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Water Quantity and Quality Management, Economic Production and Welfare Implications in the Global South

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BOOK OF ABSTRACTS

In order of presentation

Wednesday, 25 October

Keynote

Will Africa's Farming Sector Survive Climate Change? Behavioral, Technological and Institutional Aspects

Ariel Dinar, Distinguished Professor Emeritus, School of Public Policy, University of California, Riverside, United States

The African continent, part of the south cone, faces already high temperatures and low and highly variable precipitation—two of the parameters that indicate a climate-sensitive location. This locational factor, added to several economic, developmental, and structural factors such as low level of governance, and heavy reliance of the economy in many African countries on agriculture, which is one of the most vulnerable sectors to climate change, explain the motivation behind the question "Will Africa's Farming Sector Survive Climate Change?" Results from a comprehensive study conducted in 11 representing countries in Africa suggest that Africa faces challenges in coping with climate change. However, recent changes in behavioral, technological, and institutional aspects in the African society give rise to a possible change in the capacity of Africans to deal with climate change. The keynote will conclude by suggesting the ETIEA (Education, Technology, Institutions, Extension, and Awareness) as a course of action for Africa, which is also the focus of this conference.

Session 1: Innovation in Agricultural Water Quality and Quantity Management

Chair: Ariel Dinar, Distinguished Professor Emeritus, School of Public Policy, University of California, Riverside, United States

Digital Technology as a Solution to Address Negative Impact of Climate Change on Women's Agricultural Participation in Sub-Saharan Africa

Karabo Mokgonyana, Advocate for Human Rights, City of Johannesburg, Gauteng, South Africa

The agriculture sector in Africa has a huge social and economic footprint. It provides employment for about two-thirds of Africa's working population and for each country, it contributes an average of 30% to 60% of GDP and about 30% of the value of exports. In sub-Saharan Africa, more than 60% of the population are smallholder farmers, and about 23% of the region's GDP comes from agriculture. Africa has diverse agro-ecological zones, ranging from the rain-forest vegetation with bi-annual rainfall to relatively sparse, dry and arid vegetation with low unimodal rainfall. The enhancement of sustainable agricultural development is fundamental to the attainment of increased economic growth, food security

and the eradication of poverty. Women's economic labour remains concentrated in the agricultural sector, and during periods of drought and erratic rainfall, women, as agricultural workers and primary procurers, work harder to secure income and resources for their families. This puts added pressure on girls, who often have to leave school to help their mothers manage the increased burden, especially of unpaid care. Consequently, emerging scholarship is supporting the development of climate-smart varieties of staple crops such as rice in Mali, banana and plantain in Cote d'Ivoire and maize in Benin. The promise of a new climate economy requires tangible actions across key economic systems, some of which include targeted investments into sustainable water infrastructure. The World Bank says climate-smart agriculture, an integrated approach to managing crops, livestock, forests and fisheries, can mitigate the effect of climate change. For example, incorporate climate-smart farming methods such as climate forecasting tools, planting cover crops and managing climate-related production threats. Agricultural producers can strategically apply fertilisers and keep their animals out of streams to reduce nutrient-laden runoff.

Case Study: **Wastewater Reuse for Agriculture as an Adaptation Measure to Water Scarcity and Climate Change: Algerian Experience**

Chérifa Abdelbaki, Pan African University, Institute for Water and Energy Sciences Including Climate Change, University of Tlemcen, Algeria

Rachid Yahiaoui, National Office of Irrigation and Drainage, Algeria

Recently, as the world facing a water shortage due to climate change, a growing number of countries are considering irrigation using reclaimed water as an appropriate solution to secure and enhance agricultural production. Among the African countries affected by water stress, Algeria is in the category of the most water-stressed countries, namely below the theoretical threshold of water scarcity set by the World Bank at 1000 m^3 per inhabitant per year. Consequently, the country should dispose between 15 and 20 billion m^3 of water per year, by reserving 70% for agriculture, to achieve a satisfactory food security. This is a great challenge since the amount of water that the country dispose is about 5 billion m^3 per year. The pressure exerted on these resources will continue to grow under the combined effects of population growth and policies applied to water-consuming activities. The total volume of wastewater discharged annually is estimated at nearly 600 million m^3, whose 550 million m^3 are from the northern regions. This value would rise to almost 1150 million m^3 by 2025. The main objective of this presentation is to evaluate the capacities of wastewater treatment plants (domestic wastewater) in Algeria and the possibility of the water reuse for agricultural purposes. The reuse of the treated wastewater from the Algerian wastewater treatment plants for agriculture would be an adaptation measure to the water scarcity and climate change.

Case Study: Where the World is Going With Focus on Technological and Climate Smart Ag Technology

Mahmood Ahmad, Chief Technical Advisor, RIZQ Knowledge Hub, Lahore, Pakistan and Bangkok, Thailand

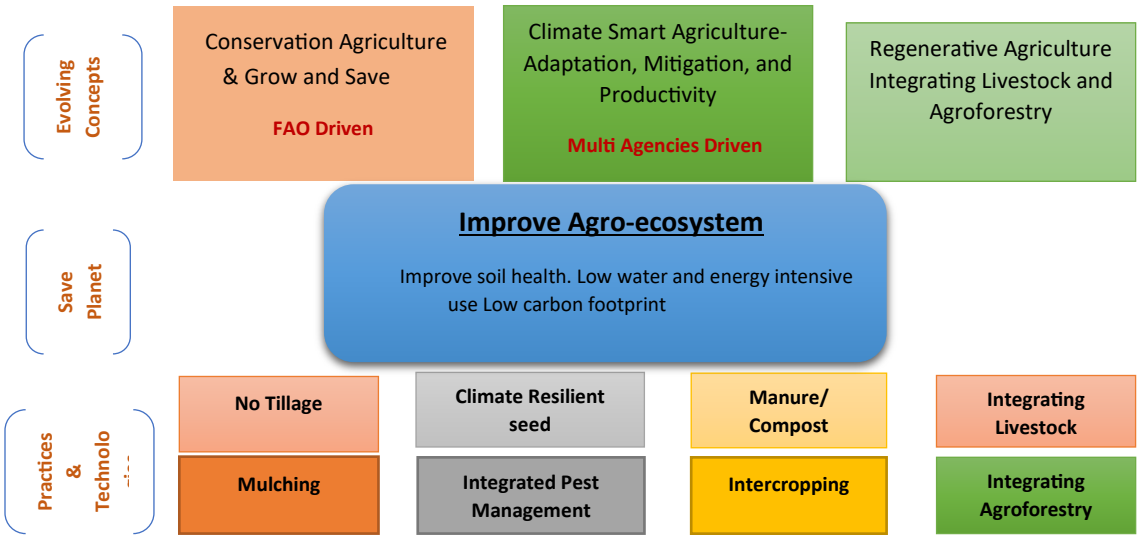
Since 2019, an additional 122 million people worldwide have fallen into the grip of hunger, a consequence of the pandemic, recurrent weather disruptions, and conflicts such as the war in Ukraine, as outlined in the State of Food Security and Nutrition (SOFI) report. The UN secretary general has proclaimed the commencement of a new era of global warming, impacting both the northern and southern hemispheres. Conversely, the demand on food systems has surged in recent decades and is projected to continue growing due to expanding global populations and increasing economic prosperity.

Yet, the bedrock of productive systems—healthy lands, soils, and clean water sources—are already experiencing immense strain. Studies reveal that 52% of global agricultural lands are presently moderately to severely degraded, with millions of hectares deteriorating to the point of abandonment by land stewards. Food inflation has struck economies across the board, but the susceptibility of food supplies and prices to climate change is particularly pronounced in sub-Saharan Africa, driven by a lack of resilience to climatic events, reliance on food imports, and excessive government interference. Climate-smart or Regenerative Agriculture technologies and practices are increasingly being hailed as the most credible solution, tailored to local conditions, crops, and cultural contexts. The figure below illustrates the technologies and practices commonly advocated by different stakeholders.

The value it brings - growing evidence requiring further research.

While Climate-Smart Agriculture (CSA) or Regenerative Agriculture is practiced globally, it has gained considerable traction due to its potential to tackle urgent global challenges. Climate-smart agriculture has been a focal point for FAO and is bolstered by support from the World Bank Group and CGIAR's new initiatives, which have been funding projects worldwide since 2016. These projects are designed to encompass all three pillars of climate-smart agriculture through collaborations with various nations. A few notable examples include India, where the significant impact of adopting modern technologies is evident in resource conservation, increased export revenue, and other critical aspects. Modern rice and wheat varieties alone have saved approximately 39 and 37 million hectares of land, while Zero-till agriculture saved nearly Rs. 100 crores during 2002-03. In Bangladesh, an ongoing project aims to enhance the productivity and resilience of livestock farmers while minimizing emissions. In China, the projects supported low-emission and resilient agriculture, leading to more efficient water use on over 40,000 hectares of farmland and the implementation of technologies to improve soil conditions.

In Pakistan, the Ahmad Nagar Pilot project funded by RIZQ Knowledge Hub, covering 2.25 acres of land, has successfully completed one wheat cycle, and has now transitioned to direct seeding of rice. The pilot project has embraced permanent raised bedding and Climate-Smart Agriculture (CSA) practices, including no-till farming, mulching, and reduced chemical inputs. The results demonstrate that CSA offers cost-effective solutions to address issues such as water scarcity, without necessitating expensive technologies that most small-scale farmers cannot afford. CSA also curtails unnecessary fertilizer usage, thus averting soil and water pollution. Policy shifts, such as decoupling farm energy needs from imported



fossil fuels, rationalizing wheat, and fertilizer subsidies, and providing bridge financing for the transition period, are imperative to support this shift.

In South America, Brazil's Low-Carbon Emissions Agriculture (Agricultura de Baixa Emissão de Carbono; ABC) Plan, which supported technology transfer investments of $6.7 billion between 2010 and 2020, stands as one of the largest climate-smart agriculture programs globally. It is expected to sequester 7.4 million tons of carbon dioxide over the next decade. In Guatemala, extreme climate events are disproportionately impacting agriculture and rural livelihoods. The benefits of CSA technologies practices indicate an internal rate of return (IRR) of 69% for conservation tillage, 144% for crop rotation, and a staggering 1933% for pest- and disease-tolerant varieties, compared to only 15% for water reservoirs/ponds with drip irrigation. A research study on the adoption of Climate-Smart Agriculture Technologies in Tanzania examined the determinants of adopting five technologies that can help achieve climate-smart agriculture outcomes in smallholder farms. Chemical fertilizer application was relatively well-adopted (34% of farmers), while irrigation had the lowest adoption rate (26%).

Way forward

While there are obstacles and uncertainties, there is also a wealth of evidence demonstrating the potential benefits of adopting these technologies/practices, though further research is crucial in critical areas. Moving forward, we must (1) establish a clear and concise definition of CSA, as the existence of multiple versions limits the recognition of benefits and allows various organizations using the term to implement vastly different ideas and practices (2) mitigate the risk of greenwashing, wherein food producers may claim climate actions without substantiating their impact (3) institute guidelines and a governing body akin to those in place for organic farming to evaluate practices based on outcomes and (4) academic institutions still teach largely industrial agriculture without imparting needed knowledge on green growth (5) provide substantial support for small-scale farmers, rather than allowing industrial agriculture to disproportionately benefit from unproven climate mitigation practices. Additionally, (6) coordinated guidelines across geographic regions are essential for effective implementation.

Case Study: Advances in Water Research: Enhancing Sustainable Water Use in Irrigated Agriculture in South Africa

Sylvester Mpandeli, Research Manager, Water Research Commission, South Africa

Luxon Nhamo, Stanley Liphadzi, Samkelisiwe Hlophe-Ginindza, Mpho Kapari, Jennifer Molwantwa, Tafadzwanashe Mabhaudhi

Water scarcity has become one of the greatest challenges facing humankind today. Its scarcity is compounded by climate change and increasing demand from a growing population. In South Africa, over 60% of the available freshwater resources are used in agriculture, mainly in irrigated agriculture. There is an urgent need to promote sustainable irrigation technologies that optimize food production without increasing water applied and with positive environmental spinoffs. Sustainable irrigation technologies and practices could enhance water use efficiency (WUE) and productivity in agriculture and reduce environmental burdens, including energy use. This chapter highlights some of the innovative irrigation practices and technologies that enhance food production and, at the same time, reduce water use in agriculture. The chapter broadly discusses WUE and water productivity (WP) in irrigated agriculture from engineering and agronomic perspectives. The chapter further highlights some of the environmental impacts of irrigation expansion and the possible solutions. We further provide the importance of accurate spatial information on irrigated areas to inform policy on irrigation expansion. The Water

Research Commission (WRC) of South Africa has been spearheading research on the sustainable use of water for the past 50 years as part of its research agenda.

Session 2: Considerations for Widespread Adoption of Improved Agriculture Water Use Technologies and Practices: Social, Economic and Policy Barriers

Chair: Andrea Gerlak, School of Geography & Development, University of Arizona, United States

Adoption of Improved Water Technology in Agriculture: Drivers and Barriers

Johannes Sauer, Ag Production and Resource Economics, Technical University of Munich, Germany

Maria Vrachioli

The adoption of new technologies in the agricultural sector not only provides opportunities to the farmers to increase their production, improves their incomes and food security, but also conserves natural resources important for the development of the agricultural sector to meet increasing world food demand. Climatic variability in combination with increasing depletion for finite natural resources in agriculture have led to the evolution of resource-conserving technologies, and their adoption has received significant attention the last decades.

Despite the conflict among different studies on whether irrigation technology adoption can lead to water conservation (Perry and Steduto, 2017), the majority agrees that the adoption of these technologies can be an effective mechanism to increase the economic performance of the irrigated agriculture. Given the water availability, water conservation technologies can lead to higher levels of agricultural production. Taylor and Zilberman (2017) find that the adoption of modern irrigation technologies (drip and sprinkler systems) in California, Israel, Greece and Spain resulted in significant economic benefits for the farmers, stemming from increased output, and also in irrigation water savings.

As identified in the Intergovernmental Panel on Climate Change (IPCC), regions of the Middle East, North Africa, South Asia, Australia and the United States are predicted to experience variable water supply and extreme events (i.e. drought, flood) due to climatic variability. Given both supply and demand threats related to water availability for agricultural purposes in the near future, the need for water conservation measures is imperative. In the Mediterranean region, promotion of micro-irrigation technologies has drawn the attention of policymakers as a way to deal with water shortages in agriculture and to mitigate poverty (Postel et al., 2001). Adoption of water-conserving irrigation technologies can improve land productivity, boost crop yields and farm employment, and decrease the crop failure risk associated with climatic variability (Hussain and Hanjra, 2004).

With new technologies being available, farmers are asked to decide whether to adopt the innovation. Adoption is defined by Rogers (1995) as "*a decision to make full use of an innovation as the best course of action available*" [p. 21]. Given the optimal behaviour of the farmers to maximize their profits (where profit is directly affected by farmer's choices of output mix and production technology), the decision to adopt or not the new technology can be changed by a number of environmental, socioeconomic and institutional factors. Previous work has found that age can have a negative relationship with adoption rates as older farmers are less likely to use new practices due to shorter planning horizon while younger farmers are more involved with innovative farming practices. For education and farming experience, it is more likely to be positively related to adoption rates as farmers with stronger educational or managerial background have more experience taking decisions and using more effectively new technologies. Income

level is expected to affect adoption levels as farmers with higher revenues can afford the costs associated with investment to new technologies, and it is more likely to benefit from tax incentives to adopt. In addition, farmers who receive governmental payments or subsidies are more likely to be aware of or participate in conservation programs that promote the adoption of new agricultural practices.

Except for socioeconomic factors that can influence adoption, the farm's agroclimatic environment can impact this decision. Farms with poor land quality (steeper slopes, low soil water conductivity, poor soil texture) are more likely to adopt new agricultural practices to offset challenges related to the farm's environmental characteristics. In addition, farm size and tenure are positively associated with adoption levels. Caswell and Zilberman (1986) were the first to examine the effects of well depth and land quality on the adoption of a modern irrigation system (drip and/or sprinkler), with Caswell et al. (1990) expanding this analysis to include the impact of environmental policies in conserving water resources. Finally, networking and extension related activities are expected to have a positive impact on adoption rates as farmers are more likely to adopt when they are exposed to ideas from others and receive outreach support. Boyd et al. (2000) find that adoption of new irrigation water systems can be affected by human capital attributes, natural characteristics, farm infrastructure, access to financial support and extension activities, and availability of technical assistance and education programs. Also, price of water and water property rights can be some other factors that can influence the adoption of water-conserving practices in agriculture (Ward et al., 2007).

Jara-Rojas et al. (2012) present a literature review on technology adoption for water conservation technologies and on factors that can influence or impede the adoption rate of these technologies. A variety of different methods has been used in the literature to understand determinants of innovations adoption in agriculture including t-tests, linear regression, logit, probit, tobit and sample selectivity models. The majority of the literature on the adoption of efficient irrigation technologies at the farm level are using logit or probit models to capture adoption patterns as a function of farmer's expected utility compared with the utility associated with the use of the more efficient irrigation technology.

While the majority of studies have focused on modern irrigation practices as ways to conserve water in agricultural, the last years alternative approaches to other water-conservation technologies have been emerged. For instance, improvements in groundwater management and expansion of groundwater metering started recently to attract more attention from policy makers and governmental agencies.

Institutional and Policy Related Challenges that Limit the Adoption of Improved Agricultural Water Use Technology and Practice: Enhancing Rainfed Agricultural Systems in the Zambezi Watercourse

Xanani Baloyi, Programme Officer, Gender and Equality Focal Point, Stockholm International Water Institute, South Africa

SIWI is working on attracting finance to farmers in the Zambezi valley through our Transforming Investments in African Rainfed Agriculture (TIARA) initiative, a programme set out to investigate the potential of different financial mechanisms, sources and approaches for scaling up enhanced rainfed agriculture. We work from the principle that 95%[i] of staple food production in sub-Saharan Africa is derived from rainfed sources, and yet only 5% of public investments in the region are dedicated to rainfed agriculture, with little support reaching the smallholder farmers dependent on rainfall. Rainfed agriculture is being severely impacted by a changed climate, but with investments in improved soil management and access to locally sourced water it is possible to increase soil moisture retention and provide supplementary irrigation. We view the smallholder farmer as the frontline water manager of

Africa, with actions she takes on her field cumulatively improving water resources management by reducing runoff, increasing infiltration into groundwater, reducing soil erosion and sedimentation. The technologies and approaches are multiple, affordable, and well understood; however, the challenge is to upscale investment in the sector to benefit the smallholder farmer.

TIARA's effort is to scale up green water and enhanced rainfed agriculture across Africa through financial investments and political leadership. By working with the Zambezi Watercourse Commission (ZAMCOM), where their Strategic Plan guiding development of the basin until 2040 identifies livelihood activities as one of four key areas of focus, our initiative is working with local NGOs in the Zambezi basin (pilots in Malawi, Zambia and Zimbabwe) to develop a robust business case for investing in rainfed agriculture and aims to persuade the national governments to establish a regional funding mechanism to support farmers in improved landscape management. Our project page has a short video giving an outline of what we would like to achieve, see: https://siwi.org/transforming-investment-in-africas-rainfed-agriculture-tiara/

The aim is to influence policy at national as well as regional level to ensure support to smallholder rainfed agriculture in Africa through building an empirical business case drawn from our field work across the Zambezi watercourse. SIWI will share some of the early results and emergent cases we are working with and make recommendations on policy and partnership actions to be taken by governments, development finance institutions, farmer and community organizations, and the private sector.

[i] *https://siwi.org/publications/unlocking-the-potential-of-rainfed-agriculture/*

Strategies to Foster the Implementation of Policy on the Ground: Regional Water Partnerships and Capacity Building – Using partnerships and people on the ground to translate policies to action – amplifying synergies, reducing conflicts and securing resources

Caroline Gelderblom, Manager, Water Source Institutional and Financing Grameworks, World Wildlife Fund International, South Africa

After the transition to democracy in 1994 the revision of the Water Act provided a sound foundation recognizing access to water and sanitation as a basic human right, the need for an environmental reserve and the importance of collaborative local governance structures. Implementation of these policy directives has however often proved challenging in practice - particularly the roll out of Catchment Management Agencies which were intended to support local governance. Over 20 years later many have still not been initiated and the footprint of those which been established have been expanded to cover very large regions. This has made it very difficult for catchment management agencies to facilitate local collaborative governance processes in practice.

The water sector recognizes that there is a significant funding gap in terms of maintenance of built infrastructure and expansion services to reach people and has responded by proposing significant increases to water tariffs including removal of a longstanding cap on agricultural and forestry users. The gap in resource allocation for the maintenance of catchments is less well recognized. Indeed, although policy frameworks theoretically charge Catchment Management Agencies with responsibility for catchment management, in practice this is not supported by adequate resourcing.

With half the average global rainfall, exacerbated by severe climate change impacts and degradation South Africa needs urgently need to ramp up our nature-based solutions to restore catchments and improve local resilience. Degraded catchments can lose over 50% of their base water flows in droughts but interventions are costly - so WWF South Africa has joined with government departments and scientific parastatals to highlight the need to focus on restoring our most important areas – our water towers or strategic water source areas. In South Africa, Lesotho and Eswatini these areas comprise just 10 percent of the land surface - but they provide 50% of our water and support over, 64% of the economy. There is now widespread recognition of their importance in government policy frameworks. The next step in the policy journey is to identify mechanisms which can be used to secure[1] these critical areas.

One of the mechanisms, which WWF has been supporting, is the development of public, private, community partnerships to facilitate collaborative governance in strategic water source areas. These partnerships work to consciously bring together stakeholders from different sectors to identify where their mandates can be aligned to capitalize on synergies and improve implementation. These strategic water source area partnerships include Catchment Management Agencies as well as other government departments such as agriculture, conservation, water affairs and local government as well as local NGOs and biosphere reserves.

Another effective mechanism to improve the sustainability of catchment management is deployment of additional extension capacity in the form of catchment coordinators who support land users in the implementation of best practice. In several cases we have placed capacity within Water User Associations as the local mandated authorities. They support land users in implementing best practice catchment rehabilitation which is prescribed by policy frameworks but which is difficult to implement without substantial support as a result of the substantial costs involved. This approach has proved to be effective and the right coordinator is often able to mobilise significant resources for catchment management. In order to build trust and traction it is also necessary for these catchment coordinators to live and work in the communities they serve. The skills and relationships needed for engagement take time to develop, however, in terms of career pathing it is often difficult to retain the most experienced and valuable extension workers in the landscape. It is important for these coordinators to have an integrative approach but the skills required are often not part of standard training programmes.

In the past extension in South Africa has often been narrowly tied to the provision of technical advice and support services for agricultural producers. However, the same principles of resource user engagement underpin participatory forest and fisheries management, biodiversity stewardship and integrated water resource management (de Satgé et al 2020). Moreover, individual land users often need to address challenges related to more than one sector in order to adapt to rapidly changing environmental and socio-economic conditions. There is consequently a growing recognition that the landscape and its challenges are connected and that the mobilisation of the limited resources supporting extension work can be optimised by working across the silos which separate the work of different institutions, sectors and communities to develop integrative cross-sectoral solutions which unlock synergies, reduce duplication and build local resilience. Adaptive solutions require innovation and connection and are often driven by local champions but it is helpful if these individuals can be supported by local platforms which facilitate mentorship. Regional platforms have the potential to support the synergistic implementation of policies but can also potentially serve as a conduit to feedback experience from the ground into policy development processes.

[1] *"Securing" is seen to refer to: as The progressive, collaborative and adaptive implementation of a range of mechanisms that aim to enhance the ability of Strategic Water Source Areas (SWASA) to deliver the maximum quantity of good quality water for people, economic activities and ecosystems, both within and downstream of the SWSA, in a way that helps assure efficient, equitable and sustainable water supply and access to water for all, now and in the long term*

Thursday, 26 October

Session 3: Water Productivity: Positive and Negative Impacts

Chair: Lucia De Stefano, Associate Professor, Complutense University of Madrid, Spain and Deputy Director, Water Observatory of the Botin Foundation

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Water for Residential Sector: Socio-Economic Welfare and Environmental Costs
Slim Zekri, Associate Professor and Department Head, Natural Resource Economics, Sultan Qaboos University, Oman

Chemseddine Mkkadem and Lamia Mokaddedm

Demand of bottled water in Tunisia soared from 78 to 225 litres/capita/day between 2010 and 2020 with an average growth rate of 11.6%. Several factors affect households' choice to consume bottled water instead of tap water. This article explores some determinants of at-home households' demand for bottled water in Tunis capital during year 2022. We collected data through a door-to-door survey that reached 834 households. The dams providing domestic water reached very low levels in 2022, which affected the raw water quality. Eighty five percent of the interviewees consider that tap water was bad to very bad quality. We use a double-hurdle approach to separately model households' decisions to consume bottled water and their level of consumption. The results show that water quality, income and having babies, children and old parents are the major variables explaining participation and the same variables lead to an increased likelihood of consuming bottled water. Results were consistent by using both Cragg Model and Heckman Model. The quality variable has a higher coefficient than income in the demand model and is significant at 1% level.

Case Study on Chile: Water for Mining - Socio-Economic Welfare and Environmental Costs
Guillermo Donoso Harris, Professor and Chair, Department of Agricultural Economics, Pontificia Universidad Católica de Chile

The presentation analyses the factors that explain why groundwater is over-exploited despite the existence of sophisticated water laws, institutions and effective state agencies responsible for water management. The analysis is based on a case study conducted in the Copiapó Valley, located in the Atacama district, in the semi-desert region of northern Chile. Since 1990, mining activities have intensified with the arrival of major foreign investors, who have opened very high-capacity copper mines. Agriculture has also developed; cultivated areas expanded from 3,400 ha in the 1960s to 7,000 ha in the 1990s and 15,000 ha in 2015. The combination of economic and demographic growth which accompanied the mining and agricultural boom also led to one of the highest population growth rates in the country. By the end of the 2000s, agricultural use accounted for 75% of groundwater withdrawals, while mining and industrial activities accounted for 15%, and drinking water supply, 10%.

Since the 1980s, a number of studies have shown that withdrawals far exceed the average recharge of the alluvial aquifer, which is estimated at 4 m^3 per second. This is confirmed by the rapid fall in piezometric levels; the levels fell from 10 to 150 metres (on average) between 1998 and 2015. The total available water reserve fell by about 38 million m^3 per year between 1990 and 2012. The shortfall then accelerated sharply between 2005 and 2012 to 55 million m^3 per year. In this 22-year period, the reserve lost an estimated 830 million m3, the equivalent of 6.5 years of average recharge.

Defining and applying water rights (WR) is a basic element of water management in Chile. However, the Chilean Water Code of 1981 (WC81) was designed essentially to regulate surface water. Consequently, it barely mentions groundwater. In response to the need to regulate groundwater exploration and pumping and provide a legal framework and technical instruments to achieve sustainable groundwater management, the General Directorate of Water (DGA) promulgated Decree 203-2013[1]. Groundwater is a national good for public use, and the state grants withdrawal authorizations. These WR were specified in terms of flow (not volume), as was traditionally the case in hydraulic systems; since 2005, WR specify both a maximum instantaneous pumping flow and an annual volume. The law also provides for an overdraft situation, which involves the uniform reduction of the flow associated with each water use right to re-establish hydrogeological balance. In restriction and prohibition zones, users are also required to form groundwater user associations (GWAs), which are in charge of ensuring that users comply with their rights.

The DGA can legally cancel WR and expropriate users (with compensation), if it is justifiable in terms of the public interest with regard to protecting the environment or third parties. However, this has not yet been applied since the promulgation of the WC81. There are two main reasons. First, the cost of expropriation is burdensome for the government, especially in arid and semi-arid basins, where the value of WR is very high on average; in the northern arid regions, the value fluctuates between USD 50,000 and USD 500,000 per litre per second. Second, its application would lead to significant social and political conflict, due to the transfer of wealth to the WR holder, who received the rights free of charge.

As the state theoretically has the regulatory tools to avoid this kind of situation, several questions arise as to how did this level of over-exploitation occur. Is the state able to perform its key missions? Was sufficient information available with regard to the status of the aquifer? If so, why did the state continue granting new permits? Is the state capable of determining the amounts of water that are actually being drawn off?

Evidence based on an analysis of water use data, policy documents and interviews with a variety of stakeholders, highlights the state's failure to perform some of its key missions. In particular, total water use has not been properly capped (over-allocation of rights) because there is a degree of uncertainty with regard to the available resources and rent-seeking behaviour is apparent among some users. The state also failed to control illegal abstraction (enforcement of rights). The development of a water market has exacerbated the problem by activating unused rights, which were transferred from seasonal activities (agriculture) to permanent operations (mining). Policies promoting water use efficiency and conservation technologies (drip irrigation) have accentuated the water deficit by reducing groundwater recharge. Last but not least, the state has not been able to provide the required incentives to encourage water users' associations to play an active role in water management despite the existence of a very supportive legal framework.

Examination of the Copiapó Valley case shows that even in a developed country like Chile (Chile's per capita income has passed the threshold defined by the World Bank for high-income or developed economies), with highly sophisticated water legislation, the state and water user associations have not applied an effective management model based on the granting of individual permits. To change this situation and move towards co-management involving the state and users, a mutual understanding of stakeholders' interests, concerns and preferences is required. This represents a key challenge in Copiapó in the years to come.

[1]*The recent water code reform in 2022, increases groundwater regulation to increase groundwater sustainability*

Natural Resources Extraction, Institutional Quality and Household Welfare: The Case of Mining in Africa

Raymond Boadi Frempong, Postdoctoral Researcher, University of Bayreuth, Germany

David Stadelmann, University of Bayreuth; Djiby Racine Thiam, University of Cape Town

The impact of mineral resource extraction on livelihoods has been the subject of many research studies. Macro studies generally show that extracting these resources in developing countries could create positive (economic growth, employment) and potential negative effects (health, income inequality). At the micro level, evidence of the impact of mining on individual welfare, especially with representative data, is limited. We close this gap by conducting a micro study to assess the impact of mineral resource extraction on water security and other household variables that affect social welfare. Mineral extraction is often associated with various forms of environmental pollution. At the same mining companies, as part of their social responsibilities, provide social amenities, including potable water, to mining-affected communities. In this paper, we study the average impact of mineral extraction on household water security in Africa.

We employ the Afrobarometer survey, which provides consistent information on five dimensions of lived/experienced poverty, i.e., food, fuel, income, medicine, and water deprivation, to assess the effect of gold extraction on households' access to clean water. Our analysis uses all eligible survey respondents from rounds three to six because we found consistency in the questions across these survey rounds (2005-2015). Information on mining activities is derived from GOLDDATA, which comprises commercial gold mines compiled by the Peace Research Institute. GOLDDATA provides descriptive information on the deposit name (type), location, and other characteristics. The two data sets are merged based on geographic proximity using the geo-coordinates provided in each dataset. We measure household exposure to mining activities with the distance to the nearest mine.

Our results show that mining operations impact the different dimensions of poverty significantly. However, the effects appear to be non-linear. A concentration of mining activities within a 50 km radius of the household improves living standards in the four dimensions analyzed. A mining operation within 50km reduces water and fuel poverty by about 4%. Beyond 50 km, mining operations tend to have a welfare-reducing effect on the household. If a mining operation is within a 50-100 km radius of the household, the likelihood of lacking clean water increases by 1%.

A potential explanation for the result is that individuals who live close to the mines have better access to the employment opportunities directly provided by the mines and indirectly through their supply chain

and backward and forward linkages. Thus, even though mining operations could lead to environmental degradation, affecting living standards, individuals can improve their welfare from their incomes. However, the adverse effect of mining may spread beyond the immediate catchment areas. In the case of water, it is conceivable that an upstream operation could pollute water several hundred kilometres downstream. However, not only do the people who live in these areas have limited access to employment opportunities in the mining sector, but also cooperate social responsibility measures, such as boreholes, which the firms usually use to mitigate these adverse effects, may not reach these areas.

Water Allocation and Trade-Offs Between End-Users
Maria Cristina Rulli, Professor, Water and Food Security, Politecnico di Milano, Italy

The past few decades have seen unprecedented changes in the global agricultural system with a dramatic increase in the rates of crop production fuelled by an escalating demand for food calories, as a result of demographic growth, dietary changes, and – more recently – new bioenergy policies. Food prices have become consistently higher and increasingly volatile with dramatic spikes in 2007-08 and 2010-11. The confluence of these factors has heightened demand for the natural resources needed for crop production, most notably, land and water, thereby increasing the environmental burden. Solutions to feed the planet often point to agricultural intensification (i.e., increase in crop yields) as the approach that could meet the increasing human demand for agricultural products with the smallest environmental impacts. Indeed, intensification avoids land use change (e.g., deforestation), habitat destruction, and an increase in CO_2 emissions that would result from an expansion of cultivated land (or "extensification"). Indeed, the impacts of intensification on freshwater resources, rural livelihoods, and equity, however, is often ignored. The ongoing agrarian transition from smallholder farming to large-scale commercial agriculture often aims to increase crop yields through the expansion of irrigation. This may result in inducing or exacerbating water scarcity conditions, thus leading to new rival water uses. At the same time, agricultural expansion has important externalities that go beyond biodiversity losses or greenhouse gas emissions; it may have important ramifications to human and planetary health. Here, a suite of model simulations and data analyses are used to evaluate the hydrological and nutritional impacts of different strategies for increasing crop production and discuss their effects on land and water sustainability, and inequality, in particular analyzing if this last is at the expense of sustainability, justice or both.

Session 4: Gender Issues

Chair: Djiby Thiam, Associate Professor, School of Economics, University of Cape Town

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Exploring the Intersection of Water, Agriculture, and Gender: Perspectives and Implications
Grace Muinga, Gender Specialist, Global Center on Adaptation, Kenya

This abstract explores the intersection of gender, water, and agriculture and its implications on water policy.

This presentation examines the complex relationship between gender, water, and agriculture, shedding light on its implications and offering valuable perspectives on water policy. By delving deeper into this crucial issue, we aim to bring about a deeper understanding of the challenges faced in water management and agriculture, and how these challenges disproportionately affect women.

Gender disparities in water access and usage have significant implications for agricultural productivity and food security. Women, who make up the majority of agricultural laborers in many parts of the world, often face barriers in accessing sufficient water resources for irrigation and other agricultural activities. These barriers stem from various factors including social norms, limited decision-making power, and unequal access to resources and technologies. As a result, women often bear the brunt of the negative impacts of water scarcity, such as increased workloads, decreased agricultural yields, and limited opportunities for economic empowerment.

In order to address these gender disparities and their implications on water policy, it is essential to take a multi-faceted approach.

- Firstly, policies and programs should prioritize the inclusion of women in water resource management and decision-making processes. This can be achieved by fostering their participation in water user associations, providing them with training and capacity building opportunities, and ensuring their voices are heard in decision-making forums.
- Secondly, investments should be made in improving women's access to water resources and agricultural technologies. This can involve initiatives such as the construction of women-friendly water infrastructure, the provision of affordable and appropriate irrigation technologies, and the support for women-led agricultural enterprises.
- Lastly, there is a need to address the underlying social and cultural norms that perpetuate gender inequalities in water access and usage. This can be done through targeted awareness campaigns, education programs, and advocacy efforts that challenge traditional gender roles and promote gender equality in water management.

In conclusion, understanding the implications of gender disparities in water access and agriculture is crucial for developing effective water policies. Water policies that recognize and address gender disparities can lead to more equitable and sustainable water management practices. Moreover, by prioritizing the inclusion of women in decision-making processes and ensuring their access to water resources and agricultural technologies, policies can contribute to empowering women and promoting gender equality in the agricultural sector.

Approaches to Resilience-Based Urban Water Governance in South Africa - What Role Does Gender Play?

Kirsty Carden, Associate Professor and Interim Director, Future Water Research Institute, University of Cape Town, South Africa

Climate change impacts and rapid urbanisation in South African cities contribute to problems associated with water scarcity (drought), flooding (lack of drainage) and environmental degradation (poor-quality runoff to local water bodies), highlighting widening concerns about the resilience of conventional water infrastructure. Water sensitive design (WSD) is a complementary approach to addressing some of the deficits of conventional urban water services that takes a total water cycle view through the integration of built water infrastructure with green infrastructure, often in a decentralised manner. These efforts contribute to achieving water sensitive cities (WSC) with associated stormwater components (often referred to as blue-green infrastructure, BGI) comprising mostly nature-based approaches that help to return urban rainfall-runoff processes to more natural hydrological cycle flows and offer cities multifunctional and alternative ways to adapt to climate change.

For the mainstreaming of approaches like WSD, it is necessary to move beyond physical experimentation towards the interrogation of existing governance structures, cultures and practices in a manner that can highlight policy windows for the anchoring of insights gained in the policy processes and outscaling possibilities. This presentation discusses current research that seeks to understand the different pathways towards urban water resilience in South African cities, with some critical reflection on the ways in which gender roles are potentially reified in the implementation and governance of BGI as part of this transition. Through an exploration of the policy landscape, as well as documentation of the lived experiences of residents involved in the BGI retrofitting of an existing stormwater pond in Mitchells Plain, Cape Town, our research increasingly highlights the potential for how such infrastructure could be managed to provide a range of water-related, amenity and liveability services without necessarily reproducing gender roles, or playing into local gender dynamics. Initial responses to our on-the-ground research highlighted that projects such as these may initially reify archetypical gender roles as men took on leadership positions and comprised the bulk of the teams building the interventions. Additionally, women tended to be poorly represented in discussions and decision-making around the co-design processes. However, over time social networks developed, predominantly among women, and these networks became involved in the ongoing BGI implementation and coordination. Of interest in the context of changing gender roles around housework and cleanliness linked to health for families, is that the decisions we make around water from a local governance perspective may include added burdens for women - with cascading effects that are often too wide-ranging such that single policies cannot address the complex ripple impacts. These considerations are difficult to address without concerted effort across departments, decision-makers and policies, but are central to dignity and self-assurance, and thus pivotal in wellbeing.

Friday, 27 October

Unpacking Water Management Complexity in the Global South

Irrigated Agriculture

Irrigation-as-a-Service for Smallholder Farms

Nicholas Brozovic, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, USA

Ishani Lal

Irrigation can increase smallholder food security globally while mitigating climate change impacts. High-efficiency irrigation technologies are expensive, leading smallholder farmers to access irrigation goods and services through a variety of informal mechanisms. One such mechanism is the sharing of irrigation equipment between multiple farmers. Such services may be operated by farmers, irrigation start-ups, NGOs, or government agencies. Irrigation-as-a-service (IaaS) is ubiquitous among smallholders in the Global South, with many previous studies on farmer-to-farmer equipment sharing. However, no economic research exists on entrepreneurial approaches involving non-farmer businesses renting irrigation equipment to multiple farmers. The objective of this study is to develop a decision-making model for IaaS. We use a crop water production function (CWPF) to model the crop yield resulting from irrigation application. We analyze how the optimal irrigation service strategy varies as a function of field-level, regional, physical, and economic parameters. Results reveal that decision-making under IaaS is complex, with solutions ranging from irrigating all, some, or only one field. Analyzing the CWPF and the value of marginal irrigation are crucial to understanding the optimal irrigation strategy. Asset utilization rates of irrigation equipment may increase or decrease in IaaS compared to fixed irrigation systems.

Results have policy implications regarding the cost-effectiveness of donor funds: IaaS can increase water-use efficiency, returns on invested funds, and asset utilization rates.

Small-Scale Irrigation Potential in Niger and Burkina Faso
Getaw Tadesse, Akademiya2063, Senegal and Rwanda

Mahamadou Tankari; Ismael Fofana

The importance of irrigation for enhancing productivity and food security, creating climate-proof resilient agriculture, and triggering jobs in rural Africa in general in the Sahel in particular is well recognized. Political wills and commitments to support the development of small-scale irrigation in the region are also gaining momentum. Local governments have started developing specific strategies for the promotion and expansion of small-scale irrigation. By focusing on Burkina Faso and Niger, this study adopts a modeling approach that integrates both biophysical and economic factors to estimate the feasibility and scalability of four selected small-scale irrigation technologies—treadle pump, motor pump, small reservoir, and communal river diversion. The irrigation potential assessment have taken into account the groundwater potential, topography, market access, distance from surface water, population density. It also factors water availability, water consumption and the yields of crops at river-basin level using topography, soil type and other biophysical factors. Then, a customized economy-wide Computable General Equilibrium (CGE) model has been used to predict the impacts of the technologies scale up to identified potential areas on growth and poverty reduction. All the different assessments showed that there exist tremendous interest, potential, opportunity and benefits for expanding small-scale irrigation in Burkina and Niger.

Combining Social Institutions and Technological Solutions for Sustained Change in Water User Behaviour within Small-Scale Irrigation in Sub-Saharan Africa
Henning Bjornlund, University of South Australia, Australia

Parry, K. and Pittock, J.

Water management complexity increases under conditions of scarcity. To alleviate projected shortfalls, management systems must become adaptable to climate change. This requires integrated socio-institutional and technological interventions, working synergistically to generate sustained change in water management. We illustrate this by drawing on ten years of research though the 'Transforming Irrigation in Southern Africa' (TISA) project, which introduced Agricultural Innovation Platforms and monitoring tools to small-scale irrigation schemes in southern Africa. We report on the changes generated during TISA's more intensive first phase, and how these changes sustained a transition to an operational phase with minimum external researcher and donor involvement.

Urban and Mining Sectors

Quality of Tap Water and Demand for Bottled Water in Tunis
Slim Zekri, Associate Professor and Department Head, Natural Resource Economics, Sultan Qaboos University, Oman

Chemseddine Mkkadem & Lamia Mokaddedm

Demand of bottled water in Tunisia soared from 78 to 225 litres/capita/day between 2010 and 2020 with an average growth rate of 11.6%. Several factors affect households' choice to consume bottled water instead of tap water. This article explores some determinants of at-home households' demand for bottled water in Tunis capital during year 2022. We collected data through a door-to-door survey that reached 834 households. The dams providing domestic water reached very low levels in 2022, which affected the raw water quality. Eighty five percent of the interviewees consider that tap water was bad to very bad quality. We use a double-hurdle approach to separately model households' decisions to consume bottled water and their level of consumption. The results show that water quality, income and having babies, children and old parents are the major variables explaining participation and the same variables lead to an increased likelihood of consuming bottled water. Results were consistent by using both Cragg Model and Heckman Model. The quality variable has a higher coefficient than income in the demand model and is significant at 1% level.

Assessing the Efficiency of Residential Water Demand: The Role of Information
María García-Valiñas, University of Oviedo, Spain

Roberto Balado-Naves, Department of Economics, University of Oviedo; David Roibás, Department of Economics, University of Oviedo

In the current context of pressure on available water resources, sustainable patterns of water consumption emerge as an important matter of concern. In this sense, efficient consumption is usually understood as the optimal usage of the available resources. Thus, we study households' efficiency levels by considering a stochastic frontier analysis of the demand for water services using a representative sample of a northern city in Spain. Besides, efficient consumption habits require a costly acquisition of accurate information, whether in terms of prices or the effective demand of a given resource. Thus, we also study the impact of several determinants on the efficiency levels of water demand. These range from the deviations between perceived and real prices to self-reported water-saving habits or household size. We find strong evidence in favour of higher efficiency levels among better-informed households, with better water-saving habits and few members. The relevance of this research to the current state of the empirical literature is threefold: first, it develops a micro-founded model which justifies the inclusion of an inefficiency term in the estimation of a Stone-Geary demand function for water with an increasing-block tariff (IBT); second, it expands the number of scarce stochastic frontiers analyses of residential water demand; third, it contributes to a better understanding of the importance of accurate information on optimal decisions of consumers. Moreover, we use a novel and exclusive database for a representative sample of households in the city of Gijón (Spain) between 2017 and 2021, where we combine real data on water prices and consumption with consumer perceptions obtained from a survey.

Mineral Extraction and Water Security
Raymond Boadi Frempong, Postdoctoral Researcher, University of Bayreuth, Germany

David Stadelmann, University of Bayreuth; Djiby Racine Thiam, University of Cape Town

The impact of mineral resource extraction on livelihoods has been the subject of many research studies. Macro studies generally show that extracting these resources in developing countries could create positive (economic growth, employment) and potential negative effects (health, income inequality). At the micro level, evidence of the impact of mining on individual welfare, especially with representative data, is limited. We close this gap by conducting a micro study to assess the impact of mineral resource

extraction on water security and other household variables that affect social welfare. Mineral extraction is often associated with various forms of environmental pollution. At the same mining companies, as part of their social responsibilities, provide social amenities, including potable water, to mining-affected communities. In this paper, we study the average impact of mineral extraction on household water security in Africa.

We employ the Afrobarometer survey, which provides consistent information on five dimensions of lived/experienced poverty, i.e., food, fuel, income, medicine, and water deprivation, to assess the effect of gold extraction on households' access to clean water. Our analysis uses all eligible survey respondents from rounds three to six because we found consistency in the questions across these survey rounds (2005-2015). Information on mining activities is derived from GOLDDATA, which comprises commercial gold mines compiled by the Peace Research Institute. GOLDDATA provides descriptive information on the deposit name (type), location, and other characteristics. The two data sets are merged based on geographic proximity using the geo-coordinates provided in each dataset. We measure household exposure to mining activities with the distance to the nearest mine.

Our results show that mining operations impact the different dimensions of poverty significantly. However, the effects appear to be non-linear. A concentration of mining activities within a 50 km radius of the household improves living standards in the four dimensions analyzed. A mining operation within 50km reduces water and fuel poverty by about 4%. Beyond 50 km, mining operations tend to have a welfare-reducing effect on the household. If a mining operation is within a 50-100 km radius of the household, the likelihood of lacking clean water increases by 1%.

A potential explanation for the result is that individuals who live close to the mines have better access to the employment opportunities directly provided by the mines and indirectly through their supply chain and backward and forward linkages. Thus, even though mining operations could lead to environmental degradation, affecting living standards, individuals can improve their welfare from their incomes. However, the adverse effect of mining may spread beyond the immediate catchment areas. In the case of water, it is conceivable that an upstream operation could pollute water several hundred kilometres downstream. However, not only do the people who live in these areas have limited access to employment opportunities in the mining sector, but also cooperate social responsibility measures, such as boreholes, which the firms usually use to mitigate these adverse effects, may not reach these areas.

Climate Change Induced Water Scarcity Risks

Hydro-Economic Modelling of Water Scarcity and Quality in the South African Region of the Limpopo River Basin

Daiju Narita[2,3], The University of Tokyo, Japan

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Water scarcity and water quality degradation are serious global problems. Many rivers in the sub-Saharan Africa region experience some of the most devastating precipitation variabilities worldwide and have a history of severe water quality degradation. The challenge is particularly relevant for policy considerations throughout the continent, given the projected rate of water demand and economic growth in the coming decades. In this study, we use a hydroeconomic optimization framework that integrates water quality, scarcity patterns, and economic value derived from different water demand sectors in the South African region of the Limpopo River Basin. The model provides an important approach to influence and improve the interactions among hydrologic, economic, and institutional frameworks in the context of water scarcity and quality degradation. Water quality improvement policies that achieve both economic and environmental sustainability goals were evaluated under normal and severe drought conditions to identify the effectiveness and robustness of water quality management policies. The results of this study highlight the strong links between water scarcity and quantity in the basin and show that drought conditions reduce water availability and increase chemical concentration in large water bodies. Considering the transboundary nature of the basin, these findings could have important policy relevance for other river basins, especially in arid and semiarid regions with similar pollution and environmental conditions.

Do Zambian Farmers Manage Climate Risks?
Chieko Umetsu, Kyoto University, Japan

Soyoka Okamura, The University of Tokyo; Ken Miura, Kyoto University

Today, the impacts of climate change are becoming more conspicuous worldwide. Developing countries are vulnerable to climate change, and small-scale farmers are especially exposed to severe weather risks. Understanding their climate risk management is critically important for designing effective and appropriate adaptation policies. Standard economic theories suggest that under risky environments, risk-averse economic agents diversify their income portfolios by increasing investment in low-risk assets in exchange for higher returns. This study tests this empirical hypothesis in Zambian agriculture, where production is prone to climate risks due to almost nonexistent irrigation facilities. The empirical puzzle motivating this study is that the mono-production mode of maize is still dominant among Zambian smallholders despite high weather risks.

Previous work has investigated how climate risks affect various agricultural decisions, including crop choice, plot location choices, and investments in agricultural inputs. However, using the same data, a few empirical attempts have been made to discuss farmers' management of weather risk and the subsequent consequences on agricultural productivity. By combining nationally representative agricultural survey data and long-term pixel-level climate data, this study examines how climate risk affects farmers' management and, as a result, farm productivity in rural Zambia.

Measuring the Resilience of Farms to Water Scarcity
Johannes Sauer, Technical University of Munich, Germany

Philipp Mennig

Agricultural systems face a number of economic, ecological and societal challenges, raising concerns about their resilience to shocks and stresses. Resilience of a farming system refers to its ability to ensure the provision of the system functions in the face of increasingly complex and accumulating disturbances,

through capacities of preparedness, absorption, adaptation and transformation. While several frameworks to assess the resilience of farming systems have been developed, its operationalisation as a dynamic instrument is still unclear.

Therefore, we develop a concept to quantify farm resilience along the dimensions mentioned earlier, taking into account specified and general resilience. Our framework further allows to identify resilience-enhancing attributes of farms. It is demonstrated using water scarcity as a theoretical case and follows a mixed-methods approach capturing effects at both sector-level and farm-level effects and analysing dynamic drivers behind the resilience capacities.

Innovations and Policy Interventions

Innovation and Water Productivity: Empirical Evidence from Water-Related Patents
Linus Nyiwul, Gettysburg College, USA

Zhining Hu; Niraj P. Koirala

This paper estimates a water productivity growth function using panel data on both developing and developed countries. The goal is to determine the effect of technological innovation on water productivity. First, using water as a factor of production, we derive theoretical parameters for factors of production in the Cobb-Douglas production frame- work and convert factors into their growth rates for ease of empirical analysis. Second, we apply panel instrumental variable (IV) and system generalized method of moments (GMM) estimations to panel data for a sample of 82 developing and developed countries over a 20-year period. Contrary to the predictions of economic theory, empirical results show that there is a negative and statistically significant relationship between innovation and productivity in the water sector in developing and developed countries, with the effects more intense in the latter relative to the former. Various statistical diagnostics and alternative estimation approaches show these results to be consistent. Thus, we find that there exists a productivity paradox in the water sector, a phenomenon that heretofore has not been shown to exist outside the information and communications technologies (ICT) sector. Our results have implications for policy design in the water sector spanning both developing and developed countries. Specifically, the analyses inform policy-makers on the effectiveness of current policies in inducing water productivity via innovation, as well as potential differences in regional experiences and potential sources of such differences.

Wastewater Reuse for Agriculture as an Adaptation Measure to Water Scarcity and Climate Change: Algerian Experience
Chérifa Abdelbaki, Pan African University, Institute for Water and Energy Sciences Including Climate Change, University of Tlemcen, Algeria

Rachid Yahiaoui, National Office of Irrigation and Drainage, Algeria

Recently, as the world facing a water shortage due to climate change, a growing number of countries are considering irrigation using reclaimed water as an appropriate solution to secure and enhance agricultural production. Among the African countries affected by water stress, Algeria is in the category of the most water-stressed countries, namely below the theoretical threshold of water scarcity set by the World Bank at 1000 m^3 per inhabitant per year. Consequently, the country should dispose between 15 and 20 billion m^3 of water per year, by reserving 70% for agriculture, to achieve a satisfactory food

security. This is a great challenge since the amount of water that the country dispose is about 5 billion m^3 per year. The pressure exerted on these resources will continue to grow under the combined effects of population growth and policies applied to water-consuming activities. The total volume of wastewater discharged annually is estimated at nearly 600 million m^3, whose 550 million m^3 are from the northern regions. This value would rise to almost 1150 million m^3 by 2025. The main objective of this presentation is to evaluate the capacities of wastewater treatment plants (domestic wastewater) in Algeria and the possibility of the water reuse for agricultural purposes. The reuse of the treated wastewater from the Algerian wastewater treatment plants for agriculture would be an adaptation measure to the water scarcity and climate change.

Water Pricing and Water Markets: Principles, Practices and Proposals

Sarah Wheeler, University of Adelaide, Australia

Céline Nauges, French Institute for Research in Agriculture & Environment, Toulouse School of Economics, France; R. Quentin Grafton, Crawford School of Public Policy, Australian National University, Australia

The allocation of water across space and time is a key challenge of water governance, with demand and supply often not well matched over time and place. Best practice water pricing and markets may promote water conservation, yet their application is limited. We highlight the governance principles needed for best practice water pricing and water markets, describe differences across regions, and provide six key water demand governance recommendations.

Dynamic Public Investment Feedback Policies for Water Scarcity Control in Dry and Semi-Arid Economies

Abdelmohssin El Mokaddem, Mohammed VI Polytechnic, University, Morocco

This study explores how the application of a feedback investment policy aimed at controlling water scarcity and its social costs can help account for the complex interplay between economic, social, and natural factors to enhance water availability and well-being. The analysis shows that under exogenous demand dynamics, the determination of timely efficient investment depends on the simultaneous change of the velocity of scarcity and the growth rate of the unit social cost of water scarcity. Efficiency of feedback investment can vary depending on the control objective and the tradeoffs it involves. This has important implications in terms of setting priorities in terms of capital allocation at national and local levels and the selection of infrastructure based on efficient capital allocation.