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Perspectives on climate change in South Asia

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Home to roughly a quarter of the world's population, South Asia is a hotspot for global warming impacts. In this Viewpoint, nine researchers from South Asia discuss the progress made in understanding and responding to climate change in the region.

South Asia is characterized by a large diversity of landscapes, ranging from high mountain areas to tropical islands. Consequently, the region experiences almost every possible consequence of climate change, from glacial outburst floods to heatwaves, droughts and fires. This variety in impacts, combined with a large diversity of social, economic and cultural contexts, also means that the responses to a changing environment are often locally specific. In this Viewpoint, local researchers discuss what they see as the most pressing science questions on mitigating and adapting to climate change in their scientific fields and in their regions. They highlight that South Asia has seen substantial progress in understanding the impacts and developing responses to global warming and argue that more communication between scientists and decision-makers and collaboration between actors and across borders are key to respond to these challenges.

Shree Raj Shakya: advancing equity and resilience in clean energy transitions

South Asia is undergoing rapid socio-economic transformation, with urbanization, industrialization and rising living standards contributing to a steep increase in energy demand. This demand is still largely met through imported and emissions-intensive fossil fuels, exposing the region to price volatility, energy insecurity and greenhouse gas emissions. At the same time, South Asia is one of the world's most climate-vulnerable regions, making a resilient and inclusive energy transition not just desirable but essential.

The region is rich in clean and renewable energy resources such as hydropower in Nepal and Bhutan, and solar and wind potential in India, Pakistan and Bangladesh. However, the deployment remains limited. Electrification through renewables offers a sustainable path forwards but systemic barriers persist. The intermittent nature of solar and wind generation, for instance, calls for investment in energy storage solutions such as pumped hydropower, batteries and regional grid integration to ensure reliability. Cross-border power trade could play a pivotal role here yet remains underutilized.

In my own work, I've seen how decentralized renewable energy systems, such as solar photovoltaic microgrids replacing captive diesel generators in urban areas of Nepal, can deliver tangible co-benefits ranging from reducing ambient air pollution and greenhouse gas emissions to improving health and enhancing energy access. These local solutions can support national net-zero ambitions, but only if they are aligned with energy equity goals.

Energy access and affordability disparities across South Asia largely affect development outcomes and energy intensity. Without intentional strategies and financing to include marginalized populations, even the best-designed clean energy policies risk deepening existing inequalities. Many national strategies are ambitious on paper, but falter in practice owing to fragmented governance, weak institutional capacity and inadequate financing tailored to local contexts.

What is needed is a fundamental shift in how we approach clean energy transitions. This means working together with communities, testing new ideas through policy, monitoring progress through effective measurement, reporting and verification mechanisms, and using climate finance to support local needs and long-term solutions. It is also important for countries in the region to learn from each other and work together to make the most of their shared knowledge and resources. For South Asia to achieve a fair and inclusive clean energy transition, it must take urgent action that reflects the real needs and experiences of the people.

Rajiv Kumar Chaturvedi: climate mitigation in India through forestry

India is one of the most densely populated regions of the world and it is remarkable that it has been able to conserve a proportion of its forest cover and biodiversity. In the context of climate mitigation, it is thus critical to understand the combined impacts of climate change and anthropogenic pressures and how these factors might impact forests in the future. However, limitations in terms

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of the availability of long-term, ground-based ecological observations and other systematic ground observations restrict our ability to assess and model long-term impacts.

India enjoys strong public support for planting new trees and restoration and expansion of its forests, thanks to their promise of both negative emissions to help meet net-zero goals and co-benefits. However, despite their potential, our experience suggests that implementation of restoration projects on the ground faces a number of challenges, including access to specialized nurseries and financial constraints. One key challenge is the lack of access to an updated, high-resolution, publicly available land use, land cover (LULC) and land-use change dataset that helps stakeholders to identify priority areas for mitigation. Another challenge is the lack of a robust verification mechanism that could robustly track survival and mortality of trees and the overall status of the plantation over time. Finally, people are increasingly concerned about the possibility of devastating forest fires in their neighbourhoods, as well as increased fatalities from tree falls and tree decay. This sometimes causes scepticism against large-scale tree-planting initiatives, especially in and around settlements.

Overall, current mitigation actions are not adequately informed by research in the forestry sector. The importance of long-term, ground-based ecological observations and other field-based observations is increasingly recognized by all the stakeholders. To increase long-term, ground-based ecological observation sites, the Government of India recently launched the Long Term Ecological Observatories (LTEO) programme as a constituent activity of its Climate Change Action Programme. However, these observations need to be scaled up further, covering a diversity of land uses, ecosystems and carbon pools. Recent technological advancements such as near-surface observations (for example, PhenoCAMs), unmanned aerial vehicles and LIDAR can help India fill part of the data gap. Remote sensing-based data products coupled with sufficient ground-based observations could also help in the development of needed open-access LULC data platforms, as well as transparent verification mechanisms to oversee and track the fate of mitigation actions.

Forest-based mitigation currently sequesters about 5% of India's national total emissions. The forest carbon sink has a critical role to play in India's net-zero strategy going forwards; however, in addition to the challenges outlined here, possible weakening of the forest sink under a warming climate remains a concern.

Abhra Chanda: biogeochemistry must be integrated into mangrove conservation

Climate change manifestations, such as sea-level rise, changes in precipitation regimes and increased intensity of extreme weather events, threaten most South Asian mangroves. The Sundarbans, the world's largest mangrove forest, situated across India and Bangladesh, is a poignant example. The ecological vulnerability of these mangroves, which safeguard 8 million human inhabitants and provide them with livelihoods through ecosystem services such as fish, shrimp, honey and revenue from tourism, is further exacerbated by the salinization of estuaries, sediment starvation and coastal pollution.

The estuaries, acting as the arteries of mangrove systems, regulate water, nutrient and sediment flow, which is key to the physiological well-being of these mangrove floral stands. Research has unequivocally shown that these estuaries are suffering from rapid salinization, persistent organic pollutants, and heavy-metal and microplastic pollution. These combined impacts of climate change and anthropogenic drivers lead to mangrove retreat, top-dying disease of mangroves, deteriorating mangrove health and changes in species assemblages that compromise ecosystem services and jeopardize the overall blue carbon stock.

Most initiatives from local governments have remained confined to post-cyclonic-disaster plantation programmes aimed at compensating for mangroves destroyed or uprooted during storms. Lately, year-round plantation drives have also been taken up by some non-governmental and private organizations. However, in the long run, most of these endeavours fail, as the colonizing capability and longevity of these seedlings depend on estuarine and sediment biogeochemistry, which remain unaccounted for during the plantation drive. Attributes such as sediment load, salinity and nutrient dynamics are seldom considered before site and species selection in plantation programmes. The primary impediment to addressing this issue is the complete lack of systematic, real-time monitoring of aquatic biogeochemical parameters across this vast estuarine complex.

Despite a substantial volume of research on aquatic biogeochemistry in the Sundarbans, a lack of dialogue between the scientific community and policymakers hinders the achievement of climate goals. Logistical and funding constraints compel most academics to frame research that is short term, hypothesis-driven and based on discrete datasets. Acquiring and interpreting biogeochemical data, followed by framing actions based on them across a pan-Sundarban scale, requires substantial government initiative to monitor and build long-term datasets.

Public awareness through community science campaigns has become imperative. In the absence of this, topics such as eutrophication, ocean acidification and salinization remain esoteric to academia. The Sundarbans, shared by two neighbouring countries, require a homogeneous monitoring protocol to be established through proper diplomatic channels, ensuring the collection of long-term datasets and enabling researchers to model the future and, accordingly, propose courses of climate action, collectively for both nations, for the betterment of the Sundarbans.

Saadia Hina: tipping towards compound climate extremes in Pakistan

In Pakistan, climate change is no longer a future threat but an immediate and accelerating crisis affecting the socio-economic situation of the country. Once perceived as isolated events, climate extremes now appear in more rapid and often overlapping succession, including frequent heatwaves, flash droughts, precipitation extremes and related catastrophic floods. These are not anomalies, but part of a new, dangerous rhythm that is reshaping risk and vulnerability across the country.

As a climate scientist from this region, I have witnessed these extremes firsthand. What worries me most is not only the increasing frequency of these events but also their compounding nature. A single extreme event is hard enough to cope with, but multiple events occurring one after another have serious repercussions and the damage multiplies. Pakistan experienced one of the most striking manifestations of such successive climate extremes in 2022. This series of events started with a spring heatwave that triggered glacial melt, followed by a severe drought phase and ended with an unprecedented devastating monsoon flood that submerged one-third of the country by area, killing 1,700 people and displacing around 8 million others. In addition, the flood destroyed farmland and livestock and facilitated outbreaks of diseases such as cholera and dengue. These impacts were compounded by preceding heatwaves and droughts that exacerbated vulnerabilities in infrastructure, healthcare and socio-economic resilience.

In light of such new climate realities, the most pressing question of the day is how to anticipate, monitor and manage the changing impacts of compound extreme events in Pakistan. The traditional climate models for single-event forecasting are no longer sufficient, as they are unable to capture the complex interconnection of concurrent extremes. Therefore, various approaches designed for synchronous extreme events are much needed.

Despite the developments in climate extreme research in Pakistan, a substantial

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gap remains between research and action. Scientific findings often remain confined to academic or institutional settings, while communities facing the impacts lack access to timely and actionable information owing to several challenges. Primarily, poor coordination among meteorological departments, disaster management agencies, research and development sectors and policymaking institutions hampers adaptation strategies. Moreover, limited in situ meteorological data and high-resolution models also remain a challenge owing to financial constraints in a struggling economy.

The pace of climate change in Pakistan is outstripping institutional response capacities. However, targeted investments in human capital, scientific research and institutional systems can help bridge this gap. In an era of climate change-induced extreme events, resilience will not come from isolated responses but from collective, informed and inclusive action. Therefore, advancing integrated early-warning systems, fostering interdisciplinary research and enhancing collaboration among scientists, policymakers and communities are essential steps towards shifting from reactive to anticipatory adaptation strategies.

Chandni Singh: labour migration as climate change adaptation

The impacts of the climate crisis are pervasive and continuous in India, with different parts ricocheting from heatwaves to heavy rains, flooding rivers and devastating landslides. Cycles of drought and flooding make farming more precarious; cyclones and salinization are challenging coastal livelihoods. When making a living in the place you call home becomes increasingly uncertain, people reduce risk by moving. Labour migration — the movement of people for employment — has been one of the oldest forms of adaptation to changing climatic and environmental conditions.

Across India, a third of the total population is on the move, primarily from rural to urban areas. These migrants typically enter the informal workforce, working as drivers, construction labourers, guards, cooks, gig workers and farm labourers. They fuel garment factories, build bricks, power solar farms and process seafood. Through remittances, these labour migrants are diversifying their livelihoods and investing in building generic capacities to meet basic needs for food and shelter.

However, labour migrants across South Asian cities tend to work in unsafe, climate-exposed sectors with poor protection from heat and pollution. They live in hazardous places with inadequate protection from extreme events; have less access to health and education; and face discrimination and xenophobia in cities. Women migrants report higher work burdens, managing both productive (waged) and reproductive work (care-giving and domestic work). Changing aspirations and social norms interact with escalating climate risk to also reconfigure masculinity, with implications on how households manage risk through cooperation or conflict or make decisions to move or stay.

As climate change impacts heighten, migration is growing but becoming riskier, narrowing the potential for labour migration to serve as an adaptive strategy. In rural areas, escalating climate risks are challenging farm livelihoods and depressing household incomes, necessitating migration. In urban destinations, climate change is making work and living conditions more precarious and unsafe, pushing labour migrants to spend more on risk-proofing already unsafe housing or on out-of-pocket health expenditures. Current social protection schemes across South Asia remain domicile-linked and do not build specific capacities required to adapt as people traverse rural and urban areas.

Labour migrants remain insufficiently acknowledged as vulnerable groups in climate action plans: why does this gap persist? First, there are limited data on labour migrants and their movement under climate change. Second, research and practice are divided between rural and urban areas, but rarely

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covers both. Third, climate change adaptation policy and implementation have a sedentary bias, with policies typically formulated expecting people to stay in place. Mobility and labour migration is a key strategy for households to manage risk. Recognizing this will go a long way towards providing effective and inclusive climate policies.

Nausheen H. Anwar: creating urban resilience through policy and planning

Pakistan's cities sit at the frontline of climate risk — facing escalating heatwaves, urban flooding, water scarcity and sea-level rise. A critical research question is how climate adaptation can be embedded within the dynamics of informal settlements and rapid urban growth in cities such as Karachi — Pakistan's largest city — and similar South Asian megacities, and even in smaller or secondary cities. This question intersects climate science with urban governance, socio-spatial justice and infrastructure resilience.

At the Karachi Urban Lab, recent work has advanced our understanding of Karachi's urban climate risks — using meteorological data to historicize warming at the urban level; mapping zones of vulnerability; putting migration and displacement at the forefront when thinking about the complexity of climate risks; and generating data on the relationship between COVID-19, extreme heat, critical infrastructure and social vulnerability. Yet, the translation of research into climate action remains sporadic. Governance fragmentation, overlapping institutional mandates and political volatility hinder systematic climate-responsive planning. Most notably, the city's informal settlements — which house more than 60% of the population — remain largely invisible to formal adaptation efforts.

Research uptake is further constrained by limited municipal capacity and financing. Urban planning remains reactive rather than anticipatory, focused on crisis response rather than resilience-building. Climate science often sits in silos, disconnected from urban development policies that prioritize short-term economic growth over long-term risk reduction. Additionally, informality in housing and service delivery makes top-down interventions difficult, demanding new models of inclusive governance.

Bridging this gap requires reframing climate adaptation as integral to urban development, not as an add-on. Examples of this can be seen in other regions, for example, the Mukuru informal settlement in Nairobi, Kenya, where the city government and partners explicitly reframed climate adaptation as a core part of urban development. Similar approaches are also needed for megacities in South Asia, such as Karachi. Moreover, in any such initiative, co-production of knowledge — engaging researchers, policymakers and community organizations — is essential. Participatory risk mapping, locally grounded adaptation plans and decentralized infrastructure solutions (such as micro-scale flood management or neighbourhood cooling strategies) can operationalize research insights.

Accessing climate finance is equally critical. Current mechanisms often bypass local governments or fail to account for informal urban realities. Tailoring climate funds to support community-led adaptation, alongside investments in institutional capacity, can shift the needle.

Karachi's experience underscores a broader reality for climate-vulnerable cities in Pakistan and, more broadly, across the global south: technical knowledge alone is insufficient. Without governance reform, inclusive planning and sustained investment, the gap between climate science and urban resilience will persist. Embedding climate adaptation into the DNA of urban policy — especially in informal contexts — is not just an academic challenge but a survival imperative.

Chaya Sarathchandra: prioritizing biodiversity and ecosystem services in decision-making

South Asia has some of the highest rates of deforestation and coastal degradation in the tropics. In countries such as Sri Lanka, which is highly susceptible to climate risk, multi-factor global change is a high threat to biodiversity and ecosystem services, and in turn impacts human health and livelihoods.

Sri Lanka, along with the Western Ghats of India, is a biodiversity hotspot and records the highest species density for flowering plants, amphibians, reptiles and mammals in Asia. However, this unique biodiversity is declining. Along with direct loss of species, these declines impact ecosystem service provisioning, including carbon storage.

Preventing these losses remains challenging. For example, implementation of the United Nations Framework Convention on Climate Change (UNFCCC) requires reporting on the changes in carbon storage capacity of different ecosystems. However, such reporting requires quantification of the changes in carbon sequestration caused by altered land uses. An array of issues, including lack of funding for basic research, insufficient data, loopholes in rules and regulations, and weak institutions make this particularly difficult in Sri Lanka.

The situation is further threatened by the ongoing economic crisis as government funds for research are reduced and many protected lands are prone to being released to attract foreign and local development projects. Such developments have particularly strong impacts on people in rural areas with less diverse livelihoods, who rely on access to ecosystem resources in buffer zones for daily requirements. Although around 30% of Sri Lanka's land is protected, a substantial portion of important ecosystems and endangered

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species are recorded outside protected areas. The country has recently developed an Environmentally Sensitive Areas project to introduce a new land-use governance framework to prioritize biodiversity preservation during ongoing development.

Most South Asian countries share the Indian Ocean for sustaining resource requirements. Healthy mangrove forests protect coastlines and are important for sequestering carbon and thus regulating the carbon cycle, but habitat destruction and climate change are altering flooding patterns and the structure of mangroves, thus affecting the ecosystem and by extension the fishery industry. Sri Lanka is the first tropical country to have formulated and implemented a centrally managed integrated coastal zone management programme, designed to manage coastal species and environments, protect ecosystem services for local peoples and support sustainable economic development. The 2024 update of this plan has broadened to include climate change resilience aspects as rising sea levels particularly affect island nations such as Sri Lanka.

Although management programmes such as this are an important step, adequate financial investments are necessary for capacity-building and for research that is crucial for decision-making. As this region moves towards a better economy, it must integrate principles of sustainable development into development policies and programmes and reverse the losses caused by environmental degradation.

Suvarna Fadnavis: air pollution and extreme events

South Asia faces a major challenge in developing effective adaptation strategies to enhance climate resilience under increasingly frequent and severe extreme weather events. This challenge is compounded by the region's complex atmospheric dynamics, influenced by the large emissions of air pollutants and greenhouse gases.

Recent research highlights the critical role of aerosols in modulating South Asia's climate. The region emits large quantities of aerosol particles from traffic, industrial activities, fossil fuel combustion, biomass burning and land-use changes. These particles interact with clouds and the Earth's radiation budget, strongly affecting convective processes over the complex South Asian topography. Their radiative effects and associated heating and cooling modulate monsoon circulation and rainfall patterns. For example, soot and some dust aerosols tend to warm the atmosphere and enhance rainfall, whereas sulfate aerosols have a cooling effect that suppresses precipitation. The dominance of dust and carbonaceous aerosols has exacerbated greenhouse gas-induced warming over the past four to five decades. This has contributed to a range of catastrophic events, including heatwaves, precipitation extremes, forest fires, lightning storms, accelerated glacial melting over Himalaya and rising sea levels. Extreme rainfall events often result in widespread flooding, water clogging and landslides, causing substantial loss of lives, damage to infrastructure, disruption of agriculture and degradation of ecosystems.

Although efforts are underway to scale up renewable energy and low-carbon technologies, promote afforestation and sustainable land use, increase investment in education and climate research, build technical capacity and foster regional cooperation, major challenges remain. Air pollution, driven by economic growth, industrial development, population density and urbanization, continues to hinder climate adaptation and disaster risk reduction. Climate models used for predicting extreme events often lack sufficient observational data, especially for greenhouse gases, aerosols and other compound chemical species, which are essential for accurately representing the complex atmospheric processes over South Asia's varied terrain.

Although some countries in the region have established early-warning systems and climate projections for extreme events such as rainfall, cyclones, heatwaves and floods, a large gap remains between warning dissemination and actionable response. This is largely due to limited public engagement and institutional capacity. To address these challenges, it is crucial to (1) raise awareness at the community level to reduce pollution-causing practices (for example, open fire burning and use of plastic), (2) promote multi-level collaborations on technology development, data collection, planning and policymaking, and (3) assimilate high-resolution observational data into climate models used for early-warning systems and disaster management. A coordinated, science-based approach that combines technological innovation, policy action and community engagement is essential to build a climate-resilient South Asia.

T. S. Amjath-Babu: system shifts underlying climate-resilient agriculture

South Asia has become a hub of agricultural adaptive innovations. Research output from the private and public sectors has been applied to real-world practices, including novel stress-tolerant crop varieties, climate-smart agronomic and irrigation technologies, digital innovations, machinery that enables quick responses to climate stresses, post-harvest storage solutions, novel finance, and insurance models. The major question now is how system-level shifts and coordination requirements that underly climate-resilient agricultural transition can be designed and governed to ensure sustained food security in South Asia.

The 'system shifts' inherent in adaptive change are not well understood. For example, shifting to a stress-tolerant crop or variety triggers changes across the value chain – from seed suppliers and agronomic practices to knowledge systems. Such a transition could affect labour demand (quantity, timing, gender and skill), soil requirements, cropping sequences, crop–livestock interactions, financing models, market channels, off-farm labouring options and consumer acceptance, varying by location.

High transaction costs along the supply chain often restrict the accessibility of stress-resilient technologies in climate-sensitive regions, especially in Bangladesh and Nepal where farmers usually have limited financial resources. These costs are amplified by the yearly shifts in climate stress zones. Furthermore, digital climate services are proliferating, but challenges persist around the digital divide (digital literacy and smartphone access deficits) and quality of forecasts. Labour shortages, ageing of farmers, indebtedness and land fragmentation also work against adaptive changes. Finally, current financing models, which rely on unregulated or micro-scale finance, may not foster resilient farming for tenants. Although crop insurance is emerging in India, it is still dependent on government subsidies and is not economically viable on its own.

For a climate-resilient future, local institutional actors need to emerge who have the capacity to coordinate farmers to identify climate stresses, assess the portfolio of options, understand system-level implications, resolve value-chain breakages, experiment with adaptive options and generate resources for catalysing change. They need to enhance adaptative change through farmer-to-farmer learning models and bridge the divide between farmers and the innovation–stakeholder landscape. If research fails to address system-level implications, the current broken value chains and insufficient institutional efforts and misaligned financing will hinder locally led adaptive changes, which would challenge future food security in South Asia under increasing climate stress.

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