Achieving Food Security under Climate Change

Policy Working Paper

November 2022

Key messages

- **A holistic approach** that recognises the need for climate finance, adaptation, loss and damage alongside climate mitigation is necessary to achieve sustainable food security under climate change.
- **The agricultural sector is one of those most vulnerable to climate change** while also being a major driver of greenhouse gas emissions (GHG). Food security in a world of climate change necessitates developing resilience to the effects of climate change as a risk multiplier, and a reduction in agriculturally related GHG emissions.
- **Data-driven approaches**, from precision agriculture and the use of artificial intelligence in agricultural production, to remote-sensing data to create integrated smart food and water management, can enhance the resilience of food systems under climate change.
- **Rapidly advancing biotechnological approaches** provide a mechanism to introduce or identify traits that introduce resilience to both biotic and abiotic stresses on crops from climate change. This will be possible only through fair access to genetic resources, sharing of benefits, mobilisation of resources and capacity-building in low- and middle-income countries.
- **Food security is underpinned by access to fresh water**, and climate change is increasing water scarcity in regions across the world. Developing smart water management practices that incorporate local, indigenous knowledge and are shaped to local conditions can help in addressing risks.
- **Agricultural extension services, citizen's science, social innovations, awareness-raising and engagement** with civil society institutions, women's groups, NGOs, and policymakers and local communities can support addressing climate change impacts on food production. Gender imbalances, economic inequality, and inequitable food distribution all shape access and attitudes to food and nutrition and must be considered in policies to facilitate behaviour change towards greater food security.
- **International collaboration to improve global food security** in a changing climate will need to minimise food loss and involve co-created, place-based initiatives that account for vulnerabilities and lack of access to nutritious food at sub-national and local scales, and which support investment in both new technological approaches and in-country capacity-building.
- **Integrating a focus on sustainable food systems into countries Nationally Determined Contributions (NDCs)** as part of the Paris Agreement and in National Adaptation Plans can enable more joined-up actions to build resilience to climate change in food systems alongside reducing emissions from the sector.
- **Climate change impacts on food production present risks to agricultural trade**, which can amplify food insecurity. Multilateral coordinated responses through international bodies like the World Trade Organization (WTO) can help facilitate global food security under climate change through use of the international standards and guidelines.

Introduction

Climate change is disrupting agriculture and food production across the world. The agricultural sector is one of those most vulnerable to climate change, with risks from extreme weather events and increasing global temperatures impacting biodiversity, land degradation, desertification, rising sea levels and water scarcity. All of these present risks to food production, food supply chains and trade, with economic and social impacts on lives and livelihoods, and overall food security.

Climate change will impact food security through causing a lower nutritional quality of crops used for food and feed and changing distributions of diseases and pests, which affects food production negatively. Ocean warming, acidification and coral bleaching are harming aquaculture and fisheries, and global warming is affecting soil health and ecosystem services such as pollination.[1]

Countries in the Global South are particularly vulnerable to food insecurity and reduced water security, and within those countries, rural communities face even greater risks from their decreased ability to adapt. At 2°C of global warming, food security risks will lead to malnutrition and micro-nutrient deficiencies concentrated in Sub-Saharan Africa, South Asia, Central and South America and Small Islands.[2]

At the same time as the agricultural sector faces major risks from climate change, it is also a major driver of climate change itself. The Intergovernmental Panel on Climate Change (IPCC) estimates that 22% of global greenhouse gas emissions (GHG) from human activities stem from agriculture, forestry and other land use.[3] If emissions associated with pre- and post-production activities in the global food system are included, the IPCC estimates that the agricultural sector could account for 21–37% of total net anthropogenic GHG emissions.[4]

As such, food security policies in a world of climate change will need to be developed around two strands: resilience to the effects of climate change, and a rapid reduction in agriculturally related GHG emissions. Against this background, there will be an extra two billion more people to feed in the next three decades, with little further agricultural land to produce food without impact on biodiversity and the production of further GHGs.

Aligning and integrating adaptation and mitigation actions for the agricultural sector will be essential in food systems to build resilience to climate change, reduce their contribution to greenhouse gas emissions, reduce waste, increase sustainable consumption patterns, and integrate climate and biodiversity considerations into food choices.

While mitigation of emissions from the agricultural sector is essential to create a climate-safe world, this paper specifically will focus on exploring some aspects of resilience-building to climate change in food systems in a global context, setting out risks and actions towards addressing these risks.

For the upcoming COP27 Presidency and international climate negotiations in 2022 and 2023, Egypt can play a key role in emphasising vulnerabilities to food insecurity in low-and-middle income countries. In Egypt, the effects of high temperatures and Mediterranean Sea level rise on agricultural lands in the delta could lead to a loss of 15-30% of the agricultural land area, in addition to increased land salinity, exacerbated by the intensification of agriculture, which will subsequently lead to a decrease in agricultural production.[5]

In the context of COP27 being hosted in Egypt in 2022, this paper will draw in a focus on Egypt as a case study throughout to exemplify the risks to food security faced by low-and-middle income countries.

Climate change risks to agriculture and food production

Climate change is a risk multiplier across the food system. For regions which already experience warm conditions, the negative impacts on crop productivity, livestock health, pest and disease prevalence, and food safety risks will be exacerbated as a result of future climate change.

The exact impacts will depend on future emissions, with the IPCC's Sixth Assessment Report (AR6) highlighting that areas for current crop and livestock production will increasingly become climatically unsuitable under a high emissions scenario . Climate change is already impacting agriculture in some of the following ways[7]:

Crops: In some mid and low latitudes, productivity growth in the three major staple crops (maize, wheat and rice), has slowed, and in some cases reversed, as a consequence of climate change over the past 50 years.[8,9,10] The suitability of crops for specific areas is projected to shift significantly[11,12], with up to 10% of land currently suitable for agriculture potentially becoming climatically unsuitable by mid-century. This effect will be accelerated and more expansive if emissions are not reduced rapidly.[13]

Livestock: Climate impacts on crop growth and pasture and rangeland conditions has affected the productivity of livestock in agricultural systems in some regions[14], as has increasing heat stress[15], reduced access to water and changing disease risks.[16] For example, more frequent high temperatures can have negative impacts on livestock productivity, fertility and susceptibility to disease.

Pests and diseases: Climate change is altering the distribution and abundance of pests and diseases, affecting agriculture and food systems, causing stresses on crops and livestock, as well as human health.[17,18]

Irrigation and water resources: Impacts of more frequent droughts and depleted water sources are evident in agricultural systems across the globe and are being exacerbated as extreme weather events become more frequent.[19,20] High intensity rainfall events are also likely to become more frequent, increasing the risk of flooding and causing higher soil erosion rates, potentially leading to poorer water quality.

Assessing risks to food systems

The ramifications of climate change for food systems are intricate and nonlinear[21,22,23] and as such require assessment through the lens of a comprehensive and integrated risk framework. An initial step toward such a framework is to recognise **biotic** (relating to living entities) and **abiotic** (relating to physical entities) risk pathways and systemic vulnerabilities.

Assessing biotic risks to food systems involves considering pests and pathogens threatening crop yields and livestock, and assessing abiotic risks involves changes in factors such as soil conditions and weather extremes like heat waves or rainfall. An integrated analysis of these risks can lead to a greater understanding of the impacts climate change is expected to have on plants, livestock and food systems as a whole, including through infectious plant diseases such as the spread potential of plant pathogens[24] and pests[25], heat stress[26], drought and dry spells[27], floods[28] and frosts, and degradation of soil biota.[29]

In exploring these risks, it is important to incorporate an assessment of prior, pre-existing vulnerabilities in food systems and societies, as conventional food systems are innately susceptible to multiple, unmitigated and chronic stresses[30,31], even without accounting for climate change. Additional attention should be given to converging biotic-abiotic risks that may act as risk multipliers.[32]

Technologies for building resilience in agriculture

Responding urgently to the risks climate change poses for food security necessitates rapid implementation of proven solutions. The success of so-called 'climate-smart' approaches[33] draws on elements such as improved access to precision farming, land management and breeding technologies combined with approaches that recognise local needs, knowledge and contexts.

However, as climate change intensifies, new tools and understanding are also required to develop longer-term solutions. Both researchers and agri-food industry experts have a crucial role to play in both supporting the implementation of known solutions today, and in co-developing the new solutions to food and nutrition insecurity needed for the future. For example, further research on agro-ecology is urgently needed.

Data-driven approaches

Smart agriculture: Food systems resilience can be improved by enhancing risk prevention, preparedness and response, as well as by increased efficiency and resource utilisation, through deploying information and communication technologies in farms, and along agri-food supply chains.

This is often referred to as '**smart agriculture**' or 'precision agriculture'[34,35], a data-driven approach where artificial intelligence (AI) systems operating in real time use sensors to perceive their environment and follow an objective function.

Artificial intelligence could support rapid plant phenotyping, farmland monitoring, analysis of soil composition, plant and livestock disease diagnosis, precise allocation of agro chemicals, forecasting weather and movement of pest populations and predicting yield, and new methods for post-harvest handling, traceability and transparency.[36,37]

However, the smart agriculture approach is not risk-free. Challenges include reliability and relevance of agricultural data, potential unintentional ecological complications resulting from autonomous systems optimised for yields, as well as safety concerns for farms and farmers associated with deployment of AI at scale.[38]

Remote sensing data: Remote sensing data allow frequent monitoring of agricultural resources and crop performance. Earth Observation (EO) technologies, in particular spaceborne sensors, can provide these data in real time and at different scales.

In Egypt, recent research used remote sensing to track vegetation changes in Fayoum and calculate modern water demand for irrigation.[39] Such information can be supplied to policymakers, irrigation managers and farmers and used alongside ground-based sensors as part of a more integrated smart agriculture system to enable effective water management policies for food production.

A number of initiatives exist to coordinate EO data sources and promote their uptake for the purposes of sustainable development, including the Committee on Earth Observation Satellites (CEOS).[40] The African Union is in the process of establishing an African Space Agency, based in Egypt, which aims to, among other things, use Earth Observation to develop agriculture.[41]

However, global satellite and remote-sensing data and models can be difficult for low-and-middle income countries to utilise given limitations in the technical skills and expertise required to gather, process and publish data.

Considerable progress is still needed to increase the uptake of remote sensing opportunities worldwide[42], in particular the integration of different sources of geospatial and statistical information, such as in integrating satellite data with the ground-based sensor networks used for 'smart agriculture'. It would also be beneficial to utilise standardised approaches to monitoring and through the provision of analysis-ready data, already part of ongoing initiatives by major space agencies.

Biotechnological approaches

Research and deployment of biotechnological approaches can support improving crop quality and yields as well as enable greater resistance to pests, diseases, heat and drought.[43]

Genetic approaches: Genetic modification, in which a gene or genes from related organisms are introduced into the plant of interest, or genome editing, in which highly targeted changes are made to an organism's existing genes, can provide faster and more precise methods for crop breeding[44]. However, there is not universal public acceptance of these approaches in many parts of the world.[45]

Genomic approaches: Genomic approaches offer a less controversial approach than genetic modification or gene editing. Genomes from varieties of plants or animals can be relatively rapidly sequenced and, through bioinformatic approaches coupled in some cases with AI, genetic markers associated with desired traits can be identified and used for fast-tracking breeding, known as Marker Assisted Breeding (MAS).

This approach can help achieve greater sustainability in the food system. For example, since the Green Revolution, much of the genetic diversity in wheat used in current varieties has been lost.[46] Sequencing of pre-Green Revolution seed stocks could unlock increased resilience to biotic and abiotic stress, with it being possible to use MAS to incorporate just the genes conferring resilience from the ancient species into modern cultivars so that the yield gains achieved post-Green Revolution are not lost.

Increased yield can be met by increasing the efficiency with which plants absorb nutrients from the soil to reduce application of energy-intensive and polluting fertilisers. The gene products that are responsible for regulating nutrient absorption and for water flow through plants can be identified and harnessed from ancient crop varieties to enhance sustainability.

Nutritional value can also be improved through biotechnologies. The genes that are responsible for healthier carbohydrates are now being discovered[47], as are those that mobilise essential micronutrients such as iron and zinc can be deployed to edible parts of crops.[48,49] However, care should be taken to address the question of bioavailability, as micronutrients that are important for human health cannot always be digested and absorbed by the human gut when the plant is consumed.

Genome mining could help build resilience to pests and pathogens. Heat and drought, however, present more challenging issues since these are usually multigenic traits. A combination of bioinformatics and AI could help identify the relevant genetic characteristics to enable rapid and directed breeding of modern-day crop varieties.

Changing water use practice

Irrigated agriculture represents over 70% of global water use[50], mainly comprising rainfed cultivation with supplementary irrigation from the ground water, and irrigation from surface sources. Food security is underpinned by irrigation, however water resources are increasingly under pressure due to climate change and unsustainable development.[51] In particular, North Africa and Asia are experiencing frequent droughts combined with water stress. To achieve water and food security in the face of these challenges, changing water use practices are needed.

Water management strategies should be tailored to their local environment and take advantage of new agro-management technologies as well as indigenous approaches. Drip irrigation, water recycling and night irrigation to reduce evaporation all increase efficiency. Water harvesting, pastureland management and equitable water tenure rights all require consideration as well.

In Egypt, 95% of water availability is from the Nile, making it important to protect the supply of Nile water at both national and international levels. In many countries, including Egypt, drainage is also needed in order to prevent salinity.[52]

A significant proportion of water can also be lost at the farm level. Water storage and soil moisture conservation can reduce vulnerability, and pumping technologies can be electrified (including using solar power) to improve efficiency and reduce costs and emissions. In Egypt, the irrigation improvement project saw diesel pumps replaced with electric pumps, reducing energy and maintenance costs, and open channels were replaced with covered channels and pipes. Farmers now receive 85% of available flow, rather than 50%, and the saved water allowed for an addition of 3 million acres to agricultural production.

In Egypt, traditional water management approaches are also used effectively in some areas and could be revitalised elsewhere, such as the ancient technology of quanats used across North Africa, the Middle East and Asia to collect groundwater sustainably. Traditional technology and indigenous and local forms of knowledge should play an essential role in co-creating solutions to enable resilient water systems and addressing scarcity.[53,54]

Addressing risks for access to food and nutrition

Climate change has multiple direct and indirect impacts on nutrition and access to food. An estimated 750 million people are currently food insecure, a number which has been rising annually since 2014 in most regions of the world.[55] The double burden of malnutrition – the coexistence of undernutrition with obesity and diet-related noncommunicable diseases – is a growing problem in many low and middle-income countries.

Food insecurity is driven by factors such as social and economic inequality, poverty, geopolitical conflict, supply chain disruption, poor access to water and sanitation, and market shocks – which are compounded and exacerbated by climate change[56]. Cascading risk factors such as simultaneous crop failures, labour shortages, health crises and geopolitical disruption to supply chains in recent years have resulted in sharp increases in food prices.[57]

Low-income households in countries reliant on food imports, as well as groups dependent on fragile ecosystems, are the most vulnerable to these impacts. Indigenous peoples, ethnic and religious minorities and women face exacerbated vulnerability, particularly in contexts where they have marginalised political voices or limited access to and ownership of resources.[58,59] As such, actions to increase food security and nutrition in a world of climate change must place considerations of equity at their core.

Information-sharing for enhanced nutrition

National adaptation plans to tackle food insecurity will need to avoid policy silos to ensure the complex relationship between nutrition and sustainability can be addressed.[60]

Gender imbalances, poverty, inequitable food distribution, unequal land and water tenure and lack of community-level guidance on nutritious diets all shape access to food and must be considered in policies to facilitate behaviour change towards greater food security and must involve processes of co-creating solutions and their delivery with the people who will utilise them on the ground and in local communities.

One approach to addressing lack of access to nutritious food is the development of climate-focused nutrition maps that can help governments address regional nutrition disparities; crop cultivation gaps, and income disparities, as well as improve the distribution of local produce more effectively while helping farmers adapt to climate change.

Data collection and adaptation programmes can be participatory in nature to ensure that the solutions provided are practical and accommodate the smallholder farm resource limits. Such an approach could also allow governments to expand climate and water smart agriculture practices with a sharper regional focus, further "climate proofing" agriculture.[62]

Domestic agri-stocktaking and data collection can provide an overview of the impacts that agriculture and social welfare policies have, opening up a transparent feedback loop. Such data impetus will be essential considering the impacts that growing climate insecurity has on trade agreement negotiations, resulting export bans, and geo-politics – all critical levers of the global food supply chains.[63] Disruptions in this supply chain have already impacted the budget, commodity prices and food stockpiles in countries like Egypt.

Case study: Mapping food and nutrition risks for behaviour change

The Indian government is promoting high-nutrition and agriculturally diverse crops at the local level using 'nutritional informatics'.[64] The 'Poshan Atlas' (nutrition atlas) maps regional and food crops across the country, with an emphasis on creating consumer awareness of the nutrition content of their food choices.

The database is open-access and utilised in decision-making at the policy as well as the household level. It allows the government to identify which regions need priority intervention and funding and is used to shape community food choices through regionally focused diet charts, a health tracker tool and food preparation guides.

In addition, India is using this map to revive crops that have been historically displaced by the Green Revolution crops. These displaced crops were more nutritious, naturally heat-resistant and had smaller water footprints.

A nutrition atlas approach could serve as a model for countries in the Global South seeking to develop their own data sources to nudge policy or crop production patterns that help address growing climate vulnerabilities. Such tools can also support rural and marginal communities who are more likely to struggle to adapt to the changing circumstances.[65]

Enabling food security through policies and institutions

Enabling greater climate change resilience in agricultural systems, for farmers and workers and in improving access to nutritious foods requires enabling institutional environments that support sustainable change. Policies and institutions that can support inclusive, whole-system and multi-sectoral design and implementation of adaptation plans for food systems both in countries and through global cooperation will be most effective.

International collaboration

International collaboration is at the centre of efforts to improve global food security in a changing climate, with governments increasingly instigating platforms and programmes that go far beyond one-way technology and information sharing, and instead involve co-created, place-based initiatives that can deliver lasting impact at sub-national and local scales.

These range from research-led programmes such as the Pest Risk Information Service[66] which combines weather data, computer models and local crop monitoring to give farmers early warning on pest and disease attacks[67], to UN FAO-led initiatives such as 'Farmer Field Schools' where farmers share good practice and can access focused advice and support.[68]

Generating focussed multilateral investment for innovation in climate-smart agriculture and, crucially, ensuring this is matched with investment in human capital and in-country capacity, is likewise a core tenet of international collaborations to achieve greater food security.

South-South and regional collaborations are also important in delivering effective knowledge and technology transfer to underpin food security in a changing climate. Common markets, production methods and, often, climate risks too, mean that shared learning and implementation of solutions can be more efficient, effective and sustainable.[69]

Integrating mitigation and adaptation actions

Incorporating food systems transformation measures into countries' Nationally Determined Contributions (NDCs) for delivering the Paris Agreement can help deliver emissions reductions alongside resilience-building across food production, consumption and waste supply chains, together with delivery of the necessary domestic and international finance. National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs) can also be better integrated to achieve both food security and emissions reduction from the agriculture sector.

Land use change from adoption of renewable energy projects and carbon sequestration projects will need to be considered carefully at both national and international scales and are considerations in low-and middle-income countries where pastoralists, local farmers or indigenous people may be forced away from land to make way for mitigation projects.[70,71] Integrating renewable energy projects with cultivating specific crops, such as in agri-solar farms, in collaboration with local communities and farmers, can deliver climate change mitigation simultaneously with agricultural sustainability measures while ensuring land rights and access for those reliant on the land.[72]

The agricultural sector itself will also need to decarbonise to reduce global emissions. This will involve enhancing energy efficiency and increasing the use of renewable power. IRENA and FAO signed an agreement in January 2021 to accelerate the deployment of renewables in the agri-food, fisheries and forestry chains, and in sustainable bioenergy[73], and domestic governments such as Egypt are set to implement this within their territories.

Due diligence, environmental regulations and stakeholder participation will need to be carefully designed and implemented to consider the whole water-energy-food nexus. Thought needs to be given, for example, to more legume crops which do not need application of energy-expensive nitrogen fertilisers and which are a rich source of non-animal protein.

Supporting agricultural workers

As the viable climate for specific production practices changes, farmers (and especially smallholder farmers) will need ongoing help to ratchet-up resilience and secure their livelihoods.

Enhanced provision of 'climate services', such as education, finance and training, is a prime target for helping to deliver such sustained improvements in adaptability and resilience. In addition to improving knowledge and advice in areas such as growing practices and strategic planning, these farmer-level support systems can open up opportunities to new markets, secure better prices, and embed core resilience services like crop insurance.[74,75]

Without such mainstreamed capacity-building there is a risk that climate and/or market shocks will undermine or even destroy many farming livelihoods, weakening the agriculture sector and exacerbating issues such as climate-induced migration.

Markets

In addition to everyday challenges facing international trade, climate change is increasing the risks of complex events such as pandemics and geopolitical crises and increasing the pressure on agricultural commodity trade, which could increase volatility and threaten the stability of commodity markets.

The high potential negative impacts on commodity production around the world drastically reduce the space in which actors can diversify and replace agricultural commodity trade risks. This creates an urgent need for multilateral cooperation to confront rising risks and develop effective and coordinated responses.

In June 2022, the World Trade Organisation adopted a ministerial sanitary and phytosanitary declaration, which recognised the important role of the SPS Agreement in responding to modern SPS challenges, including climate change and food security, and zoonotic diseases. The SPS Agreement will address such issues as how to facilitate global food security and more sustainable food systems through the use of international standards and guidelines.

While such international cooperation can play an important role in addressing food insecurity, changing trade policies are unlikely to provide sufficient adaptation potential to risks, given the many trade-offs involved. However, policies to limit trade restrictions on agricultural products, alongside widening markets and enabling self-sufficiency in domestic agricultural sectors in low-and-middle income countries can help support increased food security.

Changing subsidy schemes

The cost of nutrient-dense food in low- and middle-income countries can stretch the food budget which may form a big part of household income, and as such lead to food intake of less nutrient-dense food in favour of food that is calories-dense.[76] Re-orienting fiscal support through targeted subsidies and social protection mechanisms can help ensure access to nutritious foods.[77]

Current agricultural subsidy schemes can have negative impacts on food systems by leading to over-production of a specific commodity and malnutrition from incentivising production of staples instead of fruits and vegetables. Emission-intensive commodities (e.g. beef, milk and rice) are amongst those receiving the most support worldwide, despite the health risks and negative impacts on climate change mitigation they present.[78]

Redirecting public resources towards low-emission and sustainable farming practices and food consumption habits could help address food insecurity and lack of access to nutritious food. However, this must be done through a whole systems approach that accounts for difficult trade-offs, recognising that agricultural subsidies often offer consistent income to agricultural workers and reduce the need for food imports.

In Egypt, the Ministry of Agriculture and Land Reclamation sets production targets for key strategic crops.[79] To ensure self-sufficiency, the government subsidises nitrogen fertiliser. However, this has led to risks of overutilisation, adversely affecting soil, water and environmental health. Reallocation of subsidy funds to smart instruments and technologies that assist farmers to apply optimal levels of fertilisers could help avoid such damaging impacts.[80]

Similarly, as Egypt relies heavily on imported wheat the Egyptian government subsidises farmers to increase wheat production to enable food security. However, concerns exist that Egypt's large food subsidy system has been ineffective in reducing undernutrition.[81] Aligning subsidy policies with sustainable food production and nutrition policies can enable a better use of allocated funds and fill gaps in the production of healthy, sustainable and affordable foods.

Looking ahead to COP27

This report has identified some key challenges and approaches to address the impacts that climate change is having on food production, and the ways in which food production is driving climate change. As we look ahead to COP27 in Egypt, governments across the world have a key opportunity to embed considerations of ensuring food security more firmly into discussions of how to plan and implement ambitious climate action.

Such discussions will need to recognise the specific vulnerabilities of low-and-middle income countries in the Global South to food insecurity, and the need for international financial and capacity support to enable greater food systems resilience.

The Paris Agreement emphasises the need to scale up and distribute financial resources to achieve a balance of finance for both adaptation and mitigation, with a particular emphasis on adaptation finance for the nations that are most vulnerable to the harms caused by climate change impacts.

This goal is still far from reflected in the current reality of climate finance support. The UNFCCC Fourth Biennial Assessment and Overview of Climate Finance Flows sets out that support for adaptation has stayed between 20-25% of committed concessional finance from all sources, while support for mitigation has remained a much larger share of climate finance. (insert reference endnote number 82)

For this reason, high-income countries committed at COP26 to double climate finance for adaptation by 2025. COP27 must see progress on this goal, and on wider efforts to facilitate climate finance that can support countries in the Global South to ensure food security for all in the face of climate change.

Acknowledgements

This policy paper has been produced by the Academy of Scientific Research and Technology in Egypt, with contributions from the UK Universities Climate Network. Contributors have been listed in alphabetical order:

Prof. Ayman Abou-Hadid, Ain Shams University, Egypt; Dr Kamya Choudhary, Grantham Research Institute at LSE; Prof. Adel El Beltagy, Ain Shams University; Prof. Ahmed Magdy Gabr, Academy of Scientific Research and Technology; Dr Chamu Kuppuswamy, University of Hertfordshire; Dr Edward Pope, UK Meteorological Office; Dr Louise Rayne, Newcastle University; Prof. Dave Reay, University of Edinburgh; Prof. Mahmoud Sakr, Academy of Scientific Research and Technology; Prof. Dale Sanders, University of York; Prof. Mohsen Shoukry, National Research Centre, Egypt; Dr Asaf Tzachor, University of Cambridge; Dr Stephen Whitfield, University of Leeds; Prof. Sahar Zaghloul, National Nutrition Institute, Egypt.

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