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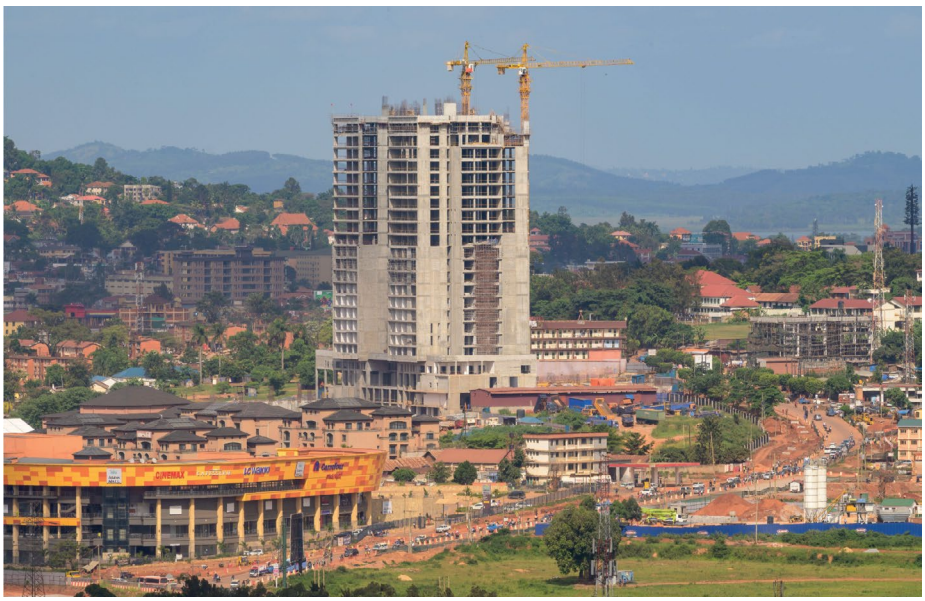
African perspectives on climate change research

The 27th Conference of the Parties (COP27) is being held in November 2022 in Sharm el-Sheikh, Egypt. Having a climate summit hosted in an African country makes it timely to highlight climate change research from the continent. We asked a selection of researchers to share their thoughts on current research questions and how they affect African responses to climate change.



The countries of Africa have contributed comparatively little to anthropogenic emissions, yet the continent feels the impacts of global warming in many different ways, with changes in hydroclimate, biodiversity and wildfire dynamics already visible today. These changes happen simultaneously with considerable societal and economic transformations in many countries. Thus, it is no wonder that much exciting research is conducted on the continent, much of which is important far beyond the respective regions. In this Viewpoint, nine researchers from seven different countries introduce what they see as the most pressing research in their field and region, discuss open questions and propose ways forward to translate this research into climate action.

Shuaib Lwasa: opportunities to achieve equitable urban transitions in Africa

Urbanization is fast progressing in the Global South, requiring new solutions for infrastructure, services, industrial development and land and energy use for these regions. In this context, fast-growing cities in Africa can take on a leadership role in driving climate change mitigation and adaptation, disaster risk reduction and sustainable development.

Cities in Africa and elsewhere in the Global South continue to grapple with the challenge of delivering equitable services, infrastructure, housing and action to respond to climate change extremes and disasters. One well-known problem is a mismatch between the pace of urban growth and the slower development of basic services and critical infrastructure. This results in, for example, deficient sanitation, water supply systems and localized waste management for large parts of the population, which in turn contribute substantially to heightened poverty and inequality. For inclusive, equitable, prosperous and climate-resilient cities, urban management needs to integrate low-income communities into the urban economy by ensuring access to water, sanitation, energy transition, waste management, poverty reduction and by improving resilience through innovative solutions.

Such an equitable urban transition requires changes in the urban infrastructure, and land and energy use, as well as water and ecosystem management. The key research question in this field is to find ways to ensure city-wide access to infrastructure and services, while minimizing emissions and resource use, and building resilience to climate change impacts. In this regard, cities in the Global South and Africa in particular can serve as examples for other parts of the world as they have the potential to adopt disruptive, innovative yet practical solutions to low emissions, resource minimization and resilience building.

For example, rapid urbanization creates the opportunity to develop economic structures in African cities that strongly integrate waste by promoting recovery, recycling, re-use and repair for lengthening lifecycles. Such a circular economy can create business opportunities, while also reducing resource use, thus creating a pathway for sustainable development. Another potential solution is hybrid systems for urban water management that are off-grid and utilize multiple water sources and treatment but that can also connect to centralized water systems. Business models for micro-to-medium enterprises have the potential to integrate some of the low-income groups through these kinds of technology and building social resilience.

These examples are part of a broader assessment of urban infrastructure innovations, their disruption of centralized systems and rethinking of urban form for more compact, walkable, co-located land use for low carbon intensity towards net-zero cities. However, to translate research on these new solutions into action, a shift is necessary in the planning, governing and managing of cities so as to allow for opportunities for leapfrogging to emerge and expand the possibilities of urban development for inclusive and resilient African cities.

Mary Mbenge: smallholder farmers in a changing climate

Climate change is already affecting crop yields and livestock production in many farming communities. One potential response

CREDIT: STEFAN ROTTER / ALAMY STOCK PHOTO

BOX 1

The contributors

Maha Al-Zu'bi is a researcher of Agriculture Water Solutions at the International Water Management Institute in Cairo, Egypt. Currently, she is co-leading the CGIAR Regional Integrated Initiative 'From Fragility to Resilience in Central and West Asia and North Africa'. Her research focuses on integrated land, water, energy and food systems and systematic innovative climate actions.

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Jean Hounkpè is the scientific coordinator of the doctoral research programme on climate change and water resources at the National Water Institute of the University of Abomey Calavi, Benin Republic, as part of the West African Science Service Center on Climate Change and Adapted Land Use (WASCAL). His research interests include flood risk assessment and forecasting through statistical and hydrological modelling in the context of climate change.

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Shuaib Lwasa is the founding coordinator of the Urban Action Lab at Makerere University in Kampala, Uganda, and a Professor of Urban Resilience and Global Development at the International Institute of Social Studies in The Hague, The Netherlands. He has worked extensively on interdisciplinary research on African cities. His research areas span urban mitigation, adaptation to climate change, urban environmental management, spatial planning and disaster risk reduction.

Mary Mbenge is currently working as the Chief Officer for Natural Resources, Environment, and Climate Change in Makueni County, Kenya. She provides strategic team leadership for development programmes and projects that promote local democracy to improve rural livelihoods, increase their resilience and reduce climate vulnerability. She provides strategic team leadership for development programmes and projects that promote local democracy to improve rural communities' livelihoods and resilience and reduce climate vulnerability. She is currently pursuing a PhD in integrated management of water, soil and waste.

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Nadia S. Ouedraogo is an economist specializing in quantitative economics, macroeconomics, modelling, energy and climate change. She is currently an Economic Affairs Officer at the United Nations Economic Commission for Africa (UNECA). Her research expertise includes economic transformation, sustainable development, inclusive green growth, energy poverty, harnessing renewables and climate change mitigation policies.

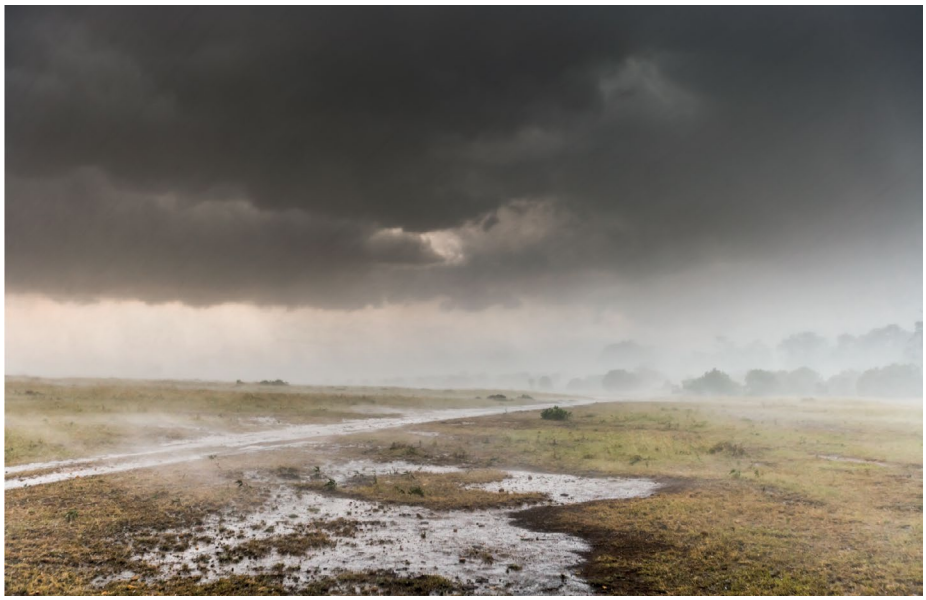
N'Datchoh Evelyne Touré is a climate and air pollution research scientist at University Félix-Houphouët-Boigny in Abidjan, Côte d'Ivoire. Her research focuses on aerosols from natural and anthropogenic origins and their impacts on the regional climate system and human health over West Africa. In addition to this, she is also interested in climate change and the induced impacts on extreme event occurrences in West Africa.

to increasing vulnerability is adopting climate-smart agriculture practices, which the Food and Agriculture Organization defines as "an approach that leads to increase in agricultural productivity, building resilience to climate change and reduces greenhouse gas emissions where possible." Adopting climate-smart agriculture practices is a possible solution, but it is challenging for smallholder farmers, as the complexity of their livelihoods, high-risk aversion and social embedment need to be considered.

When focusing on Kenya, agriculture is mainly characterized by smallholder farmers who own up to a few hectares, use minimal mechanization and inputs, and live at or near subsistence. In Makueni County, the communities that are made up predominantly of Kamba and Maasai mainly farm crops and keep livestock on the same plot due to limited space. By contrast, farmers in the Rift Valley grow cash crops such as tea and coffee on large tracts of land.

In Makueni County, many farmers combine crop production and animal husbandry with craft-making, seasonal trade and migration in search of wage jobs, an income diversification that makes them more resilient to climate risks. In addition, smallholder farmers also tend to be highly risk-averse, as they often only have limited resources to respond to stresses such as failed rains and prolonged dry spells.

Smallholder agriculture is deeply socially embedded and is about much more than the mere production of food. For example, in Makueni County, the people in villages mobilize a group of local community members to help



single-headed households with land preparation and harvesting at times of oncoming rains. For water projects, the community joins in to offer local materials such as sand, stones and labour to construct sand dams and earth pans. The diversified and networked nature of their livelihoods is an effective risk management strategy. Still, it can directly connect distant shocks to local agricultural and livelihood systems, as seen during the food price spikes in 2008.

Smallholder agriculture, as an aspect of rural livelihoods, serves to structure social orders at equitable scales from the household to the ethnic group and encompasses various roles and responsibilities in a family, community and broader society. These roles and responsibilities are often quite durable as they are passed along generations and shape decisions about climate-smart practices. When a farmer restores land with terraces, the neighbours and subsequent inheritors must continue this tradition lest they risk losing soil to the erratic rains caused by climate change.

As these examples show, the diverse and networked practices of smallholder farmers serve a multitude of functions in their communities. Therefore, it is crucial that any attempt to promote climate-smart agriculture practices identifies and honours these realities of farmers' livelihoods if a long-term, sustained adoption of a modified approach to agriculture is to be achieved.

Jean Hounkpè: challenges in investigating hydroclimatic extremes

Changes in hydroclimatic variables such as rainfall in response to greenhouse gas emissions have been detected with a good level of confidence in many parts of the world, but these changes remain uncertain over Africa. The main reason for this is that Africa has a less well-developed observation network than other continents. This problem is exacerbated by a huge and constant decline in the number of observation stations fully meeting the standards set by the World Meteorological Organization. The percentage of stations on the continent in line with these standards dropped from 57% in 2011 to 22% in 2019, due mainly to accessibility issues, conflicts and lack of investments, for example. This calls for urgent actions for maintaining and densifying existing networks in addition to using new observation technologies offered by remote sensing.

Another issue is the limited performance of climate models in reproducing observed hydroclimatic extremes, which has been widely demonstrated, even in data-rich areas. These limitations propagate in the projected hydroclimatic extremes by increasing the associated uncertainties. These uncertainties are even more important in regions such as Africa, where climate models do not agree on the directions in mean precipitation for most parts of the continent. Improving both short-term forecasting and medium- to long-term future projections of hydroclimatic extremes is one of the greatest challenges facing researchers in this field in Africa.

Focusing on West Africa, the region has been experiencing devastating flood events since 2000, following the great drought that started in the 1970s. For instance, the mean occurrence of floods per year in West Africa between 1966 and 1999 was 3, but this number rose to 12 per year between 2000 and 2017, with very high human and economic damages. In this context, it would be sensible to question whether the current scientific literature on this region provides solutions for mitigation and flood prevention efforts. With the changing climate, stationarity in hydroclimatic variables is dead and several publications in West Africa have confirmed this fact. This implies a need to revise the hydrological standards for building flood mitigation infrastructures. Apart from a regional initiative conducted by the World Meteorological Organization, research on the development of new hydrological standards is very rare in West Africa (which is also likely to be the case in other parts of the continent). It is, therefore, legitimate to call for further investigation on this aspect.

Another important aspect is that flood response in Africa is primarily a post-disaster response, despite the existence of several flood forecasting systems at the global, regional and national levels. Notwithstanding the uncertainties linked to flood forecasting, its effective consideration in the flood risk management cycle, to aid preparedness, would substantially reduce flood damages. Given that the cost of inaction might exceed the cost of taking early action, translating research outputs into action in Africa is crucially needed.

Nadia S. Ouedraogo: the potential of natural gas for a just energy transition

Despite being responsible for less than 5% of global greenhouse gas (GHG) emissions, Africa will definitely be part of the fight against climate change. Nonetheless, Africa cannot follow the same path towards clean energy as the rest of the world, and needs pragmatic solutions.

When compared with other regions of the world, Africa has by far the highest prevalence of energy deprivation. Today, nearly half of Africa's population, or about 580 million people, lack access to electricity. Despite progress over recent decades, the COVID-19 pandemic has reversed the continent's positive trend, increasing the lack of access by 2%. Furthermore, around 900 million people still lack access to clean cooking technologies and fuels. The switch from inefficient and polluting energy sources to more efficient options, which is required for climate change action, must take care to stimulate rather than hamper the region's development.

Even though it also contributes to GHG emissions, natural gas can play an important role as a transitional fuel for the continent.

Its use in power generation will allow African countries to phase out more polluting fuels such as heavy fuel oil, diesel or traditional biomass, while gradually incorporating more renewables in their energy systems. This combination of replacing old fuels and expanding renewables could limit the climate impact on the much-needed increase in energy access.

In terms of GHG emissions, macroeconomic-level modelling work shows that achieving universal access to energy using the same energy mix as in 2015 would only increase continental GHG emissions from 1,067 million metric tons of carbon (MtC) in 2020 to 1,827 MtC in 2040. Replacing currently used fuels by natural gas would reduce this relatively small increase further. In comparison, China's current GHG emissions exceed 12,000 MtC, while those of the United States and the European Union exceed 5,000 MtC and 3,000 MtC, respectively.

These numbers show that natural gas can help to ensure energy access across the continent, with comparatively small impacts on global GHG emissions. They also show that despite the important role natural gas has in the energy transition in Africa, it cannot serve the same purpose in other regions, in particular the Global North, which currently has much higher emissions. An undifferentiated uptake of net-zero targets across all countries in Africa would therefore deny Africa the chance to use its own gas, thus compromising its potential for industrialization and development.

Many challenges exist, including sparse data in many regions, a lack of substantive international assistance and a reluctance of the global research community to acknowledge the role that gas can play for the continent. More efforts in evidence-based analysis and improved modelling work are needed to explore pathways of decarbonization for the continent, which is crucial to allow research to be translated into action for Africa's shift towards more sustainable and climate-resilient development.

Sintayehu W. Dejene: linking crises in climate, biodiversity and ecosystem services

Africa is immensely rich in biodiversity and contains an estimated one-fifth of all known species of mammals, birds and plants, as well as one-sixth of reptile and amphibian species. The past decades highlight that climate change poses major threats to biodiversity, ecosystems and ecosystem services in Africa, with impacts expected to increase. Scenarios predict fast-paced extinction of species, loss of natural habitats and ecosystem services, and shifts in the distribution and abundance of species during the twenty-first century. For example, climate change affects the distribution of the endemic Ethiopian wolf (*Canis simensis*) and the African elephant (*Loxodonta africana*) by reducing the amount and availability of suitable habitats. Similarly, climate change induces habitat expansion of invasive species such as the shrub *Prosopis juliflora*, which suppresses the growth, availability and quality of palatable plant species.

Loss of biodiversity as a result of climate change can alter the structures and functions of African ecological systems. As a result, the provision of biodiversity-based ecosystem services, such as the supply of feed for livestock, is negatively affected, threatening the well-being of pastoral people that rely on these services. This is of particular concern in Africa, where local livelihoods often depend on goods and services provided directly by ecosystems. For instance, wild food plants are important for the diets of millions of people and contribute to food security, especially in rural and low-income communities, but the ranges of at least some of those species, for instance *Combretum engleri*, *Euphorbia inermis*, *Grewia schinzii* and *Searsia horrida*, are projected to decrease. What is called for in responding to these changes is less of the usual piecemeal approach and, instead, for people from different disciplines and regions to work together to increase the resilience of biodiversity and ecosystems that provide critical sustainable ecosystem services.

It is encouraging that researchers understand that incorporating the impacts caused by climate change is a critical aspect for sustainable development on the continent. Still, despite the expansion of data sources and research, many key questions related to climate change — in terms of biodiversity, ecosystems and ecosystem services — in Africa remain unanswered. Therefore, it remains unclear to what degree current and planned management strategies are able to reduce future climate impacts.

Furthermore, there is a paucity of research dealing with the interactions between different drivers of global change. So far, most studies have only focused on single aspects (mostly either climate change or habitat loss) and interactions are largely neglected in assessments under global change scenarios. We also have limited knowledge on the potential positive feedback effects of the current approaches to increase the resilience of biodiversity and ecosystems in the future. This means that increasingly deep and integrated multidisciplinary cooperation is both required and anticipated in the coming decades.

N'Datchoh Evelyne Touré: climate versus health impacts of aerosol mitigation in West Africa

Atmospheric aerosols are an important atmospheric component impacting the climate in many regions, including West Africa. For example, natural aerosols such as dust from the Sahara and Sahel region have been found to interact with the West African Monsoon system, weakening its penetration over land while also cooling surface temperatures. Besides

these natural aerosols, West Africa is also characterized by large emissions of anthropogenic air pollutants from sources such as solid fuel used for cooking, charcoal making, traffic, open waste burning and flaring. These particles can interact with local weather systems, for example by being transported by the atmospheric circulation to remote places or by impacting precipitation.

The current rapid urbanization growth in Africa is associated with a substantial increase in anthropogenic aerosol emissions of more than 80% between 1990 and 2015. This increasing trend in anthropogenic aerosol emissions is projected to continue if no measures and policies are put in place.

Besides their impacts on climate, atmospheric aerosols have substantial health impacts. This is particularly true in heavily polluted regions, such as the dust source regions and cities. The lack of access to clean energy for cooking is an additional cause for health burdens, disproportionally affecting women and children. As such, Africa is not only vulnerable to changing rainfall patterns, rising temperatures and increasing extreme weather events due to climate change, but also to air pollution effects, causing more than a million deaths per year.

As aerosols are transported to remote regions and affect larger weather systems, their effects on air quality and climate need to be assessed at both local and regional scales. One factor slowing this multiscale understanding is that air quality measurement and monitoring networks are still sparse across much of Africa. The current use of low-cost devices that are easy to install and maintain offers a good opportunity to collect more data and information about air quality and atmospheric aerosols to better understand their impacts.

Some studies comparing the health benefits of reducing aerosols against their cooling effect on climate underlined that the health benefits of reducing aerosol pollution outweighed the health benefits of aerosol cooling in East Asia, North America and Europe. Such studies are still lacking in Africa, even as countries are gradually implementing air quality policies such as fuel quality improvements or regulation of imported, used-vehicle ages. Better understanding ways to reduce air pollution and the effects this has on atmosphere dynamics will therefore be crucial, especially in West Africa, a region where populations are already struggling to adapt to climate change.

Olga Laiza Kupika: building resilient landscapes in semi-arid savannahs

Scientific evidence has proved beyond doubt that the climate is changing; we have a climate crisis that calls for emergency responses. One change that is particularly drastic in semi-arid savannahs is biodiversity and ecosystem services loss. In developing sustainable climate solutions, the most important question is: what are the best adaptation and mitigation actions that promote ecosystem recovery and resilience, while also balancing the need for society to accrue benefits from ecosystem services, and vice versa? To answer this, it is important to understand the key role of local ecological knowledge.

Efforts have been made to promote home-grown solutions with regard to climate research in Africa through availing grants and funding targeting climate research for development. Translating research into practice in the Global South is largely limited due to the lack of a framework for proper engagement and coordination between researchers and stakeholders in the community development space. One of the major challenges is the lack of coordination and networking among climate researchers in the Global South. This is linked to the lack of financing available to develop climate centres of excellence dedicated to capacity building and training towards locally driven research for home-grown solutions. Such centres can help to foster multi- and interdisciplinary studies, track climate initiatives and keep a record of databases.

Databases would provide baseline data to further understand and monitor factors influencing the complexity, diversity and abundance of vulnerable species and habitats in tropical savannah landscapes. For example, the phenology of *Sclerocarya birrea* (marula) and *Gonimbrasia belina* (mopane worms) is threatened by frequent drought. As these species have a high socioeconomic value, for example as livelihood-linked protein sources, this vulnerability requires close monitoring.

Advancing climate resilience in the Global South is also hindered by a lack of finance to support smart innovative technologies and to promote technology transfer, particularly transformational agro-ecological solutions. Participatory research recognizes the importance of local ecological knowledge, and this coupled with conventional science is critical to addressing the climate crisis impacting vulnerable communities. For instance, Indigenous people living on the edge of Gonarezhou National Park in southeastern Zimbabwe possess vast knowledge on medicinal plants that could be harnessed to promote agro-value chains for climate resilience. Similarly, promoting local knowledge on sustainable harvesting, conservation status and the utilization of edible riparian-based plant species is key to promoting drought resilience.

Still, current research programmes are carried out within a limited time period and funding, which does not allow for further engagement of vulnerable communities to allow the co-generation and co-development of research findings into practical solutions.

Providing scientific evidence on biophysical impacts of climate change is critical to ensure the sustainability of practical innovative solutions, thereby fostering resilience and recovery of ecosystems. Boosting funding and creating synergies between all actors — especially private players and development partners in the biodiversity conservation sector — is vital to translate research findings into community development programmes for resilience building.

Caroline Mwongera: climate adaptation progress and gaps in agriculture

The past two decades have seen an increasing interest in scaling-up climate adaptation to address the persistent and costly effects of climate change on cropland, livestock, forests and fisheries. The Sustainable Development Goals and the Paris Agreement have further heightened the urgency for holistic and integrated efforts to coordinate climate adaptation and transition to climate-resilient development in agriculture. The Paris Agreement establishes the global goal for adaptation by enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change.

African countries recognize the critical role agriculture plays in the global response to climate change. A common agenda is emphasized in various Africa-wide policies, including the 2014 Malabo Declaration, the African Green Stimulus Programme (2022), the African Union Climate Change and Resilient Development Strategy and Action Plan (2022–2032) and the African Union Agenda 2063. These policies underscore the need for the systematic integration of climate change responses into the planning and development of sustainable agricultural and food systems, mainstreaming climate and agricultural policies, strengthening institutional coordination mechanisms for robust monitoring and evaluation systems, and making communities climate resilient. In preparation for COP 27, the United Nations Office of the Special Adviser on Africa is advocating for an integrated approach to energy access and agriculture value chains and building climate adaptation through investments in agriculture-enabling infrastructure to minimize loss.

Climate adaptation efforts in Africa have made meaningful progress. The Consortium of International Agricultural Research Centers (CGIAR) Research Program on Climate Change, Agriculture, and Food Security and partners have developed tools and methodologies to identify context-specific climate challenges, identify and prioritize concrete actions, and evaluate lessons, successes and progress. Meanwhile, the Accelerating the Impact of CGIAR Climate Research for Africa (AICCRA) project enhances access to climate information services and validates climate-smart agriculture technologies in Africa. AICCRA's gendered outreach is bridging the gap in targeting and reaching women with customized climate adaptation technologies that address their interests. But with climate hazards increasing in frequency and intensity, adaptation responses are still limited. The CGIAR estimates that transforming food systems to thrive under climate change will need US$262 billion investment every year in sub-Saharan Africa, with the cost of inaction being far higher.

Adaptation action that corresponds to unfolding climate impacts and associated means of implementation founded on practical and comparable knowledge can help African countries work through the complexity of climate adaptation. In the process, there is a need to determine how best to scale-up approaches to improve targeting and effectiveness of adaptation finance (to support capacity building) and technology transfer (to support local communities to adapt). From a research perspective, approaches are needed to determine whether current climate adaptation responses are adequate and to further evaluate the conditions under which climate adaptation technologies can create positive or negative outcomes in agriculture and food systems.

Maha Al-Zu'bi: translating interdisciplinary research to scaled-up climate action

The Middle East and North Africa (MENA) is a climate change hotspot and a 'fragile' region for natural resources, where ensuring the sustainable planning and utilization of resources, particularly water and land, is critical. The region is characterized by a scarce and uneven distribution of resources and a growing demand, making it particularly susceptible to water, energy and food insecurities. Many of these challenges are intensified by the projected impacts of climate change.

It is critical to systematically investigate and understand the underlying interactions between natural resources management strategies and climate actions in the MENA region in order to contribute to more integrated policies, well-informed decisions and investment strategies, and resilient natural resources plans.

As a complex policy and governance problem, climate change in MENA cannot be tackled effectively by using traditional approaches. The complexity lies in the details and interactions among internal and external causal factors, social interactions, conflicting objectives and disagreements over the appropriate solutions. In addition, the perspectives of multiple organizations, stakeholders and end users are essential to ensure co-design and effective delivery of sustainable solutions. In the case of MENA, interdisciplinary research is therefore urgently needed to scale-up climate action.

In this spirit, a recently launched Consortium of International Agricultural Research Centers (CGIAR) Regional Integrated Initiative 'From Fragility to Resilience in Central West Asia and North Africa' entails a participatory and holistic approach to harness science-based solutions and to provide options for climate adaptation and mitigation that respond to the calls of, and are effective for, smallholder farmers in the region to scale-up the best solutions. This initiative is collaborating with cross-scale partners to test and upscale various climate-related innovations. These include nature-based solutions, resilient food and feed crops, weather-station-based irrigation advisory systems, scale-appropriate mechanization for dryland and irrigated systems, and farm-to-basin smart tools for water efficiency and management.

This CGIAR initiative that I am co-leading aims to overcome the challenges associated with scaling-up climate action through establishing and/or strengthening a national alliance of stakeholders, national innovation platforms, gender and youth accommodative and transformative research, innovation start-ups, digital tools and capacity building programmes. In the future, we hope to see more interdisciplinary initiatives like this one that will enable a better translation of research findings into climate actions in the MENA region.

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