the sea, and the existing measures to protect the coast were inadequate. In Thrissur the focus must be on ensuring access to healthcare and water and strengthening community-level networks. Access to drinking water is a major concern across Thrissur district and needs to be addressed urgently. The diverse situations in the two districts therefore requires careful local level planning to combat the challenges posed by climate change.

Kazakhstan's adaptation to Climate change and its development perspectives in the water-food nexus

Barbara Janusz-Pawletta[1], Larisa Kogutenko[1], Victoria Krylova[1], Maira Kusainova[1], Ekaterina Gorshkova[1]

[1] Kazakh-German University, vicerector.int@dku.kz

Being landlocked developing states, Kazakhstan is highly vulnerable to global climate change, thus having bold policies on mitigation and adaptation are imperative. Kazakhstan is a large economy with vast natural resources. It is vulnerable to natural disasters, including droughts, heat waves, floods, mudflows, and landslides, which result in land degradation, destruction of infrastructure and loss of life. Sustaining agricultural productivity is also increasingly challenged by climate change, including changes in precipitation patterns, longer seasons and increased risk from pests and diseases. Negative climate trends are expected to exacerbate the above impacts; for example, a 2–3°C temperature increase will diminish vegetation cover, which combined with increasing heavy precipitation events and glacial melt is estimated to increase mudflow occurrence tenfold. To solve the climate challenge and to fulfil its international commitments, incl. Sustainable Development Goals, and 2015 Paris Agreement Kazakhstan committed to climate change adaptation through their Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs).

Presenting a current status and future developments in relation to water as a climate connector focusing on the central role of water-food nexus in cross-sectorial adaptation in Kazakhstan is reflected on following issues: 1) The sequestration potential of crops and rangelands management, while requiring additional investments, has great potential in Kazakhstan, but adaptation to climate change is critical to ensure national water and food security. 2) In the short- and long-term perspective it is suggested to mainstream climate-smart agriculture practices, such as drip irrigation, bioenergy production, agroforestry, forest cultivation, greenhouses, organic farming as well as improve sustainable rangelands management, including natural ecosystems and agricultural lands. 3) To ensure carbon neutrality in Kazakhstan it is advisable to sustain transboundary cooperation through effective basin management, reduce water-related hazards and increase small hydropower capacities.

It's highly recommended for national policies, institutional reforms, and investments in the water sector to: 1) incorporate adaptation policies, plans, programs, and projects into river basin development planning; 2) promote access to affordable financing for climate-resilient development; 3) reconstruct and upgrade hydro-reclamation systems in high-demand irrigated land; 4) reconstruct, rehabilitate and overhaul the collector networks in irrigated farmland to ensure drainage removal; 5) execute the Regulation of Syr-Darya River Flow and Preservation of the Northern Aral Sea Project; 6) implement a project to improve irrigation and drainage systems; 7) enhance the water tariff policy; 8) engage international institutions in transboundary water management; 9) enhance the regulatory and legal frameworks in the water sector; 10) reconstruct water and wastewater treatment systems; 11) increase the share of water-efficient technologies in the manufacturing industry; 12) build the capacities of recirculated water treatment and reverse water supply; 13) prevent reduction of available water resources, entering into transboundary water agreements with all neighboring states; 14) design economical technical solutions for transferring water resources to water-deficient basins and utilizing renewable groundwater sources; 15) increase the long-term available water supply, construct and reconstruct infrastructure facilities like main channels, artificial reservoirs, and dams.

Including water quality in the water-energy-food nexus: An Upper White Nile case study

Annika Schlemm[1], Mark Mulligan[2], Ann van Griensven[1]

[1] Vrije Universiteit Brussel, annika.schlemm@vub.be

[2] King's College London

The Upper White Nile (UWN) basin plays a critical role in supporting essential ecosystem services and the livelihoods of millions of people in East Africa. The basin has been exposed to tremendous environmental pressures following extensive population growth, urbanisation, and land use change, all of which are compounded by the threats posed by climate change. The water-energy-food (WEF) nexus provides an integrated solution to sustainable development by minimising the trade-offs between water, energy, and food resources. We apply quantitative and qualitative methods to understand the most pressing WEF nexus challenges within the UWN basin, how these can be represented in indicators, and

how existing WEF nexus modelling tools could address this. This research combines semi-structured stakeholder interviews with a Co$tingNature analysis in order to map the greatest environmental pressures within the basin and disentangle the likely drivers. The findings from these highlight the importance of declining water quality, aquatic and terrestrial ecosystem health, and fish populations as a result of deforestation, growing human population, intensifying pollution, and increasing agricultural intensity within the basin, with most stakeholders expressing concerns for the uncertain impacts from climate change. Furthermore, a review of current WEF nexus modelling tools reveals how existing tools are insufficient in addressing the most pressing environmental challenges within the basin, with a significant gap regarding the inclusion of nuanced water quality and aquatic ecosystem indicators. Subsequently, these findings are combined in order to guide the development of holistic WEF nexus indicators that have the potential to spatially model the trade-offs within the WEF nexus in the UWN basin under climate change and land use change scenarios. This work demonstrates the use of a novel decision framework for WEF nexus indicator development, which ensures that outputs are fit-for-purpose and respond to the actual needs of stakeholders and policymakers. The outputs aim to strengthen water management decisions that enhance water quality, energy production, food production, and aquatic biodiversity within the UWN basin.

Fostering citizen science to optimize water resource management and resilience in Madagascar

Malalaniaina Miora Rakotoarivelo[1], Rindramampionona Randriamifidison[2]

[1] University of Antananarivo Madagascar, rakotoarivelom5@gmail.com

[2] Institut Supérieur de Technologie d'Ambositra Madagascar

Madagascar is particularly vulnerable to climate change associated-effects even if it emits, at the global level, a relatively low rate of CO2. These effects are felt more through hazards that have a direct link with change in water parameters, especially with the rainfall, and causing in most cases: drought and floods. Water resources are intimately linked to various sectors such as agriculture and food production, ecosystems, energy, health and well-being of populations; which remain potentially sensitive to the slightest change in the availability of these resources. These last decade, malagasy population has automatically adapted to climate variability by developing solutions and practices, which have allowed households to continue functioning and to be resilient despite a very fragile financial and socio-economic situation. This is usually done in modalities of recharging, retention, reuse of resources and a more sustainable consumption. The study aims to find out efficient and transdisciplinary ways to increase resilience not only of communities but also of the local ecosystems. Research explores the case of medium-sized cities in Madagascar through the case of Ambositra (20° 31′ 59″ South, 47° 14′ 42″ East), where the nexus between water-energy-food- ecosystems and climate remains very obvious. The methodology design is based on cross sectionnal surveys, a study of rainfall regime to better understand how climate can impact resources, and an assessement of water resource availability either for domestic consumption or for production. There is a need of cross-sectorial policy to maintain balance between each use of water resources, and a need of involvment of all potentials actors to enhance population awareness about climate change and its impact.

Addressing the impacts of climate change on Sri Lanka's small scale fisheries: A compelling case for implementing Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries (SSF Guidelines)

Kaumi Lakmali[1], Oscar Amarasinghe[2]

[1] Sri Lanka Forum for Small Scale Fisheries, kaumi.khklpiyasiri@gmail.com

[2] University of Ruhuna

As an occupational category, small-scale fishers are one of the most vulnerable, since they are exposed to numerous shocks and stresses, including their excessive exposure to the impacts of climate change,

which threaten their livelihoods. Since small-scale fisheries in Sri Lanka are subjected to multifaceted vulnerabilities due to extreme weather events and disasters, they provide an important case to study the impact of implementing the disaster risk and climate change related prescriptions of the SSF Guidelines. Among other things, the national consultations carried out in 12 out of 15 coastal districts, under SSF Guidelines implementation project during 2019-2020 period, attempted at identifying the issues related to climate change impacts on Sri Lanka's small-scale fishers. Loss of life and property, damages due to heavy winds and storms, income reduction due to non-fishing days under rough seas and fishing gear and craft damages due to increased wave action were identified as the major climate change related impacts. Uncertainties associated with the current weather forecasting system and sluggishness of the process of disaster warnings to fishers were found to be the major issues related to climate change impact management. Disaster risk and climate change forms the ninth section of the SSF guidelines, and the articles 9.1-9.9 call on states and other actors to take urgent and ambitious actions to mitigate climate change impacts on small-scale fisheries. Further, it emphasises the need for building resilience with the consultation of fishing communities, and the need to adopt integrated and holistic approaches in addressing climate change related impacts. While the focus and coverage of climate impact management in the SSF Guidelines are unrivalled and need to be strongly acknowledged and supported, it could be asserted that the effective implementation of SSF Guidelines by incorporating them into policy and national action plans would be a critical step towards finding solutions for climate change impacts on Sri Lankan small-scale fisheries.

Technical session 3: Assessing climate change impacts and adaptation through climate stress testing — Part 2

Irrigation area, efficiency and water storage mediate the drought resilience of irrigated agriculture in a semi-arid catchment

Bruce Lankford[1]

[1] **University of East Anglia, b.lankford@uea.ac.uk**

The presentation examines factors that mediate the resilience of commercial irrigated agriculture to drought in a semi-arid catchment in South Africa based on a framework termed 'Water, Efficiency, Resilience, Drought' (WERD) and a spreadsheet. The resilience of irrigated agriculture to drought is analysed via water accounts and a key resilience indicator termed Days to Day Zero (DDZ). This represents the number of days that a pre- and within-drought supply of catchment water available to irrigation is withdrawn down to zero in the face of a prolonged drought. A higher DDZ (e.g. >300 days) indicates greater resilience whilst a lower DDZ (e.g. < 150 days) signals lower resilience. Drought resilience arises through three main land and water management decisions (irrigation area, efficiency and water storage) in turn underpinned by four types of resilience capacities; absorptive, adaptive, anticipative and transformative. For the case study, analyses showed that irrigators, with currently approximately 23,000 ha under irrigation, have historically absorbed and adapted to drought events through construction of water storage and adoption of more efficient irrigation practices resulting in a DDZ of 260 days. However, by not fully anticipating future climate and water-related risks, irrigators are arguably on a maladaptive pathway resulting in water supply gains, irrigation efficiency and other practices being used to increase irrigation command areas to 28,000 ha or more, decreasing their capacity to absorb future droughts. This areal growth increases water withdrawals and consumption, further stresses the catchment and reduces future DDZs to approximately 130 days indicating much lower drought resilience. Our approach allows stakeholders to better understand the resilience consequences of future drought in order to; reconcile competition between rising water demands, consider new water storage; improve agricultural and irrigation planning; and enhance catchment governance.

Participatory climate risk assessment informing water adaptation strategies – a Peruvian Puna case study

Alicia Bustillos Ardaya[1], Stefan, Schneiderbauer[1], Yvonne Walz[1], Ignacio Tourino Soto[2], Oscar Higuera Roa[1]

[1] United Nations University- Environment and Human Health (UNU-EHS), bustillos-ardaya@ehs.unu.edu

[2] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Mountain social-ecological systems are strongly impacted by changing climate conditions due to elevation dependent warming, specific orographic settings, and potentially higher degrees of susceptibility and vulnerability of flora, fauna and human communities as well as power relationships, management and governance aspects. Adverse consequences of climate change do not only affect high mountain regions but influence the well-being of systems further downstream. For example, water quality and quantity may be reduced and negatively impact the whole freshwater cycle. To identify relevant mitigation and adaptation measures, a thorough assessment of all hydro-climatic risk components is critical.

The presented approach applies a participatory climate risk assessment using Impact Chains as a structural back bone to represent relevant dynamics and complexities of the social-ecological system at stake (The Vulnerability Sourcebook and supplements, 2014-2018). This approach integrates local experts' and practitioners' knowledge to (i) validate implemented approaches and assumptions, (ii) raise awareness, and (iii) create ownership for future adaptation measures. Deglaciation on the Andes Mountains represent a clear example of the consequences on socio-ecological systems upstream and downstream. An in-depth literature analysis combined with geographical data analysis supports identifying relevant risk components of hydro-climatic, biophysical, or socio-economic type. A participatory process with local experts validates the selection of context-specific factors driving risk covering the system exposure, future trends in climate hazards, and all main vulnerabilities. All these factors are systematised in impact chains created for the specific context of this case study area and allow for a spatially explicit visualisation of risk factors, namely hotspot risk maps.

The case of the Puna region of the southern Peruvian high Andean-mountains strongly affected by deglaciation, presents a complex interaction of risk factors affecting the ecosystem services and, simultaneously, the livelihoods of the rural population upstream and the population downstream.The participatory process systematising and validating the factors, included experts working at municipal and national level, researchers, and non-governmental institutions, among others. Both, the resulting impact chain diagrams and the resulting risk hotspots maps, were key to developing targeted adaptation packages composed of measures aligned with the local and traditional knowledge of communities in the region and focusing on water management issues. To timely and appropriately inform decision-making and climate risk communication activities, the presented participatory approach for assessing climate risks requires an early engagement of relevant stakeholders. It provides a tool that deems useful for decision making, and risk communication supporting activities of climate change adaptation and resilient building amid the given uncertainties.

Rethinking water resources planning in Bolivia: climate risk and uncertainty from global to local levels

Andrea Salinas[1], Carlos Saavedra[1], Carlos Arteaga[2], Sergio Villa Gomez[1]

[1] PROCEUNCA-GIZ, andrea.salinas@giz.de

[2] AKUT

In participatory, multisectoral and multilevel river basin planning, assessing the current and future climate risk is relevant to increase the resilience of vulnerable populations and ecosystems. In this article

we address the question: ¿what actions should we take today to achieve water security in an uncertain future? GIZ together with the Ministry of Environment and Water (MMAyA) of Bolivia and the Interinstitutional Basin Platforms supports the development of River Basin Management Plans (BMP) with a focus on robust decision-making in a context of climate uncertainty. This paper includes the experience in the Guadalquivir basin, located in the department of Tarija, and the San Martín and Paraguá basins, located in the department of Santa Cruz.

Planning for water security requires adaptive plans that keep alternatives open to make changes when needed. In the face of climate uncertainty, good decision-making must have two characteristics: a) be robust – that is, a decision suitable for both usual and extreme situations; (b) adapt well to new circumstances at the lowest cost. To this end, water planning combined "bottom-up" (participatory spaces such as the Interinstitutional Basin Platforms) and "top-down" (use of climate risk modelling and analysis) approaches. A comprehensive assessment of climate risk in the two basins was carried out in the dimensions of impact and action. The impact dimension focused on the evolution of temperature and precipitation trends and future water availability. In the action dimension, the adaptation strategies prioritized in the Guadalquivir BMP and the Santa Cruz Departmental Climate Change Strategy were analyzed in terms of their feasibility and cost-effectiveness for local conditions.

As a result, the development of resilient infrastructure and ecosystem-based adaptation measures for the restoration of ecosystem services have been implemented since 2021, which highlights the importance of scaling this approach to the rest of the country's basins within the framework of the National Water Resources Plan and the commitments established in the Nationally Determined Contributions (NDC). Through this assessment, awareness has been raised about the value of technical-scientific information for decision-making and training of professionals in the use of models, digital data management and their interpretation for territorial planning has been encouraged.

Bolivia still faces many challenges in the adaptive water planning process. First, water security requires good governance; that is, institutions with the appropriate capacities and instruments to face the challenge. This includes a new generation of water managers with skills to mainstream scientific data and discuss climate uncertainties, as well as strengthening current information systems to support analysis and planning under climate uncertainty. Second, the involvement of stakeholders outside the public sector provides invaluable insights into how policies and investments can impact society and what emerging issues add uncertainty to the adaptive planning process of river basins should be considered.

A Flexible Framework to Simulate the water balance of Lakes and Reservoirs from Local to Global Scales: mizuRoute-Lake

Shervan Gharari[1], Inne Vanderkelen [1], Andrew Tefs [1], Naoki Mizukami [1], Erik Kluzek [1], Tricia Stadnyk [1], David Lawrence [1], Martyn P. Clark [1]

[1] University of Saskatchewan, shervan.gharari@usask.ca

Lakes and reservoirs are an integral part of the terrestrial water cycle. In this work, we present the implementation of water balance models of lakes and reservoirs into mizuRoute, a vector-based routing model. The developments described here are termed mizuRoute-Lakes. The capabilities of mizuRoute-Lake in simulating the water balance of lakes and reservoirs are demonstrated. The main advantage of mizuRoute-Lake is flexibility in testing alternative lake water balance models within a given river and lake network topology. Users can choose between various types of parametric models that are already implemented in mizuRoute-Lake or data-driven models that provide time-series of the target volume and abstraction from a lake or reservoir from an external source such as historic observation or water management models. The parametric models for lake and reservoir water balance implemented in mizuRoute-Lake are Hanasaki, HYPE, and Doll formulations. In general, the parametric models relate the outflow from lakes or reservoirs to the storage and various parameters including inflow, demand, volume of storage, etc. Additionally, this flexibility allows to easily evaluate and compare the effect of various water balance models for a lake or reservoir without needing to reconfigure the routing model.

We show the flexibility of mizuRoute-Lake by presenting global, regional and local scale applications. The development of mizuRoute-Lake paves the way for better integration of water management models with existing and future observations such as the Surface Water and Ocean Topography (SWOT) mission, in the context of Earth system modeling.

Technical session 4: WEF-nexus impacts of Climate Change: Challenges and solutions at national and regional scales — Part 2

Towards rigorous quantitative assessment of the tradeoffs between conventional "hard" civil infrastructure and nature-based solutions for climate change adaptation

Patrick Ray[1], Jacob Tracy[1], Garima Mandavya[1], Sungwook Wi, Sadie McEvoy[2]

[1] University of Cincinnati, patrick.ray@uc.edu

[2] DELTARES

The fundamental water resources problem to be solved in adaptation to climate change is increasing rainfall variability: generally, wet season flood peaks are increasing, and dry-season water availability is decreasing. Large, centralized adaptation strategies such as reservoirs impounded behind tall dams typically perform well at both attenuation of flood peaks, and augmentation of dry season flows. They come with substantial costs, however, both in terms of capital cost outlays and damages to local ecological and human environments. Many leading institutions and agencies are currently advocating for the adoption of "nature-based solutions" (NbS), which are believed able to reduce adverse climate change impacts at community scale, while supporting biodiversity and securing ecosystem services. However, the potential of NbS to provide the intended benefits has not been rigorously assessed. This talk will present a preliminary evaluation of the ability of decentralized NbS to approximate the benefits provided by conventional civil infrastructure using a case study of the Chimanimani biosphere reserve in Zimbabwe.

Measuring Climate Change Effects on Traditional Crops of the Highlands, Ecuador

Christian Franco-Crespo[1], Jessica Guamán Pozo[2], Jonathan Chuqui[2], Rodrigo Tufiño[2], Sheila Serrano-Vincenti[2]

[1] Technical University of Ambato, franco.crespo.ec@gmail.com

[2] Universidad Politécnica Salesiana

The study of climate in Ecuador is complicated due to the country's geographical conditions and the heterogeneity of regions, which are characterized by a variety of climate forms generated mainly by the Andean Mountain chain. Extreme weather events influenced by climate change create uncertainty about the future of food availability and crop production. Crop pests, temperature increases, water shortages, and variations in rainfall are serious impacts affecting agricultural production and food availability. This study aims to determine the impact of climate change future scenarios on the production of blackberries, tree tomatoes, maize, and potato in the province of Tungurahua, Ecuador, using an estimation of water availability on rainfed crops.

Methodology

Forecasting for climate conditions is developed in this study using historical data since 1980 for the case study and RClimdex for data analysis. Water availability uses information produced in forecasting analysis to model crop production. Mathematical modeling is employed to assess four different kinds of crops in the context of climate change scenarios and GAMS software is used in the analysis.

Results

Results show that water availability will influence crop production in climate change scenarios that involve intensified pest outbreaks in the central area of the Andean region. In rainfed crops, the future modeled scenario shows a positive variation in yield and resilience of the crops analyzed. Maize is more resilient to water forecasting models in the Andean zone. On the other hand, fruit crops are less resilient and demonstrated losses due to rainfall reduction.

Conclusion

The conclusion establishes that Climate Change will modify the temporally of growth and will impact the conditions of rainfed crops because some of them are more sensitive to climate variation. Factors such as farmers' income or the availability of food for self-consumption will be affected according to the adaptation scenarios analyzed. Finally, this study shows that some crops have a resilient capability against future climate events in the Andean zone. It is necessary to understand how these crops could adapt to extreme events with the possibility of providing instruments to guarantee Food Security.

Climate smart agriculture and resilience needs paradigm shift in approach to irrigation

Santana Gopal Komandur[1]

[1] **Centre for Environment Concerns, ksgopal952@gmail.com**

Green revolution addressed India's food deficit vide irrigation, fertilizers, and plant genetics. Yield response came with the application of water and petrochemical-based fertilizers. As yield response to fertilizer dropped, farmers applied more fertilizers and water. Within two decades the highly acclaimed green revolution triggered irreversible collateral damages: alarming fall in groundwater, higher energy needing irrigation pumps, soil salinity, compaction, and nutrient imbalance, etc. Excess nitrogen fertilizer and water led to a vicious upward spiral of nitrous oxide emissions. The drained water with fertilizers pollutes water bodies and groundwater making it unfit for aquatic, birds, and human life. Green revolution threatens food security.

The "state of the art" in water efficiency is drip and precision irrigation systems. But what is its science? Drip logic is "field capacity to wilting point" suiting and driven by the requirements of chemical fertilizers. But it destroys soil micro-organisms leading to poor soils requiring more chemical fertilizers for yield. To reduce surface drip irrigation evaporation loss, precision irrigation covers drip laterals with 30-100 micron plastic mulch and is frequently replaced. With no aeration or rainwater infiltration soils and their living organisms will be dead leading to more dependence on chemicals.

Climate risks, vulnerability, and resilience building call for a change to our science and approach to irrigation. The task is to address food and nutrition security with sustainable agriculture and the efficient use of natural resources for the planet and human well-being. We must find ways to produce more using less water and fewer fertilizers and calls to foster a dynamically rich natural ecosystem of bio-diverse living organisms that maximize water storage and soil aeration with efficient suction of moisture by the roots along soil micro-nutrients.

The Centre for Environment Concerns and farmers developed criteria for "ideal irrigation systems". Six years later our innovation called "System of Water for Agriculture Rejuvenation" (SWAR) conserve natural resources and delivered by 5 M: Moisture at the plant root zone, deliver "Measured" moisture to optimize water as per plant/soil using KC values, native in-situ Microbes inoculums to improve soil biology/health, Mycorrhizae for root zone effective nutrient uptake and Moisture adequacy confidence to end over-irrigation by farmers using sensors. SWAR is a rich ecosystem to foster microbes to drastically reduce water application and improve soil health. Upon this foundation of sustainable climate-smart agriculture with higher yields, farmers and customers decide the mezzanine of their choice.

Trials in 400 farms in drought areas on multiple soils show SWAR (compared to drip) to offer a 10% higher yield with early fruiting, more bio-mass, higher root-to-shoot ratio, 40-60% less water use, 30% less nutrient application, 40% less electricity, lower HP solar pumps, 75% less labor cost on weed control, works with saline water, rations water to moist the root zone for tree survival in summer heat waves and drought and carbon and humus rich soil.

A macro-scale and granular comparison of WEF nexus and cross-sectoral adaptation – Case study areas in Tanzania and Kenya

Shilpa Muliyil Asokan[1], Joy Obando[2], Raphael Kweyu [2], Mary Makokha[2], Madaka Tumbo[3], Ronald Ndesanjo[3]

[1] The Nordic Africa Institute, shilpa.asokan@nai.uu.se

[2] Kenyatta University

[3] University of Dar es Salaam

Water is a climate connector, and is the integral connecting thread of water-energy-food nexus. The world currently is in a situation where the increasing climate shocks and ongoing geo-political crisis are severely affecting water, energy and food security. Operationalizing WEF approaches and understanding the dynamics of cross-sectoral adaptation at a local level is of high importance.

Here, we present two case study assessments on the WEF nexus. First case study is in Rufiji Basin in Tanzania, where we aim to understand the macro-scale dynamics of the nexus. The second case study is in Turkana County in Kenya, where we explore the stress factors and drivers within the sectors of water, energy and food at a granular level.

In the case of the Rufiji Basin in Tanzania, all major hydro-electric power generation plants are located in the basin. The region also have very extensive irrigated agriculture. Preliminary assessment on the policies and guidelines on the sectors indicated a lack of cross-sectoral harmony in resource management. Furthermore, it was found that the attention given to resource governance mechanisms is very limited. In the case of Turkana County in Kenya, the study looked at rural communities living in Nalemsekon village, which is located about 15 kms from Lokichar town. The nearest source of potable water for the communities is a solar-powered borehole located at the newly developed oil township. The rural communities sell charcoal at the oil township and that income is used to buy water and food for their domestic needs. According to a recently reported study in the oil drilling area in Lokichar, about 99 percentage of the total groundwater in the area is used by the oil production sector, where the other sectors are left to share the remaining 1 percentage of the total groundwater. This puts communities in this region, who primarily rely on groundwater for their daily needs, under severe stress.

To conclude, the two case studies help to understand WEF nexus at a macro-scale as well as at a granular scale. The case of Rufiji Basin shows how the increased water demand because of increased agricultural production and energy demand puts pressure on all the three sectors. The case study in Turkana County provides insights into the cross-sectoral trade-offs, which is found to be driven by climate change induced water scarcity, climate governance challenges and the marginalized socio-economic state of the communities. Both the case study examples show the need for effective cross-sectoral consultation mechanisms in order to minimize trade-offs.

Navigating Complexity: Climate Change Adaptation in the Euphrates Basin

Rasha Hassan[1], Mohamed Hassan Tawfik[2], Bassel Daher[3], Raya Marina Stephan[4]

[1] University of Barcelona, rasha.ibh@gmail.com

[2] International Water Management Institute (IWMI)

[3] Texas A&M University

[4] **IWRA**

Water scarcity is a global challenge and becomes more acute in a transboundary context like the Euphrates River basin. Its geopolitical complexity and fragmented water governance severely impact water and food security, particularly in southern Iraq, where climate change exacerbates vulnerability. To assess factors that can facilitate climate change adaptation, a survey-based approach was disseminated to various stakeholders. This was done despite the complex conditions that the Euphrates River basin has experienced for over a decade including the political unrest in Syria and Iraq, resulting in data limitations. Academia contributed most of the responses and demonstrated diverse perspectives on climate change adaptation planning. Respondents emphasized the necessity of collaborative efforts among riparian states to advance actionable solutions through dialogue. Furthermore, climate adaptation was identified as a cross-sectoral process, which requires a transformational shift in agricultural practices, the involvement of all stakeholders, particularly farmers, in decision-making and promoting participatory water governance. Since water is fundamental to this process, water resource management is a crucial starting point for any adaptive measure or action. However, the path to achieving this goal is hindered by multiple challenges, including a lack of data and low technical capacity in Syria and Iraq. To overcome these obstacles, it is essential to promote a cooperative environment based on accountability and transparency among riparian states.

Sustainable Ground (water) management as a connector for resilient communities and ecosystems in the face of water and climate challenges

Muchaneta Munamati[1], Tawanda Gijima[1], Guy Broucke[1], Martiale Zebaze-Kana[1]

[1] **UNESCO Regional Office for South Africa, m.munamati@unesco.org**

Since the 1900s, Zimbabwe's temperature profile has shown an increasing trend, with a rise in average temperatures of 0.9°C observed across the country. Conversely, Zimbabwe's mean annual precipitation has shown a decreasing trend, with a decline in average rainfall of ~5% observed across the country since 1915, with much of this decline occurring since 1970. The country is exposed to a range of hazards, including drought and flood events and destructive tropical cyclones such as Cyclone Idai, which affected 270,000 people and resulted in the deaths of more than 341 people in 2019 and three people were reported to have died in Chimanimani and Chipinge when Cyclone Freddy made landfall on March 2023. Erratic rainfall and poor water management practices have a direct negative impact on the water availability in the rural communities of Binga and Buhera districts, located in the Lower Gwayi and Upper Save catchments of Zimbabwe. As a result, water sources often dry up during the September to November dry season, causing the failure of crops and animal productive systems during this period. Even during the rainfall season, the precipitation that is received is very limited (<400 mm) and unreliable, therefore strategies are required to improve and protect livelihoods in periods with little or no rainfall. Due to limited adaptation options, an increase in unsustainable activities along key value chains is observed, leading to land degradation and deterioration of key water sources. These challenges are happening in a space where there is a weak institutional framework for farmers to participate viably in priority value chains, with weak adaptive capacities among the smallholder communities and low application of climate-smart technologies. Against this background, UNESCO regional office of Southern Africa in partnership with the Ministry of Lands, Agriculture, Fisheries, Water and Rural Development in Zimbabwe developed a project entitled, 'Strengthening local communities' adaptive capacity and resilience to climate change through sustainable groundwater utilisation in Zimbabwe.' The project seeks to address the identified challenges by implementing a number of actions at local and national levels aimed at increasing the local communities' adaptive capacity and resilience to climate change through sustainable groundwater utilisation for food security and other productive uses in rural areas of Zimbabwe. The project recognizes the central role played by sustainable ground (water) management in adapting to climate change hence building resilient communities and ecosystems.