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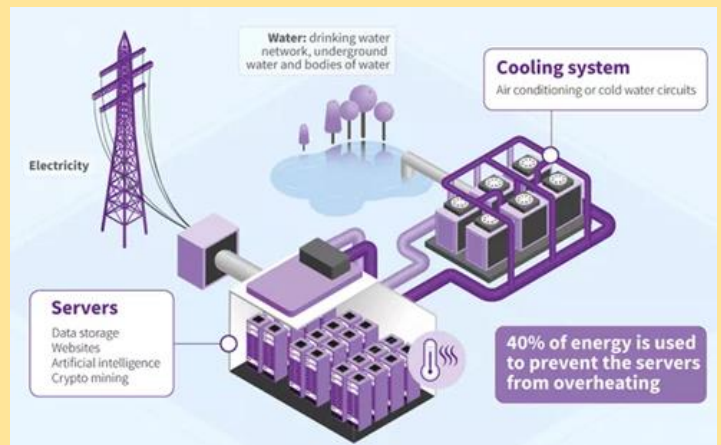
THE HIDDEN THIRST OF AI: HOW DATA PROCESSING UNITS CONTRIBUTE TO WATER SCARCITY

Dr. Sudipta Tripathi

Assistant Professor and Head, School of Environment and Disaster Management, RKMVERI

As artificial intelligence (AI) transforms modern life—propelling advancements in fields like medicine, finance, education, and entertainment—its hidden environmental cost is becoming increasingly alarming. A particularly neglected aspect is the extensive water usage necessary for cooling the sophisticated hardware that drives AI systems. Central to this issue are Data Processing Units (DPUs), along with Graphics Processing Units (GPUs) and Central Processing Unit (CPUs), which function in expansive data centers worldwide. These processors are tasked with meeting the immense computational requirements of AI models, especially resource-heavy applications such as generative AI and large language models (LLMs). However, the heat produced by these processors during ongoing operations needs careful management to avoid system failures and deterioration of hardware. Although some facilities utilize air-based or hybrid cooling methods, numerous ones still depend predominantly on water-intensive techniques like evaporative cooling and chilled water systems to achieve optimal temperatures. This escalating reliance on water for thermal regulation exerts added pressure on already strained freshwater resources—an issue that has not garnered adequate public or policy focus.

The extent of water consumption by AI data centers is staggering. For example, in a 2023 report by Bloomberg, Microsoft revealed a 34% spike in its global water use from 2021 to 2022, partly attributed to the rise of generative AI tools like ChatGPT, which Microsoft backs through its partnership with OpenAI. Google, another leader in AI, reported using over 5.6 billion gallons of water in 2022 for cooling its data centers—



enough to fill more than 8,400 Olympic-sized swimming pools. These statistics are particularly concerning when data centers are situated in areas already experiencing water stress. One notable instance is Google’s data center in The Dalles, Oregon, which attracted public criticism for its high water consumption amidst severe drought conditions in the region. Additionally, Meta (formerly Facebook) has been scrutinized for its data center in Mesa, Arizona, an arid area where water scarcity is an urgent issue. These examples underscore a troubling inconsistency: tech giants frequently establish facilities in regions with favorable tax incentives and cheap land, yet these same locations often face significant water shortages, creating increasing friction between technological expansion and environmental preservation.

Cooling methods in data centers fall into two categories: evaporative cooling and chilled water systems. Evaporative cooling efficiently absorbs heat using water but wastes most vapour. Chilled water systems recycle better but still require freshwater. As global AI demand rises, these cooling methods significantly impact local ecosystems and water resources, especially during hot periods or droughts, competing with domestic, agricultural, and industrial water needs. This raises ethical concerns and worsens water crises. To address these issues, solutions include relocating data centers to cooler regions, like Nordic countries, which reduce cooling needs. For example, Microsoft tested underwater data centers off Scotland in its “Project Natick,” successfully lowering water and energy use. Another method is advanced liquid cooling systems, which use minimal water and function on closed-loop principles, reusing treated water. In Singapore, strict water conservation regulations require data centers to adopt liquid cooling and water-saving technologies for operating licenses.

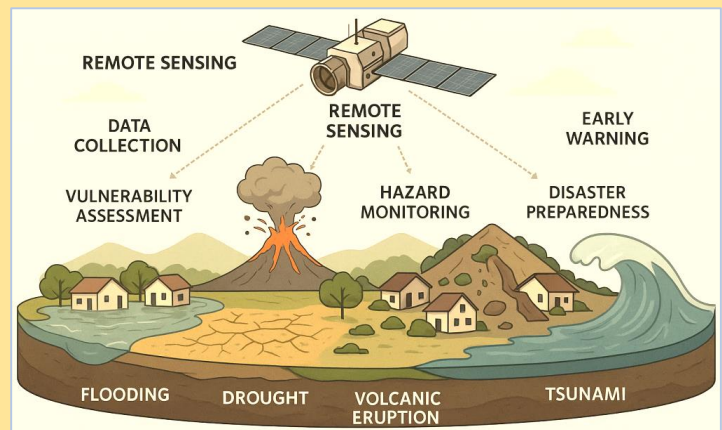
There is a growing movement encouraging tech companies to use recycled or non-potable water instead of freshwater. In Santa Clara, California, some data centers now use treated wastewater, known as “purple pipe” water, for cooling, helping conserve potable water. Increased transparency is also crucial; environmental organizations and local communities want businesses to disclose their water usage and conduct environmental impact assessments before building large facilities. This accountability could lead to better planning and reduce water-related disputes. AI has the potential to tackle global challenges, but it must prioritize environmental responsibility. Sustainable cooling technologies, strategic data center locations, and transparency are essential for the tech industry to innovate while preserving the environment. It’s not a question of whether AI can change society—it’s about how we can develop AI sustainably for both humanity and the environment.

LEVERAGING REMOTE SENSING FOR DISASTER RISK REDUCTION IN VULNERABLE REGIONS

Dr. Sumanta Das, Asst. Professor, School of Environment and Disaster Management, RKMVERI

Disaster Risk Reduction (DRR) has become an imperative for sustainable development, especially in vulnerable regions where the intersection of socio-economic fragility and environmental exposure intensifies the impacts of natural hazards. Remote sensing (RS), with its ability to provide consistent, synoptic, and near real-time data over large spatial extents, has emerged as a pivotal tool in the DRR framework. It facilitates timely risk identification, hazard monitoring, early warning dissemination, and post-disaster impact assessments, thereby enhancing the resilience of communities at risk.

Vulnerable regions, including coastal deltas, mountainous terrains, drought-prone semi-arid zones, and densely populated urban slums, often suffer from inadequate infrastructure, weak institutional capacity, and limited access to conventional monitoring systems. In such contexts, remote sensing offers an invaluable alternative by enabling the continuous observation of earth system variables such as land surface temperature, precipitation, vegetation cover, soil moisture, topography, and land use/land cover dynamics. These parameters are critical for understanding the hazard landscape and modeling potential disaster scenarios, including floods, droughts, landslides, and cyclones. For instance, satellite-based rainfall estimation (e.g., TRMM, GPM) and soil moisture monitoring (e.g., SMAP, Sentinel-1) contribute significantly to flood forecasting and drought risk assessment. In mountainous regions, RS-derived digital elevation models (DEMs) from missions such as SRTM and TanDEM-X enable the delineation of landslide-prone zones, supporting the design of early warning systems and slope stabilization strategies. Moreover, vegetation indices like NDVI and EVI derived from MODIS or Landsat help in assessing agricultural drought and ecological degradation, which are often precursors to food insecurity in marginal lands.



One of the critical contributions of remote sensing is its role in multi-hazard mapping and vulnerability assessment. By integrating RS data with socio-economic and infrastructural datasets in Geographic Information Systems (GIS), composite risk indices can be developed, pinpointing hotspot areas requiring urgent policy intervention. This approach is particularly beneficial for resource-constrained countries where ground-based observations are sparse. The synergistic use of RS and GIS not only enhances spatial accuracy but also aids in scenario-based planning and climate-resilient infrastructure design. However, the effective application of remote sensing in DRR is not without challenges. The spatial and temporal resolution of satellite imagery must be carefully selected to match the scale and dynamics of the hazard in question. Furthermore, the interpretation of RS data requires skilled human resources and robust computational infrastructure, which are often lacking in vulnerable regions. Bridging this capacity gap necessitates international cooperation, investment in education and training, and open access to satellite datasets and processing tools.

Source: Author own created using BioRender

In recent years, the integration of Artificial Intelligence (AI) and machine learning algorithms with remote sensing has opened new frontiers for predictive analytics in DRR. These technologies enable the automated classification of landforms, real-time anomaly detection, and pattern recognition from voluminous satellite data, thereby accelerating decision-making processes. Initiatives such as the Sendai Framework for Disaster Risk Reduction (2015–2030) have emphasized the role of space-based technologies in enhancing global and regional resilience through improved risk governance and anticipatory action.

ECO-INTELLIGENCE: HARNESSING ARTIFICIAL INTELLIGENCE FOR A GREENER PLANET

Dr. Malini Roy Choudhury, Assistant Professor, School of Environment and Disaster Management, RKMVERI

Artificial Intelligence (AI) is playing an increasingly vital role in addressing environmental challenges such as climate change, deforestation, pollution, and water scarcity. By enabling rapid data analysis, improving predictive modeling, and optimizing resource use, AI supports global efforts toward sustainable development.

A major strength of AI lies in its ability to process and analyze vast environmental datasets generated by satellites, sensors, and field observations. Traditional methods often fall short in handling such data efficiently. In contrast, AI, especially through machine learning and deep learning, can identify patterns and anomalies swiftly. Applications include detecting illegal deforestation, monitoring glacier retreat, and tracking wildlife movements, thereby enabling more timely and accurate conservation strategies.

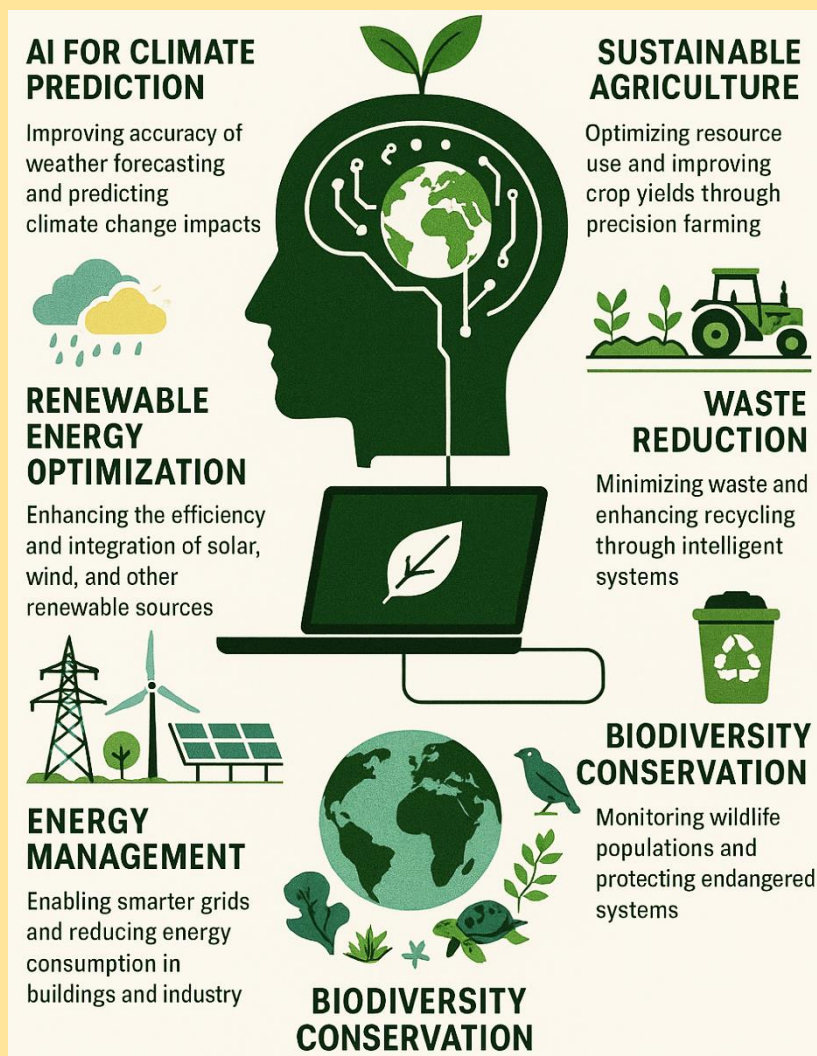
AI also enhances climate modeling by analyzing massive datasets related to temperature, ocean currents, and greenhouse gas emissions. This improves the accuracy of climate forecasts, aiding in disaster preparedness and climate adaptation. In agriculture, AI promotes precision farming by analyzing data on soil, crops, and weather. This leads to smarter decisions on planting, irrigation, and fertilization, minimizing waste and pollution while increasing sustainable crop yields. Drones and remote sensing further enable early detection of crop stress.

Air and water quality management benefit from AI through predictive analytics that identify pollution trends and contamination sources. Real-time monitoring systems, powered by AI, help cities track air quality and warn residents of hazardous conditions. In water systems, AI improves purification and distribution efficiency.

Biodiversity conservation is also supported by AI. Automated image and sound recognition systems identify species from camera traps or acoustic data, reducing the time and effort of ecological surveys. AI models can forecast the effects of human activities on wildlife and assess habitat suitability, aiding in policy development.

However, challenges remain. AI systems often require large, high-quality datasets, which may not be available everywhere. There are risks of algorithmic bias and unintended outcomes from poorly designed systems. Moreover, the energy demands of large-scale AI models can contribute to environmental harm if not sustainably managed.

In summary, when thoughtfully designed and responsibly implemented, AI serves as a powerful tool for environmental protection. It enhances our understanding of complex ecosystems, supports better decision-making, and contributes to building a more sustainable and resilient planet.



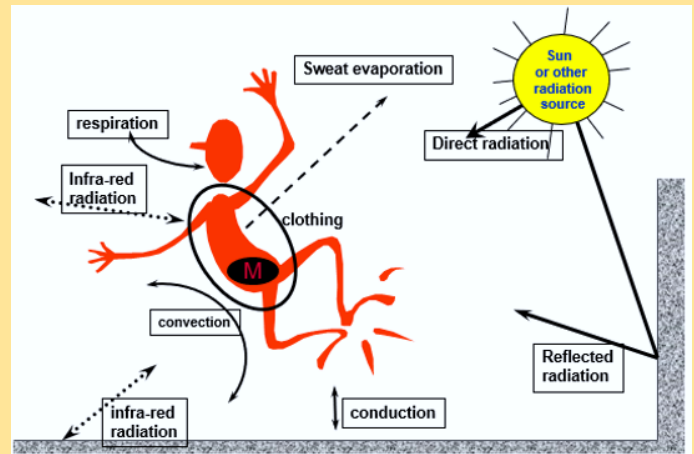
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HEAT STRESS AND CLIMATE CHANGE: RISKS AND RESPONSES

Dr. Mahadev Bera

Heat stress refers to the build-up of body heat produced internally through muscle exertion or absorbed from the surrounding environment. It occurs when the amount of heat that the body takes in surpasses its capacity to release it, resulting in physiological strain. With climate change intensifying, global temperatures and the occurrence of extreme heat events are increasing, which significantly heightens the risk of heat stress in both work environments and everyday life. This escalating environmental issue calls for a better understanding of how heat impacts the human body.

Heat stress generally results from a combination of various factors, including high ambient temperatures, increased humidity, intense physical exertion, and insufficient hydration. Climate change intensifies these dangers by causing longer and more severe heat waves, which diminish the efficacy of natural cooling methods like sweat evaporation. The human body's capability to maintain its core temperature relies on the heat budget, a balance between the heat generated internally and the heat exchanged with the environment. This equilibrium is upheld by the thermoregulatory system, which includes the hypothalamus, sweat glands, circulatory system, and skin, as well as by physiological and behavioural responses such as clothing choices, hydration, physical activity levels, and periods of rest.



Heat Stress, Heat Strain, and Health Impacts

Signs of heat stress include a rise in core body temperature, faster heart rate, quickened breathing, excessive perspiration, nausea, dizziness, and in serious situations, heat-related conditions like heat exhaustion and heat stroke, which can be life-threatening emergencies. In contrast, heat strain pertains to the body's physiological and psychological reactions to heat stress. It includes measurable alterations in body functions such as increased heart rate, core and skin temperatures, and rates of sweating. Keeping track of heat strain is crucial in work environments, sports, and areas with high temperatures to prevent injuries and safeguard individual health and performance.

Risk Factors and Vulnerable Populations

Various risk factors impact a person's likelihood of experiencing heat stress. Key contributors include environmental conditions like high temperatures and humidity, particularly since humidity restricts the evaporation of sweat, which is the body's primary method of cooling. Engaging in intense physical activity generates more internal heat, increasing the risk. Individual traits such as age, existing health issues, and certain medications (like diuretics and beta-blockers) can also affect heat tolerance. Elderly individuals and those with compromised thermoregulatory systems are more susceptible. Additionally, a sudden lack of acclimatisation to hot conditions, often seen during unexpected heat waves, can further hinder the body's capacity to adjust.

Measure heat stress

To evaluate and manage heat stress, various physiological and environmental metrics are utilised. One of the most commonly used indicators is the Wet-Bulb Globe Temperature (WBGT), which combines temperature, humidity, wind speed, and solar radiation to gauge overall heat stress exposure. Another detailed index is the Universal Thermal Climate Index (UTCI), which offers a “feels-like” temperature by merging air temperature, radiant temperature (both solar and long-wave radiation), wind speed, and humidity. The UTCI assesses how the human body physiologically responds to different thermal environments and classifies heat stress into several levels. This index is notably useful in the realms of occupational health, urban planning, public health policy, and strategies for climate adaptation, providing valuable insights into the health impacts of increasing global temperatures.

Recognising and addressing heat stress becomes more crucial in light of climate change. With an increase in exposure to extreme heat, there is an urgent requirement for effective monitoring, risk evaluation, and intervention strategies. Tackling environmental and individual risk factors, boosting public awareness, and enacting protective measures are vital steps toward ensuring health and well-being in a progressively warming world.

REGENERATIVE NATURAL FARMING

Br. Soumitra

In the condition of climate change, soil degradation, and biodiversity loss on global food systems, agriculture stands at a critical crisis. Conventional farming, with its heavy reliance on synthetic fertilizers, chemical pesticides, and intensive monoculture, has led to long-term environmental degradation and increased vulnerability for small farmers. In contrast, **Regenerative Natural Farming** is a holistic agricultural system that combines ecological sustainability with traditional knowledge. Natural farming is a chemical-free, traditional farming method considered an agroecology-based diversified farming system integrating crops, trees, and livestock with functional biodiversity. Natural farming, as the name suggests, involves farming with nature without using modern tools and technology like machinery, genetically modified seeds and soil testing. This method operates on the principle that soil contains all the essential nutrients for plant growth. Plants obtain 98-98.5% of their nutrition from air, water, and sunlight, with the remaining 1.5% from the soil. Thus, the system can sustain and flourish without nutrient supplementation, similar to a forest ecosystem. It emphasizes the synergistic effect of plant and animal products on crop establishment, soil fertility and microorganisms. Masanobu Fukuoka's (1913–2008) philosophy focuses on working with nature to produce healthy food, maintaining the health of both people and the land, and is distinct from biodynamic agriculture. The principles of natural farming were first popularized by Japanese farmer and philosopher **Masanobu Fukuoka**, whose "do-nothing farming" advocated for minimal human intervention, no tilling, and no chemical use. In India, **Subhash Palekar's Zero Budget Natural Farming (ZBNF)** brought similar ideas to the forefront, empowering smallholder farmers with cost-effective, eco-friendly practices. Natural farming minimizes human labor and adopts nature's methods for producing cereals, fruits, vegetables, and ornamentals in biodiverse agricultural ecosystems. Seeds germinate without plowing on the surface, depending on microclimate conditions. Several naturally-prepared concoctions can be added to provide the soil with the environment for activating the soil biota for its independent sustenance. Palekar calls these concoctions, the "four wheels of **Zero Budget Natural Farming (ZBNF)**": Beejamrit, Jeevamrit, Mulching and Waaphasa. Beejamrit is

the microbial coating of seeds with formulations of cow urine and cow dung. Jeevamrit is the enhancement of soil microbes using an inoculum of cow dung, cow urine, and jaggery. Mulching is the covering of soil with crops or crop residues. Waaphasa is the building up of soil humus to increase soil aeration. In addition, ZBNF includes three methods of insect and pest management: Agniastra, Brahmastra and Neemastra (all different preparations using cow urine, cow dung, tobacco, fruits, green chilli, garlic, and neem).



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Therefore, it is concluded that Natural farming is a system where the laws of nature are applied to agricultural practices. It has emerged as a farming model for small and marginal farmers to overcome the farming distress and sustaining the livelihood. It reduces farmer's costs through eliminating external inputs and utilising in-situ resources to rejuvenate the soil, simultaneously increasing incomes, restoring ecosystem/soil health and climate resilience through diverse multi-layered cropping systems and ensuring food security through a symbiotic partnership with nature.

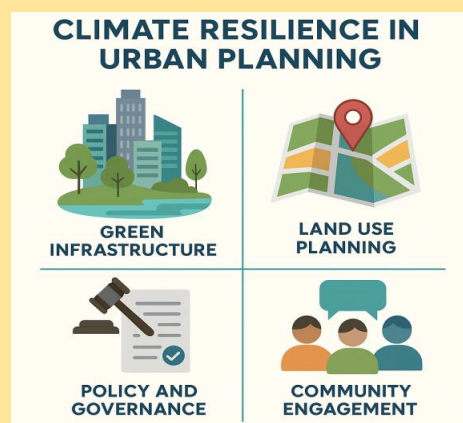
INTEGRATING CLIMATE RESILIENCE INTO URBAN PLANNING: STRATEGIES FOR ADAPTIVE AND SUSTAINABLE CITIES

Sujan Mandal

Urbanisation now accounts for more than 50% of the world's population, and projections are that city dwellers will make up nearly 70% by 2050. Cities, as the hubs of economic and cultural life, are the drivers of national development. But they are also disproportionately susceptible to the effects of climate change. From soaring temperatures and urban heat islands to increased flooding and extreme weather events, cities are up against unprecedented environmental challenges. Traditional urban planning, frequently devised under the presumption of stability and predictability, will need to contend with a world of swift environmental change. Climate-resilient urban planning has therefore been identified as a critical approach for sustaining the functionality, liveability, and equity of cities in a climate-stressed world.

Urban climate resilience is the ability of an urban system to absorb, recover from, and adapt to climate stress or hazard in a timely and efficient manner such that essential functions, structures, and identity are sustained. The concept extends beyond the city's physical form to include its sociology, culture, economy and governance. Climate-proof urban planning seeks to anticipate potential climate effects and to minimise the exposure of and sensitivity of the urban population to these effects. Proactive and defensive essential to protect the well-being of humans and ecology, and particularly when the intensity and number of climate events surge.

Climate-resilient urban planning involves risk assessment, land use and zoning regulations, infrastructure adaptation, and policy and governance frameworks. Risk assessment helps identify areas most susceptible to hazards like flooding or heat stress, while advanced tools like GIS and climate modelling help forecast future scenarios. Land use policies restrict development in high-risk zones and promote compact, mixed-use developments. Resilient land-use strategies include green buffer zones, coastal setbacks, and managed retreat from high-risk areas. Infrastructure adaptation includes green infrastructure like urban forests, green roofs, and permeable pavements, which mitigate heat, absorb excess rainwater, and improve urban biodiversity. Resilient water management systems, including flood retention basins and improved storm water drainage, are essential for coping with extreme precipitation events. Policy and governance frameworks provide institutional support for implementing resilience strategies, and coordination among government and public-private actors ensures consistent and adequate funding. Social resilience is equally important, with community-based approaches, participatory planning, and public education initiatives ensuring local populations are aware of risks and equipped to respond. Vulnerable groups, such as low-income residents, the elderly and informal settlers, often face the greatest climate risks, and inclusive planning must prioritise their protection.



Many cities are now incorporating resilience into their plans globally. Rotterdam, a city in the Netherlands, is frequently held up as an example of a leader in climate-adaptive design. Rotterdam can handle storm water efficiently and create high-quality urban public spaces by combining water management measures such as "Water Squares" and multifunctional dikes. Surat, also in India, has a city-wide Climate Resilience Strategy which delivers better drainage systems, disease surveillance and disaster readiness. As one of the 100 Resilient Cities member cities, Surat shows that Global South cities can overcome climate vulnerability using multi-stakeholder engagement and data-informed governance.

Financial limitations remain a major hurdle, especially in low- and middle-income countries, where urban governments struggle to finance infrastructure upgrades and disaster mitigation projects. Fragmented governance and a lack of coordination among agencies can delay or distort resilience-building efforts. Additionally, many cities lack reliable, localised climate data, making it difficult to conduct accurate risk assessments or plan effectively. To overcome these challenges, urban planners and policymakers must mainstream climate resilience into all aspects of city development, including transportation planning, housing, energy systems, and waste management. Developing innovative financing models, incorporating technology and data analytics, such as satellite monitoring and predictive AI models can enhance risk mapping and planning accuracy.

ECONOMIC VALUATION OF MANGROVE ECOSYSTEM SERVICES

Diksha Kar

Mangroves are coastal intertidal forests that provide vital ecosystem services supporting biodiversity, livelihoods, and climate resilience. For coastal communities and the health of the environment worldwide, mangrove forests offer vital ecological and economic advantages. They provide everything from nitrogen cycling and fisheries assistance to carbon sequestration and coastal protection. Despite their significance, mangroves are disappearing quickly as a result of pollution, climate change, and land development.

Ecosystem services are the direct and indirect benefits that ecosystems—also known as natural capital—provide to well-being and living standards. These include cultural benefits, such as reducing stress, as well as practical supplies like food and water, and environmental regulation. Mangroves, located in tropical and subtropical coasts, are intertidal forests that support diverse ecosystems and various services (ES). These services include: providing (wood and fisheries), regulating (storm protection and carbon sequestration), cultural (heritage and recreation), and sustaining (nutrient cycling). Valuing these services in monetary terms helps bridge ecological significance and economic decisions, especially in areas threatened by environmental degradation and climate risks.



The economic value of services offered by mangrove ecosystem services (ES) can be assessed using a number of techniques. For example, market pricing assigns value to goods like timber, fish and fuelwood at existing market prices. The replacement cost method attempts to calculate how much it would cost to replace the lost functions of mangroves with artificial structures – for example, sea walls. Contingent valuation (CV) estimates valuation through a survey where respondents state their willingness to pay (WTP) for the conservation or restoration of mangroves. Using the travel cost method (TCM) the value of recreational services in relation to the expenses incurred while traveling to a particular location can also be estimated. Finally, the benefit transfer approach makes valuation estimates for one context and applies them to another, using local conditions to make some changes where necessary.

The mangroves ecosystem in India comes with a wide range of services that have tremendous economic importance. It's believed that the total value of the mangroves can be as great as Rs. 92,662/ha/year to Rs. 3,361,144/ha/year with the average value being Rs. 958,766/ha/year. This contributes significantly to the coastal community's well-being and assists the policy makers in the conservation of the mangroves.

Details of Specific Ecosystem Services and Their Valuation:

Provisioning Services: Mangroves supply local communities with timber, firewood, and additional products. They are also important for food security as they support fisheries and aquaculture. The total economic value of provisioning services is estimated at Rs 383 billion.

Regulating Services: Mangroves assist in coastal erosion control and protection from cyclones and tsunamis while also helping with carbon sequestration. The estimated value of regulating services is Rs 655 billion.

Supporting Services: Mangroves provide areas for many species which helps in increasing biodiversity. They also assist in nutrient cycling and water cleansing, purifying processes.

Cultural Services: Mangroves are advantageous for the local economy through tourism and recreational needs.

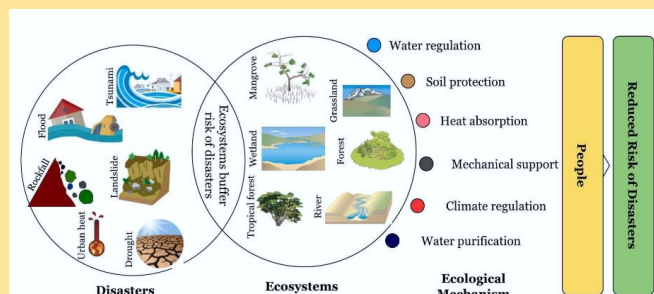
Mangrove ecosystems provide vital economic benefits essential for sustainable development, climate adaptation, and biodiversity conservation. Integrating their value into national accounting and coastal planning, supported by context-specific interdisciplinary valuation methods, can drive more effective preservation and governance.

ECOSYSTEM-BASED DISASTER RISK REDUCTION (Eco-DRR): NATURE AS OUR FIRST LINE OF DEFENCE

Suchismita Roy

When the storm clouds darken and the world wobbles beneath our feet, we want to build walls, fences, levees. But we take shelter or keep sheltering under concrete and steel. However, the single best protection against the wrath of nature is not what humans make or create, but what they nurture. Envision a coastline where mangroves stand like sentinels, their interwoven roots absorbing the fury of crashing waves. Forests seizing hold of mountain slopes, their whispers bracing against landslides threatening human lives. Visualise wetlands sprawling over floodplains, soaking in storm water drop by drop. Some of these are pure left-field fantasy, but not these, these are real-world natural defence systems that have evolved over millennia and are now endangered, it seems, by the primary offending species- our own. With the planet at a tipping point, a radical idea is emerging: we need to let nature protect us. Ecosystem-Based Disaster Risk Reduction (Eco-DRR) goes beyond managing disasters; it heals that delicate relationship between nature and humanity.

Ecosystems are not passive backdrops to human life—they are active protectors. Ecosystem-Based Disaster Risk Reduction (Eco-DRR) is an integrated approach for reducing disaster risks through the sustainable management, conservation and restoration of ecosystems, sustaining and enhancing livelihoods, and promoting the resilience of communities. The tool acknowledges the value of intact environments in delivering protective services against several hazards (notably floods, storms, droughts, and landslides) mechanisms are also important in providing co-benefits related to conservation of biodiversity, regulation of climate, and support of livelihoods.



Eco-DRR is grounded in strong scientific evidence. It has been demonstrated through research that investment in ecosystems is a more cost-effective way to reduce disaster risk than traditional infrastructure. Eco-DRR is highlighted as a strategic priority in many major global frameworks. The Sendai Framework for Disaster Risk Reduction (2015–2030) highlights the importance of including environmental and ecosystem management considerations in national disaster strategies. Nature-based solutions are also promoted as essential approaches anchored on both climate adaptation and disaster mitigation by the Paris Agreement and the Convention on Biological Diversity.

The beautiful thing about Eco-DRR is that it always works at the community level — close to people, close to the land, close to the ecosystems on which they depend. Indigenous peoples and traditional land users have thousands of years of experience living sustainably on the land. They know the rivers' rhythms, the forests' cycles, and the coastal tides' behaviour. Their customs—ranging from sacred groves, seasonal capture land, to rainwater control—are often integrated with present-day Eco-DRR principles. The inclusion of these communities in planning, restoring, and managing ecosystems also makes for culturally relevant, sustainable, and durable interventions. Carbon-storing wetlands support migratory birds; evidently, resilient watersheds catalyse water security across borders; and healthy forests cool regional climates and scale carbon sequestration. Eco-DRR thereby serves as a bridge between local community empowerment and global environmental objectives

Climate change adaptation is not just a technical fix to build resilient infrastructure but an essential, transformative shift to the age of working with nature instead of against it. Central to this transition is Eco-DRR, which provides a green transition for safer and more sustainable futures. In this, resilient communities and thriving ecosystems are two sides of the same coin, making a living barrier against the tempests of the future.

RENEWABLE AND NON-RENEWABLE ENERGY IN THE INDIAN CONTEXT

Aveek Roy

“The Earth provides enough to satisfy every man’s needs, but not every man’s greed.”

– M.K. Gandhi.

India, currently the most populous country in the world with a population of over 1.4 billion, is standing today at a critical juncture. With its rapidly increasing economy, the energy demand is also at an all-time high. Fulfilling its energy demand while keeping up with the latest globally acknowledged environmental norms has put India in a rather tough spot. However, India has been juggling the two challenges by implementing a mix of renewable and non-renewable energy sources to satisfy its energy requirement, which is playing a critical role in its developmental trajectory.

Non-Renewable Energy: The Torch Bearer of Industrial Growth:-

India fulfils a large share of its energy requirement through Non-renewable resources such as coal, natural gas, and oil, which account for approximately 80 % of the total energy production. The major share of this 80 percent is of Coal, which contributes to approximately 70% of the total electricity generation. India is blessed with abundant coal reserves, and it holds the world’s 4th largest coal reserves, and states such as Jharkhand holding the major share of the total reserve. However, it also contributes about one-third of India’s total GHG emissions, causing degraded air quality and public health impacts.

On the other hand, oil and gas play a significant role in the country’s industry and transportation systems. Oil and gas are mostly imported due to a shortage of adequate reserves to cover India’s demand, which in turn puts a strain on the foreign exchange and energy security.

Renewable Energy: A Shift Towards a Sustainable Future:-

In recent times, a significant shift has been seen in India’s energy security policy. The decision to shift from non-renewables to clean and green energy has been made to address climate change and energy poverty. As per the Ministry of New and Renewable Energy, the total installed renewable energy capacity of India for FY 2025-26 stands at 220 GW, and India aims to achieve 500 GW capacity by the year 2030. As per the year-end review report of 2023, published by Press Information Bureau, India holds 4th position globally in total installed renewable capacity, showing a substantial potential in achieving its desired target.

India’s geographical location in the world map puts it at an advantage for harnessing solar energy potential as it receives more than 300 sunny days annually. Solar energy is the largest contributor of renewable energy, having a share of more than 45%. National Initiatives and flagship schemes of the Government of India, such as the National Solar Mission, have played a major role. The second contributor to the total installed renewable energy capacity is made by wind power, having a total share of more than 23%. Other sources of renewable energy installed in India are hydropower, waste-to-energy projects, etc.

Non-renewables remain indispensable for now, however, renewables offer an opportunity for energy security, job creation, and climate resilience. India’s stride towards achieving Net Zero by 2070, however ambitious, doesn’t seem far off given its current trajectory in implementing renewables at a large scale. The key lies in collaborative efforts among governments, industries, institutions, and their citizens in achieving a future of sustainable energy.

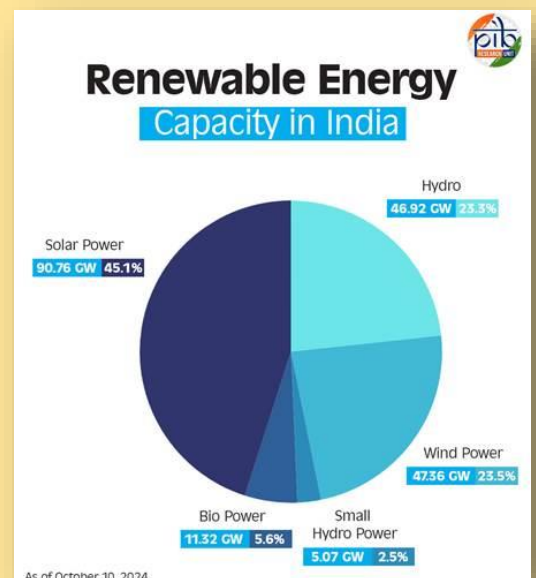


Figure: Pie Chart Visualizing Total Renewable Energy Capacity in India.
Source: <https://npp.gov.in/dashBoard/cp->

SPOTTING THE INVISIBLE: HOW SATELLITES AND DRONES ARE DETECTING METHANE LEAKS

Biplab Pal

The air we breathe, which seems to be clean and pure, can sometimes contain a silent but powerful aggressor: methane. Methane is a colorless, odorless gas that is mainly released from industrial processes, landfills, and agricultural operations, creating a significant contributor to global warming. So, what if we could see the unseen? Thanks to satellites and drones, we can assess the direct and indirect methane release into the atmosphere. Satellites and drones are detecting and combating methane leaks, offering a bird's-eye view of a problem that demands immediate attention.

Methane is a greenhouse gas that carries a high greenhouse gas intensity. While natural sources like wetlands contribute to atmospheric methane, it is emitted from human activities like landfills decomposing waste, the extraction and transportation of oil and gas, and even livestock farming. Over a 100-year timeframe, methane's Global Warming Potential (GWP) is 27 to 30 times higher than CO₂.

At this very moment, many satellites are scanning the sky for the invisible plumes of methane. The detection of methane is based on spectroscopy, which measures the absorption of certain wavelengths of light in the infrared spectrum. A primary benefit of a space-based system is to capture data over large areas, often inaccessible to ground-based systems. Wide-area survey satellites like the European Space Agency's Sentinel-5P TROPOMI and Japan's GOSAT give a broad picture of areas of concern concerning both methane concentration and eventual discovery of emission problems over wide areas. High-resolution point source imager satellites, operated by companies like GHGSat, Carbon Mapper, and Environmental Defense Fund's MethaneSAT, function as comprehensive methane detectives that are sensitive to emissions and can pinpoint individual leaks at industrial facilities. Recent advances in satellite methane detection include some satellites now able to detect leaks with improved spatial resolution down to just a few meters, and hyperspectral imaging is improving the capacity to separate methane's distinctive signature from other gases.

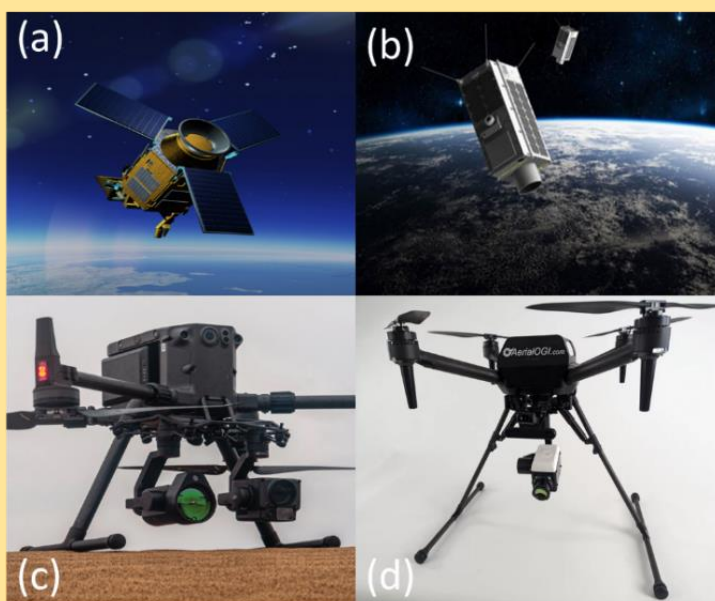


Figure: (a) Sentinel-5P TROPOMI (Source: European Space Agency); (b) GHGSat (Source: European Space Agency); (c) Drone with TDLAS (Source: iRed); (d) Drone with OGI camera (Source: Sierra-Olympia Technologies INC.)

Drones can take a highly localized and detailed approach to methane leak detection. Drones are unmanned aerial vehicles that can be equipped with an array of advanced sensors to detect methane plumes. Laser-based sensors leverage Tunable Diode Laser Absorption Spectroscopy (TDLAS) as a measurement technique to assess methane absorption of laser light, which can provide extremely accurate methane readings. "Sniffer" sensors sample the air directly and measure the concentration of methane molecules. Optical Gas Imaging (OGI) cameras operate in the infrared spectrum and visually represent gas leaks as if they were smoke, making the invisible visible. Drones offer several advantages in methane detection, including localized high-resolution detection and the ability to cover difficult or unsafe areas. They are cheaper and faster than ground-based methods and can obtain real-time data for detailed maps of methane concentrations.

Overall, drones and satellites are powerful tools for methane monitoring. The best response is to use a chain of surveillance layers with satellite data flagging potential candidate areas for drone surveys. As the fight against climate change intensifies, it becomes increasingly important to detect and clean up methane leaks.

CLIMATE WATCH: ATMOSPHERIC RIVERS INTENSIFYING DUE TO WARMING

Disha Roy

Over the past decade, researchers have focused on a captivating and potent weather phenomenon—**Atmospheric Rivers (Ar)**—and the frightening pace at which they are strengthening as a result of global warming. This is usually referred to as "rivers in the sky". These invisible yet incredibly potent weather phenomena are long, narrow channels of concentrated water vapor, spanning thousands of km, transporting huge quantities of water vapor from the tropics to mid-latitudes. When these moisture-laden air streams collide with land, they release heavy rainfall or snow, significantly impacting weather patterns of the west coast of North America, several parts of Europe, and southern Chile. The most well-known among them is the "Pineapple Express," which brings moisture from near Hawaii to the U.S. West Coast. As the planet warms, the atmosphere is able to hold more moisture—about 7% more for each 1°C increase in temperature. This directly enhances the water-carrying capacity of atmospheric rivers. A warmer climate does not necessarily increase the quantity of ARs, but it turbocharges them. That means more snow or rain over a short period of time, raising the risk of flash floods, overwhelmed infrastructure, and soil saturation and the increased runoff could hinder water storage and agricultural planning. Increased flooding risks lives and property, overwhelming drainage systems and increasing the risk of landslides. Infrastructural damage such as that to roads, bridges, and dams can be huge and expensive.

Historically, atmospheric rivers have played a vital role in replenishing water supplies, particularly in regions like California, where they account for nearly half of the state's annual precipitation. A 2023 study in *Nature Climate Change* cited that atmospheric rivers will become not only wetter but longer and wider, increasing their destructive potential, especially in urban or vulnerable rural areas. In recent years, this intensification has resulted in record-breaking floods, such as those seen in California in 2023 and Pakistan in 2022. Warmer oceans, particularly in the Pacific, feed ARs with even more moisture, making landfalls more extreme and unpredictable. The American West Coast and especially California have borne the full force of such amplified systems. The 2022–2023 winter experienced a series of intense ARs that brought widespread flooding, loss of power, and great numbers of fatalities. In Europe, ARs are increasingly associated with heavy rainfall events that contribute to flooding in places like the UK and Germany.

The scientific evidence points to a future with potentially more intense atmospheric rivers as the planet continues to warm. This underscores the urgent need for both reducing greenhouse gas emissions to mitigate future warming and adapting to the changing climate. Hence, there is a need for better stormwater management, strengthened levees, and updated urban planning to deal with downpours. Building more flood-resilient infrastructure, improving early warning systems, advanced satellite systems, improved forecasting models and implementing updated land management practices are essential measures to prepare for the growing strength of these sky rivers. Countries prone to these weather events, such as the United States, China, and Australia, are advancing research on early warning systems and flood prevention measures. Sustainable urban planning, such as reinforcing drainage systems and preserving wetlands, can also reduce the impact of extreme rainfall. Climate change isn't a far-off concern; it's a pressing challenge that's reshaping our lives through the weather we experience. Comprehending and conforming to these alterations is no longer a choice; it is a matter of survival.

DESALINATION WASTE DISPOSAL CONCERNS

Falguni Murmu

Desalination is increasingly vital for tackling global water shortages, particularly in arid and coastal regions where traditional sources are scarce or threatened. Over 16,000 desalination plants operate worldwide, with leading countries like Saudi Arabia, the UAE, and Qatar providing millions of people access to fresh water. However, a significant environmental issue persists: the disposal of brine, a highly concentrated saline waste produced during freshwater extraction through methods like reverse osmosis. Roughly 1.5 liters of brine are created for every liter of freshwater, containing toxic chemicals that threaten marine ecosystems and human health when improperly managed.

The primary disposal method for brine is direct ocean release. Despite natural seawater dilution, localized discharge raises salinity and temperature, disrupting osmotic balances and lowering dissolved oxygen levels near the seafloor. This threatens plankton, fish larvae, and benthic organisms, leading to biodiversity loss, ecosystem degradation, and altered marine population dynamics. Additionally, untreated brines may contain toxic substances that bioaccumulate in marine species, jeopardizing aquatic life and the food security of coastal communities reliant on fishing. Pollutants can enter the human food chain, posing long-term public health risks.

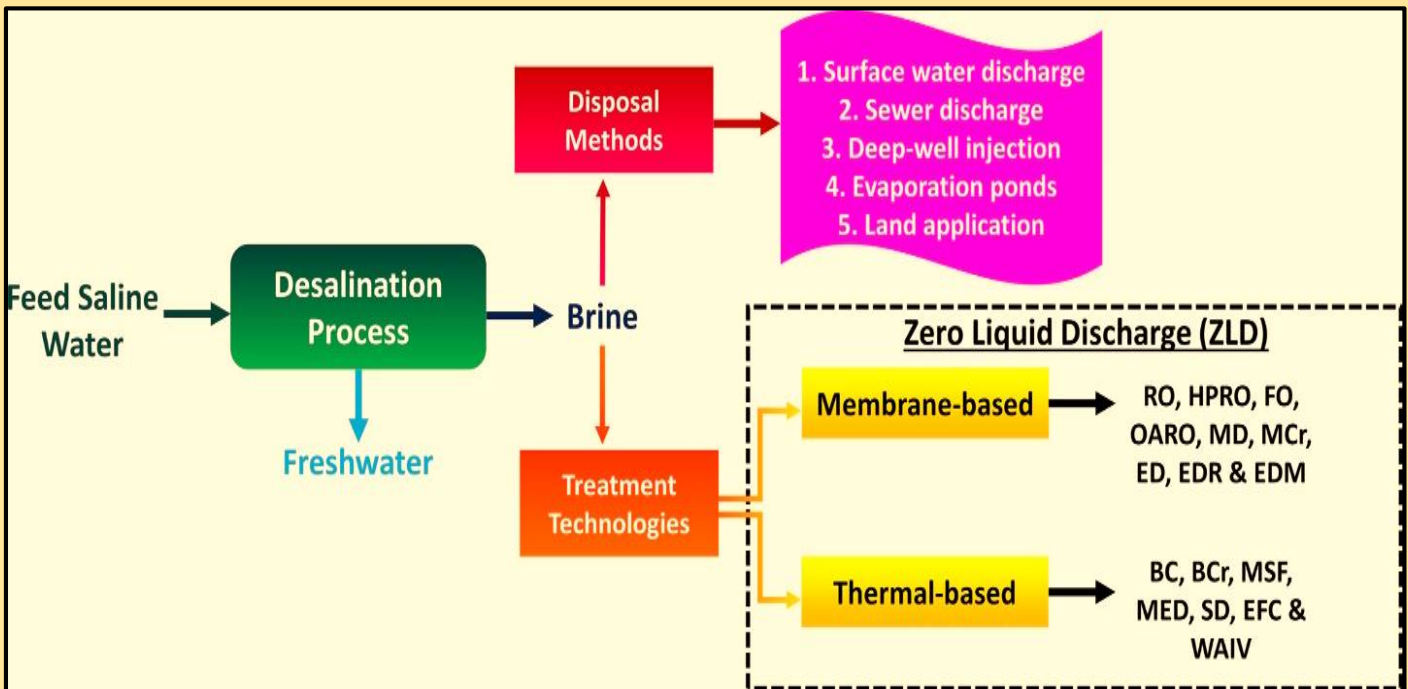


Figure: Integrated Brine Management and Zero Liquid Discharge (ZLD) Strategies in Desalination Systems, Source: (Panagopoulos et al., 2019).

Alternative methods for land disposal, such as evaporation ponds and deep-well injection, present significant environmental challenges. Evaporation ponds, typically located in arid regions, can lead to soil salinization and harm wildlife due to toxic residue exposure. Deep-well injection risks contaminating aquifers if not managed properly. Weak regulatory oversight in developing countries exacerbates these issues, especially regarding desalination plants discharging brine uncontrollably. Innovative solutions are emerging, like advanced brine dispersal systems and zero-liquid discharge systems that recover valuable salts. Additionally, evaporation ponds can be repurposed for salt harvesting. However, high implementation costs hinder widespread adoption of these technologies. While desalination holds great promise in securing water for future generations, the environmental cost of brine disposal must be addressed proactively. Sustainable solutions require a combination of technology, regulation, and public awareness. Only then can desalination evolve from a water supply remedy into an environmentally responsible long-term solution.

DEEP-SEA MINING IMPACTS ON OCEAN BIODIVERSITY

Joyeta Basu

The deep sea, encompassing regions below 200 meters of ocean depth, harbors some of the planet's most mysterious and ecologically significant ecosystems. With technological advances, industries are now targeting mineral-rich zones on the ocean floor for deep-sea mining. These include polymetallic nodules in abyssal plains, cobalt-rich ferromanganese crusts on seamounts, and polymetallic sulfides at hydrothermal vent fields. While deep-sea mining offers a potential source of valuable metals such as nickel, cobalt, and rare earth elements—critical for electronics and renewable energy technologies—it also poses significant threats to ocean biodiversity.

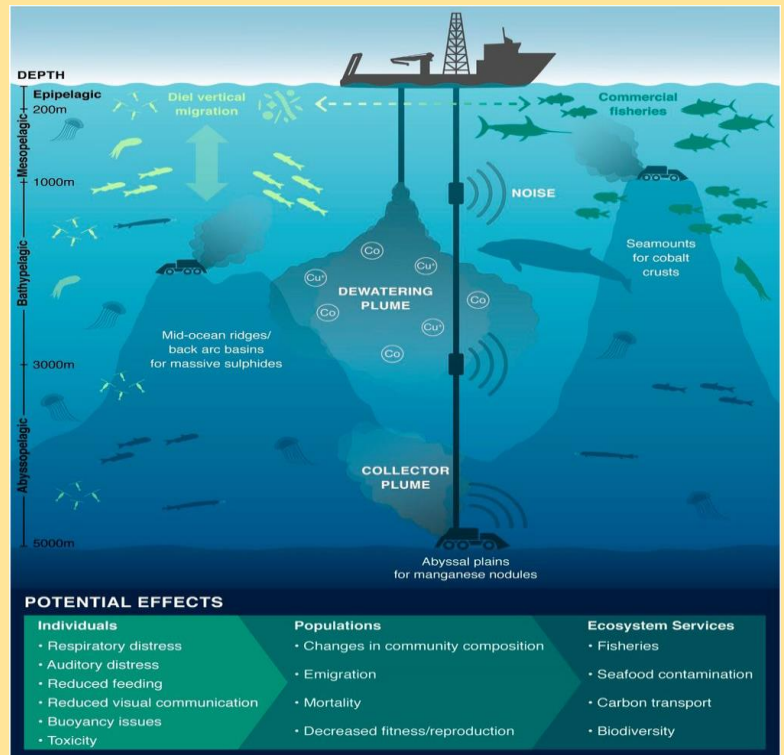
Ecological Sensitivity of Deep-Sea Environments: Deep-sea ecosystems are characterized by low temperatures, high pressure, and limited light. Organisms living in these environments—many of which are endemic and uniquely adapted—typically grow and reproduce slowly due to nutrient limitations. This makes them particularly vulnerable to disturbances. Unlike terrestrial environments, where disturbed ecosystems can regenerate over decades or centuries, deep-sea ecosystems may take millennia to recover from even minor disruption, if at all.

Physical Disturbance and Habitat Loss: One of the most direct impacts of deep-sea mining is the destruction of seafloor habitats. Mining machinery scrapes, dredges, or drills the ocean floor, removing not only the targeted mineral deposits but also the associated biological communities. This mechanical disruption destroys habitats such as sponge fields, coral gardens, and microbial mats.

Sediment Plumes and Water Column Impact: Mining operations generate sediment plumes—clouds of suspended particles that can spread for kilometers beyond the mining site. These plumes may smother benthic organisms, clog their feeding and respiratory systems, and reduce water clarity, affecting photosynthetic organisms in shallower waters. Moreover, the plumes may carry heavy metals and toxic substances that further degrade the surrounding marine environment. The long-term ecological consequences of these plumes remain largely uncertain but are likely to be significant.

Noise, Light, and Chemical Pollution: Mining operations introduce artificial noise and light into the deep-sea environment, which can disorient or repel sensitive species. The machinery used in mining emits continuous noise that can disrupt communication, migration, and feeding patterns of marine organisms, particularly deep-diving cetaceans like whales and dolphins. Chemical leaks from machinery, hydraulic fluids, and processed slurry may also introduce pollutants into otherwise pristine environments.

Loss of Ecosystem Services and Scientific Knowledge: The deep ocean provides critical ecosystem services such as carbon sequestration, nutrient cycling, and climate regulation. Disruption of microbial communities that mediate these processes can have far-reaching consequences for the planet's biogeochemical balance. Additionally, the deep sea is a frontier of scientific discovery, offering insights into evolution, biotechnology, and climate change. Irreversible damage from mining could destroy valuable genetic resources and hinder future research opportunities.



SHIFTING MONSOON PATTERNS: A THREAT TO BILLIONS

Lopamudra Mukherjee

Monsoon is a crucial phenomenon of climatic conditions that create a huge impact on agriculture, water resources and the economic condition of a country or region. It mainly creates a huge impact on regions like South Asia, east Asia and Africa as well. But nowadays climate change which is a major environmental issue creates changes in monsoonal patterns that affect billions of people worldwide. It is not only harmful to people but also creates threats to agriculture, food security, and water supply as well.

Climate Change and Changing Monsoon Patterns- The high rise of global temperature changes the time frame of monsoons; it also alters the distribution and intensity of monsoons across the world. In many regions sometimes the monsoon comes early, sometimes it is delayed, and their intensity fluctuates trends to either excessive rainfall sometimes or dry conditions for prolonged periods in an area. This unavoidable condition leads to some natural disasters like floods or drought. As a result, the changes in monsoonal pattern cause a serious threat to billions of people.

Impact on Agriculture- Agriculture and monsoon rains are in interrelationship because without monsoonal rains agricultural productivity can't grow properly. Due to this relationship irregular rainfall pattern tends to crop failure and food insecurity. Crops like Rice, Wheat, Grains, Vegetables and Pulses are highly vulnerable to this pathetic condition. Uneven patterns of monsoonal rains disrupt the irrigation system, reducing the productivity level of an agricultural field, and creating a threat to the livelihood of the farmers. It also disrupts the economic condition of an agricultural-based economic area.

Disruption of Water Resources- Uneven rainfall patterns pose a challenge in water resource management. Decreasing rainfall amounts leads to the diminishing of water flow in a river affecting water availability for drinking, irrigation, and hydropower production purposes. Due to the change in monsoon patterns, many areas of water reservoirs, wells are dried up leading to water scarcity conditions. The low level of usable water generates long-term challenges in the communities and ecosystem of an area.

Impact on Live and Livelihoods- Now we already know that irregular monsoon patterns are a threat to human lives and the economic condition of an area. Extreme changes in weather conditions and rainfall patterns create disasters like floods, landslides, and droughts which affect people's lives. Many people lose their lives and the communities of an area are displaced due to the disaster. Agricultural instability leads to the loss of farmers and affects food availability and economic security. Flooding in urban areas sometimes creates infrastructural damage and leads to economic strain. At that time getting clean water for drinking or domestic use purposes was difficult.

Mitigation and Adaptation Strategies- Though it is a natural factor we can't stop this but we can try to mitigate the impact of this condition with some adaptation strategies as well. The early warning system of the weather information must be improved because through this warning; communities are prepared themselves for unpredictable conditions. Promoting sustainable agricultural practices such as drought-resistant crops and efficient water resource management are helpful for a farmer. Investing in flood-resistant infrastructure, and improving the drainage pattern is helpful for urban areas to cope with the flood conditions. Proper disaster preparedness and mitigation plans reduce the impact of this unpredictable condition.

Overall, irregular monsoonal patterns are no longer a warning sign - they already start adverse effects on billions of people. When the rainfall pattern changes; agriculture, water supply and daily life of a person start to suffer. To overcome the situation, we do not need a short-term mitigation plan rather we need a long-term plan including sustainable agricultural practices, climate-smart agriculture and disaster-resilient infrastructure in urban and rural areas.

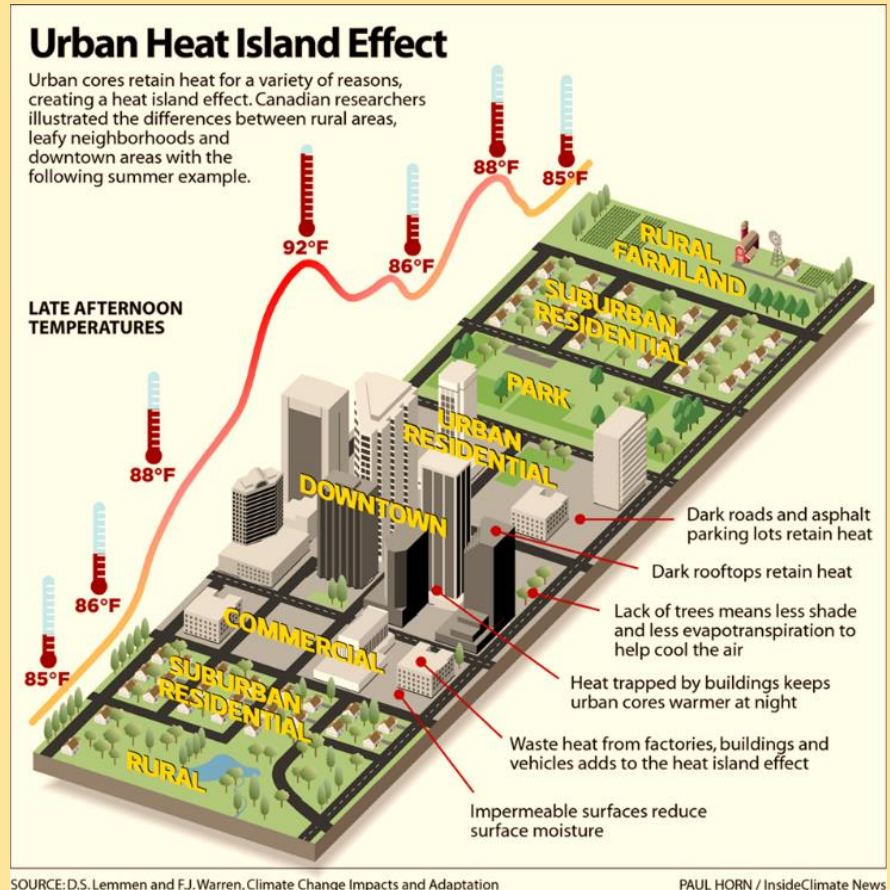
URBAN HEAT ISLAND AMPLIFICATION IN MEGACITIES

Maitreyee Biswas

Urbanization has been a concern since the latter part of the 20th century for several reasons. Megacities are becoming scorching hot due to the urban heat island (UHI) effect, which results in these densely populated areas being warmer than their surrounding rural environments. This effect is increasing alarmingly, leading to significant environmental, health, and economic impacts.

Global climate change presents another major challenge for human society. The frequency, intensity, and duration of urban heat waves have escalated, further jeopardizing urban residents. Human activity, such as the removal of green spaces and the use of heat-absorbing materials like asphalt and concrete, has exacerbated the UHI effect. Since the mid-20th century, human health has also been adversely affected; for instance, cities like Bangkok, Hong Kong, and Delhi have recorded a rise in mortality rates of 4.1% to 5.8% for every 1 degree Celsius increase above approximately 29 degrees Celsius.

Additionally, the construction of high-rise buildings creates urban canyons that trap warm air, preventing proper air circulation and intensifying the UHI effect. Heat is further generated by air conditioning units, automobiles, and industrial activities. Greenhouse gases, including carbon dioxide, act as a barrier that retains this heat.



Addressing the UHI effect is essential for improving urban resilience to climate change. Implementing green solutions, such as parks, gardens, and green spaces, can enhance air quality, reduce heat islands, and promote climate adaptation. These green areas help trap carbon, preserve biodiversity, and allow rainwater to seep into the ground. However, more comprehensive measures are needed.

'Blue solutions' also play a crucial role in cooling cities. Water features can effectively lower local temperatures by capturing and dissipating heat, often cooling the air by one to three degrees Celsius. Moreover, evaporative cooling systems or misting technology can help to lower temperatures and improve the overall health of city residents.

To better understand UHI processes in megacities and other contributing factors, remote sensing and advanced urban climate modeling technologies are valuable tools that enable more effective interventions. Furthermore, residents can contribute through temperature surveys and by spreading awareness about the issue.

In summary, tackling the UHI effect in megacities is a significant challenge for the 21st century. It is crucial to develop a comprehensive understanding of the diverse drivers of urban heat and to establish inclusive adaptation and mitigation strategies. This effort is essential to safeguard the health, longevity, and resilience of our urban communities. Ignoring this escalating crisis will lead to increasingly severe environmental and societal consequences in our ever-urbanizing world.

SALTWATER INTRUSION INTO FRESHWATER SYSTEMS

Mir Wasif Ahammed

Saltwater intrusion is a silent yet major environmental threat along the coastline. This phenomenon refers to water moving landward, seawater moving into freshwater rivers, estuaries, and, more importantly, underground aquifers, which provide much to drink and water for irrigation. The mere evolution, as climate change gets faster, and human demand for freshwater grows, makes it all the more pertinent for saltwater intrusion to be researched and tackled.

How Saltwater Intrusion Happens?

Saltwater intrusion occurs through natural and anthropogenic activities. In coastal areas, freshwater aquifers are maintained to provide pressure to maintain the dense seawater inside the bay. When there is high groundwater pumping for agriculture, industries, and urban use, it may lead to the lowering of water tables, disrupting this balance and allowing seawater to intrude. On one hand, rising sea levels resulting from melting glaciers and thermal expansion would push the seawater inland, while droughts and the presence of dams upstream would diminish the freshwater flow that would otherwise be draining saltwater back to the ocean. On the other hand, extreme weather conditions such as hurricanes and storm surge can bring seawater inland into intakes and estuaries, causing instantaneous contamination.

Consequences for People and the Environment:

Under the effect of saltwater intrusion, society and nature become increasingly interrelated. Drinking water becomes unsafe with excess salinity-causing health-related hazards such as hypertension and kidney diseases. The communities are forced to spend heavily on alternative sources, further deepening inequalities; for instance, a richer place will be able to build a desalination plant, but a poorer one would hardly be able to afford. The salt goes to damage the very structure of the soil on which agriculture is practised, while salt worsens plant growth problems. In some regions, farmers have resorted to switching from rice to shrimp farming, which is only a temporary resolution in the real sense and worsens soil degradation. Ecosystem collapse ensues with the disappearance of freshwater species and the entry of salt-tolerant competitors that disrupt the food chains. Wetlands that provide natural storm buffering vanish, whereas storm surges increasingly flood coastal areas.

Regions Already Under Threat:

The impacts are felt farther around the world. In Bangladesh, saltwater intrusion has contaminated drinking wells across the coastal belt, pushing millions to use rainwater or expensive desalinated water. The Mekong Delta, the rice bowl of Vietnam, faces increasing salinity due to upstream dams and reduced flows of rivers, threatening the food security of millions.

Solutions and Innovations:

Given that addressing saltwater intrusion requires intersecting approaches of policy, technology, and community action, balancing these is a sustainable water management act. Controlling groundwater extraction, promoting agricultural practices that conserve water, and enabling the recharge of aquifers with treated wastewater or stormwater maintain that freshwater pressure. Nature-based methods entail restoring ecosystems such as mangroves and wetlands that absorb storm surges, filter saltwater, and provide habitats for flora and fauna. Policymaking measures that bring strict control on the use of groundwater and international cooperation on river basin management (e.g., Mekong River Commission) can lay the foundation for further overexploitation.

The challenge is big, but not impossible. Investing in monitoring systems to identify early signs of intrusion, supporting research on salt-tolerant crops, and putting climate adaptation front and center for coastal planning will lessen some of the worst effects. Yet, without annual action on climate change, saltwater intrusion will rise, increasing the impact of water scarcity and food insecurity. Now is your chance—before the freshwater you have known becomes a mere memory.

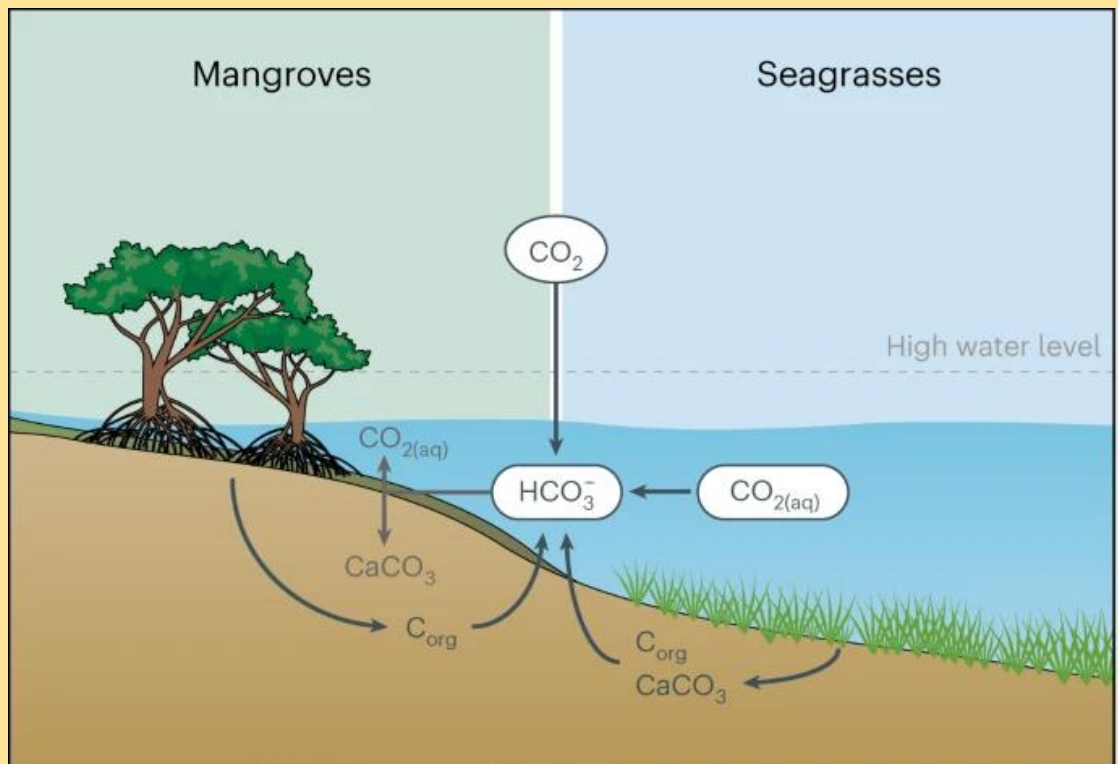
BLUE CARBON ECOSYSTEM DEGRADATION

Priti Biswas

The term "blue carbon" was coined in 2009 to refer to the organic carbon that is stored or sequestered in coastal and marine ecosystems. The term "blue carbon ecosystem" describes the entire coastal or marine habitat that facilitates the process of carbon sequestration. This ecosystem includes mangrove forests, salt marshes, and seagrass meadows. Blue carbon ecosystems provide numerous benefits to the overall environment, both directly and indirectly.

Coastal ecosystems, such as mangroves, seagrasses, and salt marshes, protect coastal waters from land-based pollutants, including agricultural runoff and wastewater, which can lead to algal blooms and deplete oxygen levels in water bodies. These ecosystems also help prevent shoreline erosion and provide protection from storms. Unfortunately, due to various human activities, these ecosystems are among the most threatened, and a significant portion is destroyed each year. Reports indicate that approximately 67%, 35%, and 29% of the global coverage of mangroves, tidal marshes, and seagrass meadows, respectively, have been lost, leading to the degradation of blue carbon ecosystems.

The main causes of degradation in these ecosystems stem from human activities such as aquaculture, agriculture, pollution from terrestrial and marine sources, and urban or industrial development, often referred to as human encroachment.



The impacts of blue carbon ecosystem degradation include the release of greenhouse gases, particularly CO_2 , into the atmosphere, worsening climate change, reducing carbon sink capacity, declining water quality (as these ecosystems act as filters for pollutants in surface runoff), and increasing coastal vulnerability due to the loss of natural buffers like mangroves and salt marshes.

Additionally, blue carbon ecosystems serve as habitats for many species, and their degradation results in habitat loss and decreased biodiversity. Many coastal communities rely directly on these ecosystems for their livelihoods through fishing, tourism, and sourcing materials like timber and thatch.

To help mitigate the degradation of blue carbon ecosystems, several remediation techniques can be employed. These include habitat restoration, which involves planting mangrove seedlings in degraded or newly suitable areas and re-establishing native vegetation in degraded salt marshes. Designating these ecosystems as protected land can also prevent destructive activities. Involving local communities in conservation efforts is crucial since they possess valuable knowledge about these ecosystems.

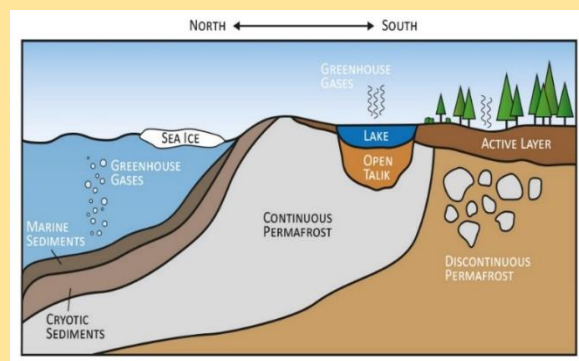
In conclusion, the degradation of blue carbon ecosystems presents a significant and complex challenge. Human activities are primarily responsible for this decline, and it in turn impacts both human communities and the environment. Therefore, proactive and integrated measures should be implemented at local, national, and international levels to safeguard and prevent further degradation of these vital ecosystems.

THAWING SUBSEA PERMAFROST AND ITS GREENHOUSE GAS EMISSIONS

Sanchita Saha

The Arctic's subsea permafrost is a crucial storage of frozen carbon located beneath the ocean. However, climate change is increasingly threatening this important resource. In recent years, subsea permafrost has been thawing at an accelerating rate, primarily due to warming bottom waters and geothermal heat. This thawing poses a significant risk of releasing large amounts of greenhouse gases into the atmosphere.

Subsea permafrost is defined as permafrost that became submerged in marine waters after sea levels rose following the last glacial maximum. It can be found underneath extensive areas of the shallow Arctic shelf, particularly on the eastern side of the Siberian Arctic Shelf, which is the widest and shallowest continental shelf in the world. This frozen sediment contains vast stores of organic carbon accumulated over millennia from ancient plants and animals. As permafrost thaws, this organic material becomes exposed to microbial decomposition, leading to the release of methane (CH₄) and carbon dioxide (CO₂), both potent greenhouse gases. The rate at which subsea permafrost is thawing is a serious concern. Unlike terrestrial permafrost, which thaws from the top down, subsea permafrost thaws from both above (due to warming bottom waters) and below (due to geothermal heat flux). The relatively warm river waters, along with Atlantic and Pacific waters penetrating deep into the Arctic Ocean, are rapidly warming the shelf waters. This warming destabilizes the permafrost, leading to the formation of "thaw bulbs" and taliks, which are zones of unfrozen ground within the permafrost.



Methane emissions from this region are particularly alarming. The Arctic Ocean, especially the East Siberian Arctic Shelf (ESAS), is known to be a significant source of methane. There is evidence of large plumes of methane escaping through bubbling from the seabed of degrading subsea permafrost. Various mechanisms enable methane to escape from thawing submarine permafrost. For instance, thaw bulbs create pathways for ancient methane trapped either as free gas or within ice-like structures known as hydrates to be released. Additionally, anaerobic microbes decompose organic carbon in newly thawed sediments, which generates methane. Moreover, the warming of bottom waters and the degradation of permafrost destabilize methane hydrates, leading to rapid dissociation and a substantial release of this potent greenhouse gas.

While methane has a high global warming potential in the short term, carbon dioxide presents a long-term threat due to its longer atmospheric lifetime. The ratio of CO₂ to CH₄ emissions is influenced by the availability of oxygen and microbial activity.

The consequences of significant greenhouse gas emissions from subsea permafrost are extensive. These emissions could initiate a positive feedback loop, where warming oceans cause increased thawing of permafrost, releasing more greenhouse gases, and further exacerbating global warming. This process could push Earth's climate past critical tipping points, making it increasingly challenging to mitigate the more severe effects of climate change.

Scientific research on subsea permafrost is relatively new compared to studies on terrestrial permafrost, leaving important uncertainties regarding the precise magnitude and timing of future greenhouse gas emissions. However, there is strong evidence suggesting that subsea permafrost is a vital component of the Arctic climate system that requires urgent attention. Increased monitoring, in-depth studies of thaw rates, mechanisms of gas release, and advanced modeling are essential to enhance our understanding and to predict the future behavior of subsea permafrost thawing and its implications for global climate. To mitigate this hidden danger, we must prioritize global collaboration to reduce greenhouse gas emissions and prevent further warming of the Arctic, thereby protecting a key element of our planet's climate system.

OCEAN ACIDIFICATION AFFECTING CORAL CALCIFICATION: DISENTANGLING THE THREAT TO REEF SUSTAINABILITY

Sneha Bhattacharyya

Ocean acidification threatens coral reef futures by reducing the concentration of carbonate ions that corals need to construct their skeletons, considering it as an important threat to coral reef ecosystems. As ocean acidity increases, the availability of carbonate ions declines, leading to slower growth rates and potentially weakens coral skeletons.

Ocean acidification is a direct consequence of the ocean absorbing excess carbon dioxide from the atmosphere. This absorption lowers the pH of seawater and reduces the concentration of carbonate ions, which are essential building blocks for calcium carbonate. Corals, along with other marine calcifiers, rely on carbonate ions to create their skeletons and shells. When these ions become less available, the rate of calcification slows down, making it more difficult for corals to grow and maintain their skeletons. Reduced calcification can lead to a decrease in coral skeletal density. This leads to making corals more vulnerable to damage from storms, predation, and disease. This can also impact the overall structure and biodiversity of coral reefs, as they are built and maintained by calcifying organisms.



Decline in coral calcification has both ecological and economic consequences. Ecologically, coral reefs support marine life by providing essential habitat, breeding grounds, and protection for countless species. The entire reef ecosystem is compromised when the corals struggle to calcify and grow. Less structural complexity means fewer hiding places and resources for fish and invertebrates which ultimately lead to declining biodiversity. Habitat loss for over 25% of marine species that depend on reefs, impacts coastal fisheries, food security and livelihoods. Economically coral reefs contribute billions of dollars annually to global economies through tourism, fisheries and coastal protection. Diminished coral growth due to acidification reduces attractiveness, decreases fish populations, and increases vulnerability of coastal regions to storm surges, threatening livelihoods and economies reliant on healthy reef systems.

Scientific evidence has shown numerous studies supporting the negative impact of ocean acidification – The Great Barrier Reef has experienced a 44% decline in calcification rates since the 1970s. Experiments in lab-controlled environments show that partial pressure of carbon dioxide levels projected for 2100 significantly reduces coral growth and health. Aragonite saturation state, crucial for calcification, is decreasing worldwide especially in tropical and polar oceans.

To mitigate this some strategies have been adapted at global and local level. Global actions have been taken to cut carbon emissions through renewable energy, reforestation, and carbon capture. Enforce international agreements like the Paris Agreement. Local actions like reducing pollution by limiting the runoff from agriculture and sewage that exacerbates coral stress, established Marine Protected Area (MPAs) to safeguard resilient coral populations, introduced sustainable fisheries management to protect reef herbivores (e.g., parrotfish that control algae).

In conclusion, Ocean acidification significantly hampers coral calcification, reducing the availability of carbonate ions which weakens coral reefs, making them more vulnerable to erosion and collapse, threatening marine biodiversity and coastal ecosystems. Urgent global efforts are needed for essential protection and preservation of coral reef systems.

IMPORTANCE OF NATURAL RESOURCES IN AGRICULTURE

Souvik Dey

Agriculture is the backbone of human civilization, playing a pivotal role in providing food security for all living organisms. The sector's success hinges on the availability and sustainable management of essential natural resources. These resources—soil, water, air, forests, and minerals—form the foundation of the agricultural ecosystem. However, overexploitation, pollution, and climate change pose significant threats to these vital resources. By adopting sustainable practices and conservation methods, we can ensure that future generations have the opportunity to live healthier, more prosperous lives than our own.

Soil: The Foundation of Farming- Soil is arguably the most crucial natural resource in agriculture, serving as the medium in which crops grow. Fertile soil not only supports plant growth but also ensures better nutritional content and higher yields. Unsustainable farming practices, such as excessive tillage, monocropping, and the overuse of synthetic fertilizers, disrupt the soil profile and degrade soil health. In contrast, sustainable techniques—including crop rotation, organic farming, and agroforestry—enhance the biological diversity of the soil ecosystem. Healthy soil promotes efficient nutrient management and significantly increases the productivity of agricultural outputs, providing more food while maintaining ecological balance.

Water: The Lifeline of Agriculture- Water is another essential natural resource in agriculture; without it, crop growth is impossible. It facilitates the transformation of soil nutrients into forms that plants can readily absorb. Unfortunately, the overuse of chemical fertilizers and pesticides can contaminate water supplies, adversely affecting the agricultural ecosystem. To ensure optimal plant growth, water quality is paramount; clean water not only boosts plant health and enhances yields but also fosters beneficial microbial activity in the soil. This microbial activity plays a key role in maintaining soil parameters such as pH, cation exchange capacity (CEC), and electrical conductivity (EC), all of which are critical for healthy plant growth.



Air: The Breath of Agriculture -Air plays a crucial and often overlooked role in agriculture. It is indispensable for multiple processes, including plant respiration, photosynthesis, pollination, and seed dispersal. Furthermore, air also influences soil aeration, which is vital for root health and nutrient availability. A healthy air composition promotes the proliferation of microorganisms in the soil, which in turn release essential nutrients for plant uptake. However, air pollution can severely hinder crop yields and plant vitality, as pollutants such as ozone and black carbon have detrimental impacts on plant development. Additionally, air dynamics are responsible for seasonal changes, with phenomena like monsoon rains being influenced by wind patterns.

Forests: The Lungs of Earth- Forests are profoundly important for agriculture, significantly contributing to food security and promoting sustainable agricultural practices. They play a vital role in regulating the water cycle, reducing runoff, and enhancing water infiltration into the soil. Moreover, forests foster biodiversity and can diversify income for farmers through approaches such as agroforestry, allowing for the cultivation of specialty crops alongside traditional agricultural practices. This integration not only supports the ecosystem but also creates economic opportunities for communities reliant on agriculture.

Minerals and Nutrients: The Building Blocks of Plant Health- Natural minerals and nutrients are essential for maintaining plant health and promoting agricultural productivity. Organic matter, such as compost and manure, naturally replenishes soil nutrients, fostering a rich nutrient profile that is crucial for plant growth. Unlike synthetic additives, natural minerals do not degrade soil health; rather, they positively influence soil pH, enhance structure, and improve fertility. These minerals are abundantly available in nature, and plants continually absorb them to support their growth processes, making their presence in the soil indispensable.

In summary, a harmonious relationship among these resources is critical for sustainable agriculture. By ensuring their responsible management, we can secure a future where agricultural practices are both productive and environmentally sound, ultimately leading to a thriving planet for generations to come.

WILDLIFE ON THE MOVE: HOW CLIMATE CHANGE DRIVES SPECIES MIGRATION

Srinjoy Roy

As the temperature rises and weather patterns change, the natural world is rearranging its map. From mountain meadows to coral reefs, wildlife is on the move — not seasonally, but as a long-term adjustment for try to cope with this warming planet. Species are moving into new areas, often abandoning habitats that no longer sustain them. It is not only a few birds or butterflies — according to scientists, climate-forced migration now impacts over half of all species on the planet. The migration is reshaping ecosystems, changing food chains, and posing new conservation problems for the world.

Major Factor:

- **Rising heat:** Due to warming many species shift their location in higher altitude. For instance, animals living in mountains are already moving to higher region to remain cool.
- **Rainfall:** Changes in rain pattern and weather force their movement. Droughts or intense rains can make areas unliveable, so species often “travel to other regions that fit their climatic range”
- **Human Activity:** Human’s unscientific and non-sustainable land use practises can trap wildlife. If habitats become patchy, animals may be stuck because roads or farms cut off escape routes or their natural migration corridors.

Effected region are hamper for climate change:

Even the frozen vastness of the Arctic feels the insidious creep of heat, affecting even small animals. Lemmings, rodents that tunnel under snow, now frequently discover their dens frozen-over, resulting in fewer offspring for their predators such as foxes, gulls, and owls. Bigger Arctic animals are changing, too, with polar bears spending more time on land and venturing further to hunt as sea ice is lost. The white Arctic fox also experiences mounting threat from south-intruding red foxes, which adapt better to the warmer conditions and perturb the balance of the polar ecosystem.



Warming seas are causing a shift in marine life, with sub-Arctic fish and tropical species moving into Arctic and temperate waters, disrupting food webs and fisheries. Terrestrial ecosystems are also affected, as highland fauna and trees migrate to cooler areas, with predictions of subtropical trees replacing firs by 2100. Urban environments like Toronto may experience significant species turnover, losing native birds while welcoming warm-climate species previously found further south.

Ecological ripple effects:

These migrations affect ecosystems in several ways:

- **Food-web disruptions:** Predators face challenges due to predators' movements and disappearances, such as the Arctic lemming collapse and timing mismatches, affecting their ability to raise young.
- **New competitors:** Arriving species often out-compete locals. The northward red fox threatens the Arctic fox. Likewise, insects and plants in new areas often act like invasives, overwhelming native species.
- **Extinction risk:** Not all species can keep up. Creatures at the warm edge – mountain summits or polar tundra – have nowhere to go. Scientists warn warming will greatly increase extinctions in these sensitive regions.
- **Human impacts:** Shifting wildlife affect people too. Warmer, wetter climates are enabling [mosquitoes’] spread to new places. Dengue, malaria, and other pests are reaching new areas, posing health challenges.

To Conclude: Safeguarding Biodiversity Through Adaptation:

As climate change forces species to migrate, maintaining connected habitats through wildlife corridors is essential to prevent isolation in fragmented landscapes. Conserving stable climate refugia and facilitating species migration are also crucial. Most importantly, reducing emissions is needed to give nature time to adjust. Additionally, climate-induced migrations are altering ecosystems with uncertain effects on species, highlighting the need to shift conservation efforts towards habitat preservation, efficient land use, and significant emissions reductions to protect biodiversity in a changing world.

PLASTIC POLLUTION FROM SYNTHETIC MICROFIBERS

Susmita Sarkar

Microfibers are the tiny synthetic fibers that are made from synthetic textiles such as polyester, nylon, and acrylic, have emerged as a notable contributor to global plastic pollution at the global level. These fibers are emancipated throughout the life cycle of clothing – during production, wear, and especially during washing. A single laundry can release 600,000 microfibers into the wastewater systems, many others of which go to treatment plants and enter rivers, lakes, and oceans.

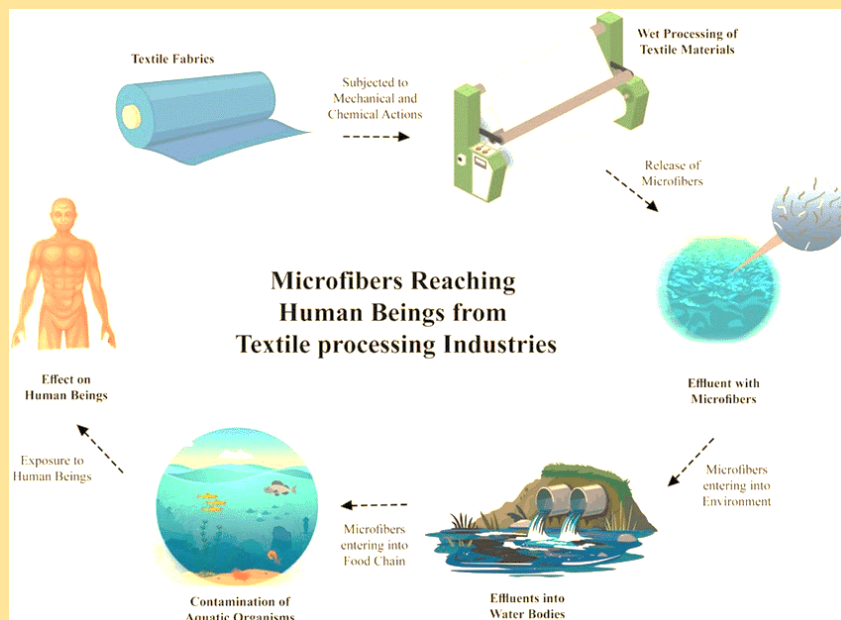
Synthetic textiles are responsible for about 45% of microplastics released into the ocean. In India, the second largest producer of polyester and viscose, studies have detected high concentrations of microfibers in major water bodies such as the Ganges River. These microfibers are a threat to marine life, as they can be consumed by aquatic organisms and exacerbate physical harm and potential bioaccumulation of toxins in the food chain, which affects ecosystems.

This Microfibers influenced health effects also affect humans. Microfibers have been found in various human tissues and fluids, mostly in lung tissue, feces, and even the arteries. Prolonged period of exposure can cause inflammatory responses, and it is linked to conditions such as chronic diseases, such as lung damage, heart disease, and reproductive dysfunction.

Fast fashion mostly influence the problem, Clothes that are quickly and cheaply produced, those are contain low-quality synthetic fibers that shed more microfibers, especially during the initial wash. But now, following the trends, Global demand for these types of clothing has increased, with synthetic fiber production expected to reach 78 million tons annually by 2030.

Tackling microfiber pollution, it is necessary for multi-pronged approach. By which Consumers can reduce their impact by washing clothes less frequently, using cold water. Suggested to use fiber-catching devices such as Cora balls or specialized laundry bags. On a larger scale, Novelty in textile production, such as developing biodegradable fibers and improving the wastewater treatment processes very carefully, which is crucial. Policy interventions such as mandating microfiber filters in washing machines have been proposed in some regions, although implementation varies from one region to another. In India, despite the country's significant role in synthetic textile production, awareness of microfiber pollution is limited, and the effects of microfibers will be high. Increasing public understanding, awareness, and encouraging sustainable practices in both production and consumption processes it is essential steps to mitigate this environmental challenge.

It is primarily shed from synthetic clothing like polyester and nylon, which are a major yet often overlooked form of plastic pollution. These fibers, thinner than a human hair, and released into the environment during laundry and garment production. Since wastewater treatment plants often cannot filter out such tiny particles, millions of microfibers are flow into water bodies such as rivers, lakes, and the ocean. Marine organisms frequently ingest these fibers, mistaking them for food, which disrupts aquatic ecosystems and allows masticated microplastics to enter the food chain. In humans, microfibers have been detected in blood, lungs, and placental tissue, raising concerns about long-term health effects or chronic diseases such as respiratory and hormonal disorders.



AQUIFER DEPLETION IN FOOD-EXPORTING COUNTRIES: A QUANTIFIABLE CRISIS FOR GLOBAL FOOD SECURITY

Triparna Pal

Aquifer depletion has critically affected major food-exporting nations, threatening global food systems, as confirmed by statistical analyses. The findings indicate that 11% of global groundwater extraction is unsustainable, with 60% of this shortfall linked directly to agricultural exports (Perez et al, 2024). For instance, the 'Ogallala Aquifer,' beneath the U.S. High Plains, is vital for 30% of U.S. irrigation. In certain areas of Kansas, this aquifer declines at a rate of 2-3 meters per year, having lost over 330 km³ since the pre-industrial period. Similarly, the 'Indus Basin,' which sustains around 25% of agricultural output in Pakistan and 10% in India, experiences a depletion of 10-16 km³ annually, leading to a yearly drop in water levels by 3-4 cm (Dalin et al, 2017). This basin exploits rapidly depleting water resources to cultivate high-value cash crops. To bolster its export-driven economy, the U.S. allocates 35 km³ annually for maize and wheat production, while India consumes 54 km³ per year, utilizing 90% of its groundwater for rice and cotton cultivation.

The concept of "virtual water" entwined in global food trade exacerbates resource inequities. Wealthy nations such as the U.S. and China, with India, are responsible for 67% of groundwater depletion linked to exports. Meanwhile, water-scarce importing countries like Iran, Mexico, and Egypt depend on these exports for 22 to 34 percent of their staple food supply. Pakistan, for instance, annually exports 3.6 km³ of water through rice, which constitutes 40% of its yearly groundwater depletion, despite facing severe water scarcity (Dalin et al, 2017). Saudi Arabia has transitioned from being a major wheat producer, exploiting fossil groundwater, draining 4.2 km³ per year until 2016, when it ceased production and turned to imports.

Currently, over-exploited aquifers are responsible for supporting 21% of the world's irrigated croplands located in food-exporting nations (Perez et al, 2024). Future forecasts predict alarming scenarios: the U.S. High Plains could experience a 35% reduction in irrigated areas by 2100, while the Punjab region of India might lose 70% of its cropland to irreversible infertility by 2030, due to a groundwater extraction recharge rate of 145%. In South Asia and the Mediterranean, river flows have nearly ceased, with surface water access restricted by 15-20%. This situation traps farmers who depend on free surface water, forcing them to exploit groundwater, which has increased usage by 25-40% since 2000. Uncontrolled resource usage may drive these regions toward an unsustainable resource crisis and agrarian overpopulation.

Data-driven policies are crucial for finding solutions. In India's Punjab region, adopting drip irrigation could decrease water use by 30-50%, while implementing a charge of \$0.03-\$0.05 per m³ of groundwater could reduce consumption by 20-35% (Perez et al, 2024). Political complacency exacerbates the issue; in the U.S. and India, over-subsidizing crops that demand excessive water costs \$10 billion yearly, fueling inflation and resource depletion. If systematic policies remain unaddressed, aquifer subsidence is expected to rise, leading to a 6-8% reduction in food production and exports from food exporters by 2050. This situation would adversely affect 500 million residents in resource-dependent countries.

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GLOBAL FRESHWATER SECURITY UNDER CLIMATE PRESSURE

Trisha Mondal

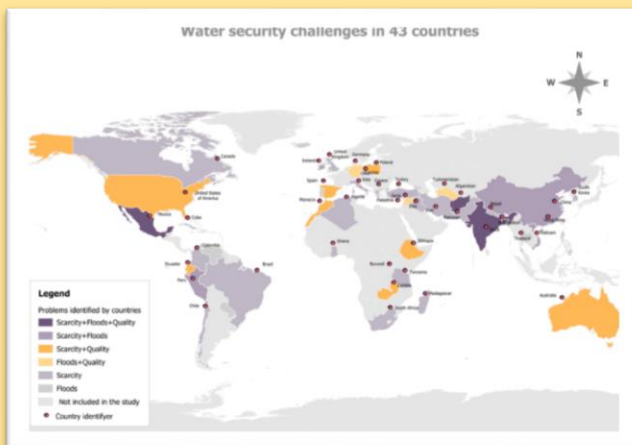
Global freshwater security is the ability of human populations to maintain adequate water resources for their living, well-being, and economic growth. It has multiple facets that include water quality, sustainability, and resilience to water-related risks. All these require an elaborate process of coordination among various governance levels, sectors, and political divisions. Freshwater is a life-sustaining natural resource for all forms of life, which societies develop and place constraints on. Threats to its security will surely have grave consequences. Climate change presents a substantial threat to water security by making water resources from a source of abundance to a source of scarcity, by making them unreliable and most often polluted, thus affecting all programs toward sustainable development goals, threatening biodiversity, and halting universal access to basic water and sanitation services.



Unlike before, climate change, disturbed hydrologic cycles on Earth, increased evaporation, storms, and droughts. These are adverse effects on the effective management of water resources. Increased temperatures cause a lot of damage to freshwater resources, eminent among them being water pollution, disruption of ecosystems, impairment of human health, and increased operational costs. The risk to runoff from increased flooding and droughts is also under climate change. Groundwater resources as an insurance to surface water fluctuations are now under threat from increased precipitation fluctuations. Surface water resources are most threatened by climate change.

Climate change has been posing serious threats to water security, which includes impacts **on food production, agriculture, human health, sanitation, and environmental health**. Short to medium water scarcity leads to

food insecurity due to low production in agriculture. Also, drought frequency generally increases, rainfall patterns are altered, and seasonal water reservoirs are depleted because of climate change. Contaminated water can spread diseases, disrupt sanitation systems, and degrade ecosystems. The lack of adequate clean water supply can hamper economic growth. Worldwide acute freshwater insecurity has been propelled by global warming, especially in Africa, Asia, the Middle East, and SIDS. Africa has faced enormous water stress, and it may displace about **700 million** people by 2030. Asia faces similar water insecurity pressure with huge river systems vulnerable to severe degradation. The Middle East and North African region is the most water-stressed region.

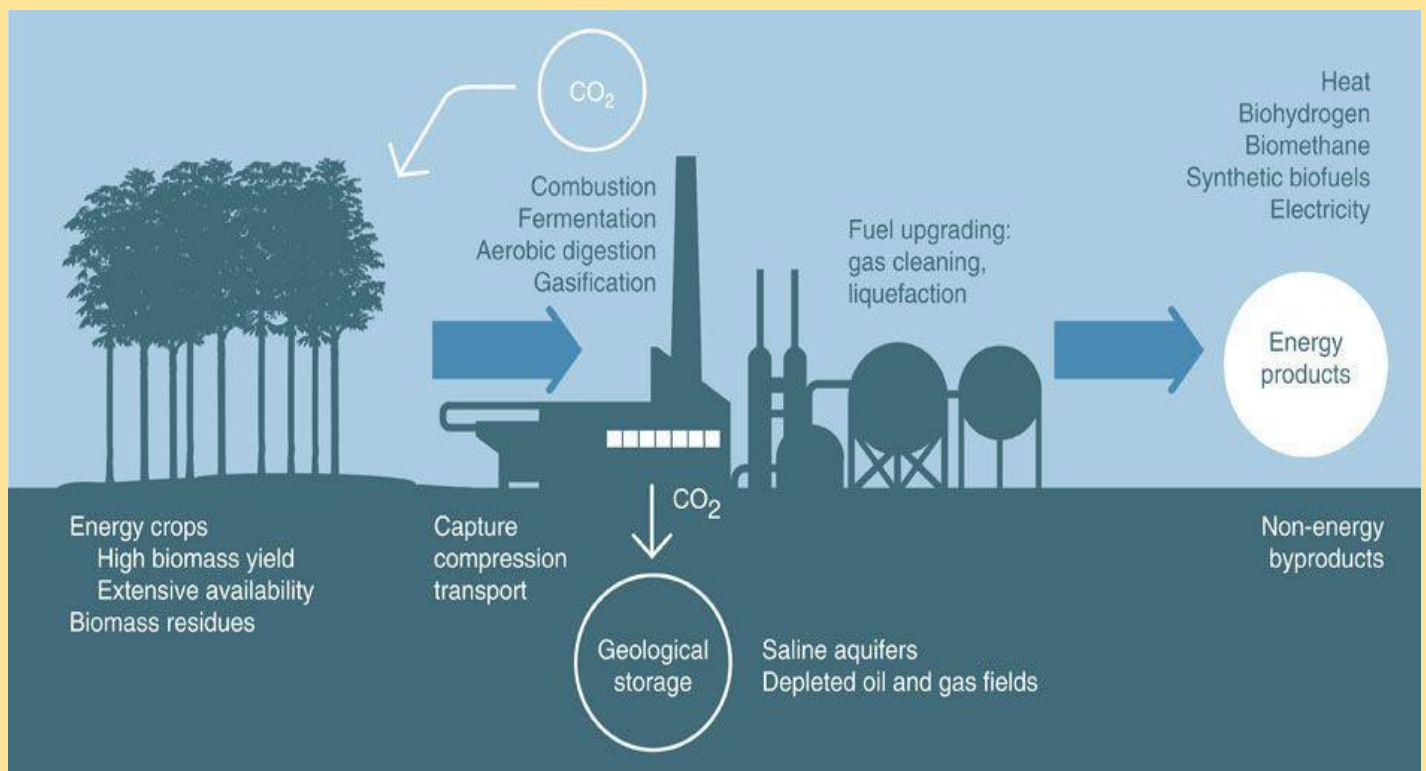


The global freshwater security crisis demands sustainable water management approaches like Integrated Water Resources Management-IWRM-and technology. Such approaches ensure the balanced withdrawal of water in the different sectors, minimizing wastage, safe wastewater reuse, and equitable share of water. In addressing freshwater security and resilience to climate change, the necessary policy frameworks can include water pricing and nature-based solutions. Freshwater security around the world is complicated and calls for interventions along various sectors. It needs cross-cutting and multilateral approaches, shedding light on the inter-linkages between water resources, food, energy systems, and ecosystem health.

ATMOSPHERIC CARBON REMOVAL TECHNOLOGIES TO COMBAT THE CLIMATE CRISIS

Trisha Ghosh

International Panel on Climate Change (IPCC) defines atmospheric carbon removal technologies as a cluster of technologies, practices, and approaches to remove and sequester carbon dioxide from the atmosphere. Atmospheric carbon removal technologies will help to reduce global warming by decreasing the amount of carbon dioxide from atmosphere. Atmospheric carbon removal technologies require significant energy, land, water, and material resources to work efficiently. Direct air carbon capture and storage requires huge energy for sorbent regeneration and CO₂ compression, while Bioenergy with carbon capture and storage needs afforestation compete with agriculture for land which is a threat for food security and biodiversity. To remove 1 gigaton of CO₂ annually by direct air carbon capture and storage method, it needs to be processed air volumes equivalent to global natural gas flows which demand up to 10% of current global energy output. Large-scale afforestation required land areas, with long-term carbon storage efficacy but this method can be uncertain due to low humidity and wildfires.



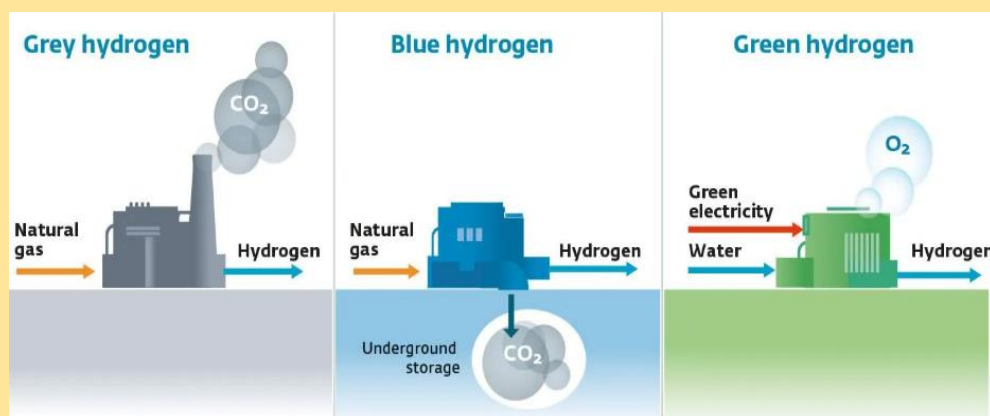
Carbon dioxide removal methods are important to minimize environmental trade-offs. Overdependence on CDR could delay urgent emission reductions and control the climate risks. To avoid this, rapid decarbonisation of energy in industry, and transportation sectors need to be adopted some sustainable methods. It also recommends assessing net carbon removal, energy use, and environmental impacts. Public engagement and interdisciplinary collaboration are needed to address socio-technical challenges like public acceptance; cost barriers etc. atmospheric carbon removal works as a crucial tool to reduce excess CO₂ and reduce the rate of global warming. Carbon removal technologies offer an approach to restore balance. Innovations such as direct air capture, enhanced weathering, and reforestation have the potential to reduce carbon from the atmosphere. But there are some challenges like scalability and cost that have become barriers for those methods. Collaborative action of governments, industries, and individuals are required to form an effective carbon removal strategy for society. Investment in research, policy support, and public awareness programmes can improve progress. Ultimately, atmospheric carbon removal is not just a technological method to follow; it is also a sustainable practice for safeguarding the planet for future generations.

HYDROGEN ENERGY AS A CLEAN PATHWAY TO ENERGY INDEPENDENCE

Akash Chakraborty

Every modern-day assessment of the world's energy prospects assumes that the growing demand must be met by a varied energy mix. Numerous energy sources exist in the world that can be used to provide an even greater range of energy carriers. Today world's primary energy sources and carriers are fossil fuels, but the supply of fossil fuels is finite, and using them harms the environment. Also, the societies cannot operate effectively with energy only in the form of electricity, as they also need chemical fuels. So, in this era of increasing climate crises and environmental degradation, the concept of environmental security has gained importance. This concept refers to protecting the environment to assure sustainability and human well-being, preventing resource-based disputes, and protecting the ecosystems from adverse impacts. In the centre of this concept, there is an idea of the transformation of our global energy systems, which are currently dominated by fossil fuels. One of the best options on the horizon for the global energy sector is hydrogen energy, a sustainable, clean, and unlimited energy carrier with which we can address multiple areas of both environmental and energy security.

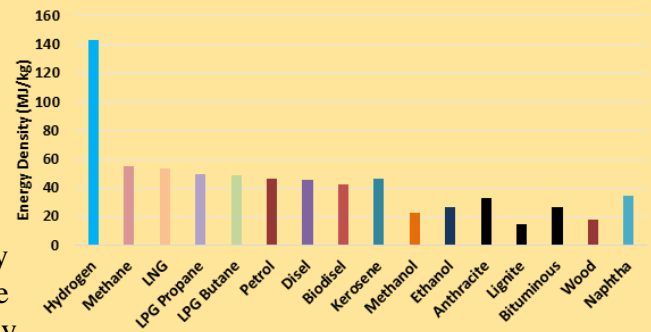
Hydrogen is the most abundant element in the universe, with the highest gravimetric energy density, and may be harnessed to generate clean energy without emitting greenhouse gases at the time of usage. It can replace coal and natural gas in industrial processes, and can serve as an alternative fuel that can reduce the environmental burden. According to the IEA (International Energy Agency), demand for hydrogen across the world is estimated to be 97 million tonnes in 2023, and it can reach more than 500 million tonnes by 2050. At present, 95% of all produced hydrogen is "grey", which is made out of fossil fuels without any carbon capture, and emits nearly 900 million tonnes of CO₂ yearly. But hydrogen can be produced through various pathways from renewable sources, with one of the cleanest being "green" hydrogen from water electrolysis, emitting zero greenhouse gases. The cost of green hydrogen has dropped by more than 50% in five years, mainly helped by solar and wind prices, and the World Bank has projected it to outprice grey hydrogen by 2030, particularly in



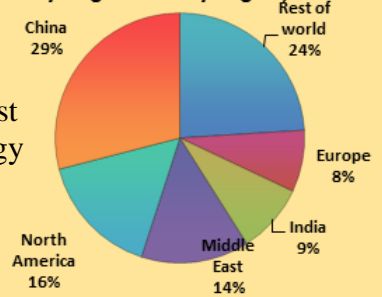
of hydrogen, requiring 9 liters of water, which raises concerns about water security in arid and semi-arid regions. Still, many countries with a focus on energy security have released hydrogen roadmaps, and over \$500 billion in investments are planned by 2030.

Due to its higher energy density and clean emissions, hydrogen energy can lead the way towards sustainable development. As the nation's contemplate climate challenges and energy insecurity, green hydrogen investment is neither merely a solution nor an option, but it's a strategic necessity for a cleaner, resilient, and self-reliant global future.

Gravimetric Energy Density of Different Fuels



Hydrogen Used by Region, 2023



BIO-WASTE MISMANAGEMENT IN MEGA-CITIES

Ashis Sarkar

Biowaste, comprising organic waste such as food scraps, agricultural residues, and biodegradable materials, poses a significant challenge in the waste management systems of megacities around the world. As urban populations soar and consumption patterns shift, the volume of biowaste generated increases exponentially. When mismanaged, this waste contributes to severe environmental, public health, and infrastructural issues. Mega-cities, due to their sheer scale and complexity, often struggle with sustainable solutions for biowaste, resulting in a growing urban crisis.

In India, the situation is emblematic of the broader challenges faced by developing nations. Cities like Mumbai, Delhi, and Bengaluru generate thousands of tonnes of municipal solid waste daily, of which nearly 50–60% is biodegradable. Despite this, the segregation of waste at source remains alarmingly low. In Mumbai, for example, more than 7,000 tonnes of solid waste is generated daily, yet a significant proportion of this ends up in landfills without proper segregation. The Deonar dumping ground, one of Asia's oldest and largest landfills, periodically catches fire due to the build-up of methane gas from decomposing organic matter. These fires emit toxic smoke, contributing to air pollution and causing respiratory problems for nearby residents. Moreover, open dumping of biowaste leads to leachate formation that contaminates groundwater and attracts disease vectors such as rats and flies.

Bengaluru, once known as the "Garden City," is now grappling with severe waste management issues due to rapid urbanization. A lack of adequate composting infrastructure has led to organic waste piling up on streets, clogging drains, and increasing the risk of vector-borne diseases during monsoons. Though some citizen-driven initiatives like the '2bin1bag' campaign have promoted waste segregation, the city's processing capacity has not kept pace with waste generation, resulting in unprocessed biowaste being dumped or burned.

Outside India, similar challenges are visible in cities like Jakarta, Indonesia, and Lagos, Nigeria. In Jakarta, uncontrolled dumping of organic waste into rivers and drainage canals has not only degraded water quality but also contributed to frequent flooding. The Ciliwung River, flowing through the city, is heavily polluted with biowaste, which clogs the river flow and exacerbates the impact of seasonal rains. The government's attempts to implement biowaste separation programs have largely failed due to a lack of public awareness, poor enforcement, and insufficient infrastructure.

In contrast, some global cities offer models of more successful biowaste management. For instance, Seoul in South Korea has implemented an advanced food waste recycling program where residents are charged based on the weight of the food waste they dispose of. Smart bins using RFID technology ensure accountability and encourage households to minimize and properly segregate their organic waste. The collected waste is processed in bio-conversion plants to produce biogas and compost, contributing to both renewable energy generation and urban farming initiatives. Similarly, in Milan, Italy, a well-organised door-to-door collection system supported by public education campaigns has achieved over 90% compliance in source segregation, enabling efficient composting of biowaste.

The core challenges in biowaste mismanagement include the lack of source segregation, insufficient infrastructure for composting or anaerobic digestion, and poor policy enforcement. Additionally, socio-economic factors such as informal waste picking, public apathy, and political fragmentation hinder progress. In most mega-cities, the informal sector plays a significant role in collecting and sorting waste, but their efforts are often unrecognized and unsupported.

Addressing biowaste mismanagement requires a multifaceted approach. Municipal authorities must invest in decentralized composting units, provide incentives for households and commercial establishments to segregate waste, and integrate informal waste workers into the formal economy. Public education campaigns, technological innovations, and robust policy frameworks are also essential for changing behaviors and sustaining long-term impact. As cities continue to grow, the urgency of addressing biowaste mismanagement becomes ever more critical—not only to prevent ecological degradation but also to create cleaner, healthier, and more sustainable urban environments.

HIGH ALTITUDE WIND ENERGY: INFRASTRUCTURE IMPACTS AND ENVIRONMENTAL CONSIDERATIONS

Ashmita Rakshit

The increasing urgency of global climate change mitigation has fuelled the transition from fossil fuels toward sustainable and renewable energy sources. Wind energy, as a mature and rapidly expanding part of this transition, has traditionally relied on terrestrial and offshore installations. However, technological innovations over the past two decades have expanded the conceptual and engineering horizons of wind harvesting into the realm of high-altitude wind energy (HAWE) – that leverages the stronger, more consistent wind currents available in the upper troposphere (typically between 500 to 2000 meters above sea level).

HAWE systems aim to exploit wind resources beyond the reach of conventional wind turbines by using tethered airborne devices like rigid wings, soft kites, aerostats, or drones equipped with onboard turbines or mechanical winches. These airborne devices are connected to ground-based stations via high-strength tethers that serve both structural and transmission functions. Energy conversion can occur either aloft (via onboard generation and transmission through conductive tethers) or terrestrially (through mechanical – to – electrical conversion at the ground station). The theoretical potential of HAWE is immense. Estimates suggest that atmospheric winds contain approximately 870 terawatts of kinetic energy- an order of magnitude higher than global human energy demand- much of which resides in high-altitude layers. Thus, developing this untapped domain necessitates a thorough understanding of infrastructure impacts, particularly as HAWE transitions from experimental prototypes to commercial deployment. While HAWE offers substantial theoretical advantages in terms of energy yield and spatial efficiency, it also brings forth a new class of infrastructure impacts- both beneficial and adverse- that span environmental, socio-economic, technological, and regulatory spheres.

Environmental and Ecological Impacts: Though HAWE systems use less land than traditional wind farms, their ground stations, mooring platforms, and access roads can still cause habitat fragmentation, vegetation loss, and soil disturbance- especially in sensitive highland ecosystem. Wildlife impacts, particularly on birds and bats, are a concern as the tethered systems operate at altitudes used by migratory species, increasing collision risks. Visual intrusion from airborne devices and noise from cables and onboard machinery can disrupt both wildlife and human communities. Moreover, large-scale HAWE systems may potentially alter local airflow or weather patterns, though such effects remain speculative and require more research.

Technological and infrastructure challenges: HAWE systems depend on advanced tether materials like carbon fibre or aramid composites to withstand high stress, UV exposure, and extreme weather. Ground stations equipped with generators, winches, and control units must operate in real time with airborne components, using AI-driven systems and telemetry. Airspace management is another major issue, as HAWE devices often operate in zones shared with civil or military aviation, requiring updated safety protocols, radar integration, and regulatory oversight.

Socio-economic and Political Impacts: In regions such as the Himalayas or Andes, HAWE infrastructure could conflict with indigenous land rights, grazing routes, or sacred sites. Without community engagement and free, prior, and informed consent (FPIC), such projects risk causing social tension. While HAWE creates high-skilled jobs, it may also exclude local labour unless technical training is provided. As wind is steadily available at higher altitudes, the operational costs are low, but initial investment, insurance, and compliance costs are high, posing challenges for implementation in low-income regions.

Regulatory and policy gaps: HAWE technologies operate in partially unregulated airspace, raising questions about international liability. Current environmental impact assessments (EIAs) are not designed for vertical systems, and energy policies may not yet support their integration into national grids. New legal and planning frameworks are needed to manage these unique infrastructural impacts.

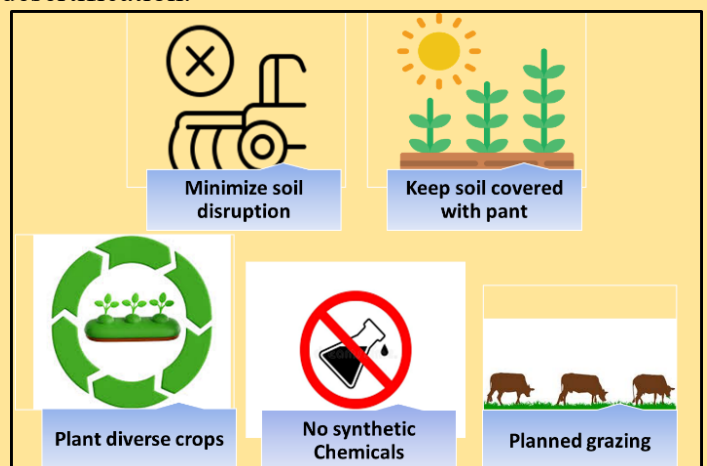
REGENERATIVE AGRICULTURE AND CLIMATE CHANGE

Dipayan Laha

Regenerative Agriculture is a holistic land management practice that leverages the power of photosynthesis in plants to close the carbon cycle and build soil health, crop resilience, and nutrient density. Regenerative agriculture counters climate change and promotes food security by restoring soil, organic matter, and biodiversity, as well as reducing atmospheric carbon. Regenerative agriculture has a wide range of environmental and societal benefits. Moving to this system would slash greenhouse gas emissions from farming — a significant contributor to climate change — and capture carbon in the soil. By enhancing its organic content, regenerative methods would increase moisture and help protect against drought. And they can play a big role in preserving indigenous agrarian knowledge, resurrecting family farming, and reviving rural regions. Believe it or not, a solution to climate change may lie beneath our feet. The buzz around regenerative agriculture is growing – not only as a climate solution but also as a tool for drought protection, a way to improve farmer incomes, and to ensure our food security into the future.

Regenerative agriculture follows five principles, such as:

- Minimizing disruption to the soil ecosystem keeps plant roots connected to unique communities of microorganisms that are key in the processes to build healthy soil and store carbon.
- Keeping the ground covered with plants has many benefits: It allows for water and carbon to be absorbed by the soil, which keeps the soil alive, helps eliminate soil erosion by preventing the soil from blowing or washing away, and prevents desertification.
- Multiple crops rotated in fields, perhaps with integration of livestock, mimics natural ecosystems and enhances biodiversity, which contributes to healthy soil.
- Utilizing synthetic chemical fertilizers discourages the plant to seek nutrients deeper in the soil and work with microbes for its nutrition, which results in less carbon sequestration. Utilizing chemical pesticides further disrupts the soil microbial community and has other negative impacts on biodiversity, and contributes to land and water pollution. And pesticide exposure through the food we eat, the air we breathe, and the water we drink has been linked to health impacts that range from birth defects to cancers and neurological disorders.
- Planned or rotational grazing of grasses mimics the patterns of animal herds, which ensures land is not overgrazed, and manure fertilizes the soil and contributes to carbon sequestration. Animals in pastured systems tend to be healthier and do not need antibiotics to treat disease.



Climate change is increasing at a fast rate and is causing deterioration in the areas of human settlement, the environment, and the agriculture industry. One of the positive steps taken in response to this crisis is regenerative agriculture -- a type of farming that makes use of nature instead of working against it. Through the application of techniques like cover cropping, reduced tillage, composting, and agroforestry, farmers can cultivate healthy soils that will be able to take carbon dioxide out of the atmosphere and hide it safely beneath the earth's surface. Not only is this an effective way to mitigate global warming, but it also promotes the productivity and resilience of farms. Research findings reveal that the employment of regenerative farming methods may lead to a significant increase in soil carbon as well as yield gains without the necessity of excess synthetic fertilizers. A total area of over 600 million hectares is already being farmed using these methods, while several notable instances of success have happened in Brazil and Africa. Regenerative agriculture also features a lot of support from farmers, governments, and companies, and thus it is a very real possibility for the restoration of the earth and the mitigation of the global warming problem. It is a solution that we must not ignore.

FLOATING SOLAR FARMS

Ditsa Maity

The Energy Information Administration predicts a 50% increase in global energy consumption between 2020 and 2050. In 2021, primary energy demand for heat, electricity, and transportation rose by 5.8%, compared to a 1.3% increase in 2019. To meet this growing demand, the global community is increasingly adopting renewable energy sources, such as hydroelectric power, solar power, biomass, and wind energy. The United Nations reports a steady trend in renewable energy usage, with electricity production from these sources rising from 19.7% in 2010 to 26.2% in 2019.

Solar energy, in particular, has experienced remarkable growth, accounting for 58% of installed capacity between 2017 and 2021. Importantly, solar panels do not have to be mounted on the ground; they can also be installed on floating platforms, known as floating solar farms. Floating solar photovoltaic (PV) power is a clean, green, and renewable energy source that can be set up on water bodies like lakes, reservoirs, and ponds. This method not only utilizes otherwise unused water surfaces but also enhances efficiency and conserves water resources by reducing evaporation losses. Floating solar photovoltaics present a sustainable solution for climate change. The history of floating solar PV dates back to the 1930s when a U.S. warship, the "Jacona," was converted into a power-generating plant in England. This technology doesn't require land, making it suitable for agricultural or construction purposes. Water bodies can improve solar panel performance by 5-10% due to their cooling effects, which lead to cost savings by reducing shading, civil works, and contributing to better water quality by minimizing algae blooms. There is significant potential for floating PV (FPV) to expand in the future.



FPV technology was first formally introduced when two Japanese companies, Mitsui Engineering & Shipbuilding Co. Ltd. and Mitsui Zosen KK, filed a patent application, establishing Japan as a leader in this field. In 2007, Japan became the first country to install FPV systems, followed by the United States, Europe, South Korea, China, India, and Brazil. Following a 2008 European conference that studied the enhanced performance of solar PV on water, FPV technology gained increased traction and attention. This conference marked an important turning point in the evolution of FPV technology.

Since then, the installed capacity of FPV power plants has grown significantly, increasing from 100 MW in 2016 to over 3 GW in 2021. Forecasts predict a bright future for FPV, with an expected growth rate of 22.5% by 2030. In the South Asian region, floating solar projects are currently operational in India, the Maldives, and Bangladesh, while Pakistan and Sri Lanka are in the early stages of exploration. India has the potential for floating solar energy generation capacities of 280-300 GW; however, only a small fraction of this potential has been installed in states such as Madhya Pradesh, West Bengal, Andhra Pradesh, Kerala, Telangana, Bihar, and Rajasthan.

Currently, the cost of generating floating solar power in India is higher than that of ground-mounted installations for several reasons. The eligibility criteria for floating solar sites are unclear, and manufacturing capacity for floating solar equipment is limited. Additionally, the standards and certifications required to install these plants are not comprehensive. As costs continue to decline and technological advancements improve efficiency, we can anticipate a significant increase in floating solar projects across India.

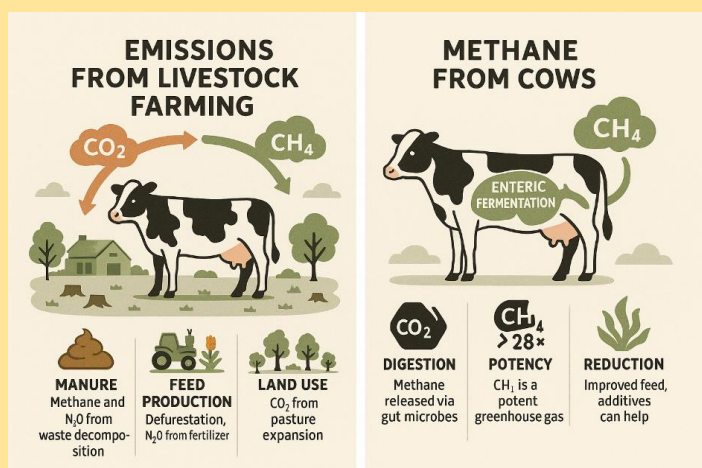
COMMERCIAL ANIMAL FARMING EMISSIONS

Riyanka Das

Commercial animal farming is a major source of greenhouse gas (GHG) emissions. The sector contributes around 14.5% of global anthropogenic emissions. Rising demand for meat, dairy, and eggs has intensified environmental impacts. Livestock production generates methane, nitrous oxide, and carbon dioxide. These emissions accelerate climate change and ecological degradation. Sustainable solutions are urgently needed to mitigate these effects.

Ruminant animals like cows produce methane during digestion. This process, called enteric fermentation, releases CH_4 via gut microbes. Methane has 28-36 times the warming potential of CO_2 . Cattle account for nearly 30% of human-caused methane emissions. Feed quality and animal genetics influence emission levels. Reducing enteric methane is critical for climate mitigation. Livestock waste decomposes to release GHGs. Stored manure emits methane under anaerobic conditions. When applied to fields, manure releases nitrous oxide. N_2O is 265 times more potent than CO_2 . Pig and poultry farms contribute significantly to these emissions. Improved manure handling can lower GHG outputs. Growing livestock feed drives deforestation. Soy and corn cultivation expands into forests. Fertilizers used for feed crops emit N_2O . Feed production causes 45% of livestock emissions. Sustainable feed practices could reduce this footprint. Pasture expansion destroys carbon-rich ecosystems. Deforestation for grazing releases stored CO_2 . Amazon deforestation is largely linked to cattle ranching. This land conversion reduces biodiversity. Protecting forests is vital for carbon sequestration.

Fossil fuels power farm operations. Energy is used for feed processing and transportation. Barn heating and cooling also require energy. While smaller than other sources, these emissions add up. Renewable energy could lower this impact. Livestock emissions contribute significantly to global warming. Methane causes strong short-term heating. N_2O persists in the atmosphere for centuries. Unchecked, these emissions could use half the 1.5°C carbon budget. Rapid action is needed to curb warming. Ammonia from manure creates air pollution. Nutrient runoff contaminates water sources. Habitat destruction threatens wildlife species. The Amazon and other regions face ecosystem collapse. Sustainable farming must protect biodiversity.



Seaweed supplements can cut methane by 80%. 3-NOP is another effective additive. These solutions reduce emissions without harming animals. Widespread adoption could make a major difference. Research continues on new feed innovations. Anaerobic digesters turn waste into biogas. Composting manure reduces methane release. Proper storage techniques minimize emissions. These methods also create renewable energy. Better manure management benefits farms and climate.

Rotational grazing improves soil health. Agroforestry combines trees with pasture. These systems store more carbon. They also support biodiversity. Regenerative agriculture offers multiple benefits. Plant-based meats have lower emissions. Cultured meat is an emerging technology. These alternatives could reduce livestock demand. Consumer adoption is growing steadily. They represent a key future solution. Carbon pricing could discourage high-emission farming. Subsidies might support sustainable practices. Regulations can enforce better manure management. International cooperation is essential. Strong policies drive meaningful change.

Animal farming emissions pose serious climate risks. Multiple solutions exist across production systems. Combining feed, manure, and land use improvements is crucial. Dietary shifts and policy changes must complement these efforts. A comprehensive approach can make livestock farming more sustainable. More studies on feed additive scalability are needed. Long-term impacts of alternative proteins require assessment. Best practices for small farms need development. Climate-smart breeding programs show promise. Continued innovation will be essential for progress.

EMERGING CONTAMINANTS OF THE 21ST CENTURY: AN INCREASING DANGER TO ENVIRONMENTAL AND HUMAN HEALTH

Saikat Dutta

The 21st century is opposite a new and often elusive danger—emerging contaminants (ECs). ECs are also referred to as contaminants of emerging concern (CECs). They are mixes that have originated in the environment but are not yet characteristically checked or controlled. Though they are moderately low in attentiveness, they are of countless hazards to ecosystems, wildlife, and human well-being. The increase in ECs is a pointer of the joint reply of contemporary technological growth, lifestyle changes, and environmental absconding.

Increasing contaminants contain a complete variety of substances like pharmaceuticals and personal care products (PPCPs), endocrine-disrupting compounds (EDCs), nanomaterials, microplastics, per- and polyfluoroalkyl substances (PFAS), flame retardants, and pesticides. They are not new resources in the setting of their appeal, but it is only with new loans in analytical skills that their attendance in water forms, soils, and even in human tissues has been noticed.

The mainstream of ECs finds its way into the environment via domestic sewage, industrial effluent, agricultural runoff, and chemical disposal. Wastewater treatment plants are usually not designed to totally eliminate these chemicals, so they last to exist in rivers, lakes, and groundwater. In most occurrences, ECs have the ability to bioaccumulate in aquatic life, nosey with hormonal and reproductive procedures.

One of the greatest significant anxieties regarding ECs is that they may disturb hormonal plans in animals and humans. EDCs, for example, act like hormones and can result in developing, generative, nervous, and immune problems. Antimicrobial resistance (AMR) is endorsed by antibiotic leftovers in water bodies, which are increasingly flattering a universal health anxiety. PFAS, commonly called "forever chemicals" since their permanency, have been connected with cancer, liver harm, and thyroid illness.

Ecologies, too, are extremely vulnerable. Aquatic organisms, particularly fish and amphibians, exhibition irregularities, behavioural changes, and population declines in contaminated locales. Pollinators like bees can be pretentious by exposure to neonicotinoid pesticides, intimidating food safety.

One of the major challenges to the adjustment of ECs is that they are not comprehensively controlled. Most countries lack values for nursing or regulating these contaminants. Moreover, their complicated chemical nature, low concentrations, and empathy for other contaminants complicate their detection and elimination. The fate of many ECs in the environment and their long-term impact are yet unknown.

In order to control emerging contaminants, there is an essential for a multi-faceted approach. This involves:

- The transformation of wastewater treatment facilities with methods such as triggered carbon adsorption, progressive oxidation processes, and membrane filtration.
- Introducing regulatory measures to screen and restrict ECs in water, air, and soil.
- Public teaching on correct disposal of drugs and minimizing the use of toxic chemicals.
- Asset in research on the behaviour, effect, and control of ECs.

In swift, emerging contaminants are a sinister but urgent environmental issue of the 21st century. They need to be skilful through scientific innovation, policy change, and a modification to sustainable living. The destiny of global health and environmental sustainability pivots on how well we meet this hidden risk.

“Pollution and climate change by excessive burning of fossil fuels are real threats, not the people who warn that we must take these threats seriously.”

- David Suzuki, Canadian Academic & Environmental Broadcaster

NET ZERO EMISSION

Sanchari Roy

Over 51 billion tons of greenhouse gases are absorbed by the Earth each second, contributing to an uncertain future for our planet. The world is uniting around a single, ambitious goal: reaching net-zero emissions as climate threats become increasingly pressing.

Net-zero emissions refer to the balance between the amount of greenhouse gases released into the atmosphere and the amount removed. To achieve this balance, it is crucial to reduce current emissions and implement strategies for carbon dioxide absorption, such as reforestation and carbon capture technologies. While "carbon neutrality" and "climate neutrality" are often used interchangeably with net zero, their definitions can differ. For example, some carbon-neutral certifications may allow for significant carbon offsetting, whereas strict net-zero standards require a reduction of emissions by over 90% before offsetting the remaining 10% or less in order to align with the 1.5°C global warming target. Stopping global warming necessitates reaching net zero. Research indicates that reducing CO₂ emissions to net zero is the only effective way to halt global warming. The Paris Agreement aims to balance human-made emissions with removals in the latter half of this century, based largely on this understanding. Achieving and maintaining net zero global anthropogenic CO₂ emissions would prevent human-induced global warming over multi-decadal timescales, according to the Intergovernmental Panel on Climate Change (IPCC).



In recent years, net zero has become the primary framework for climate action. As of November 2023, 145 countries had declared or were considering net-zero targets, covering nearly 90% of global emissions. Among these pledges are nations that had previously resisted climate action. However, the credibility of these targets varies significantly. While net zero targets encompass 61% of global carbon dioxide emissions, only 7% of these targets are deemed credible. This disparity highlights the urgent need for legally binding regulations as well as ongoing research and funding to enable decarbonization.

India, a significant contributor to global emissions, has set a target to achieve net zero by 2070. This goal was announced at the 2021 United Nations Climate Change Conference (COP26), alongside interim objectives, including increasing non-fossil energy capacity to 500 gigawatts (GW) by 2030 and reducing the carbon intensity of the economy by 45% by the same year. Although India's commitment has a longer timeline compared to some other countries, it represents a substantial step forward in global climate action.

Reaching net zero requires a multidimensional strategy:

- Transition to Renewable Energy
- Enhance Energy Efficiency
- Implement Carbon Sequestration
- Enforce Policy and Regulation

While individual actions are important, systemic changes are also vital. Advocating for environmental policies, promoting sustainable products, and reducing personal energy consumption all contribute to achieving the larger goal of net zero. When individuals work together, they can influence policy decisions and increase demand for greener solutions. Achieving net zero emissions is one of the most critical goals in the fight against climate change. As we celebrate World Environment Day, it is essential to recognize the significance of this goal and the collaboration required to achieve it. A sustainable, net-zero future is attainable through international cooperation, innovative thinking, and personal commitment.

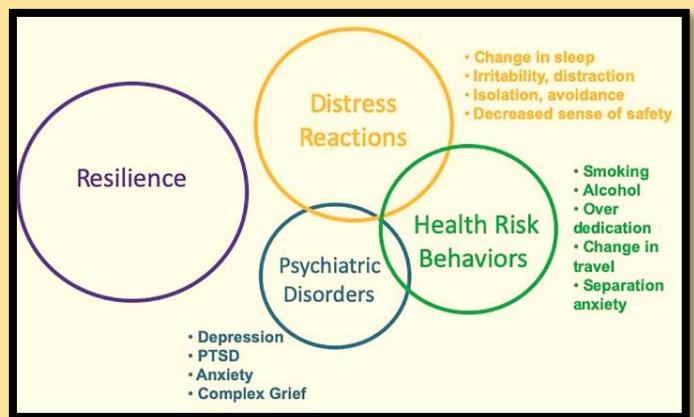
MENTAL HEALTH IMPACTS FROM ENVIRONMENTAL DISASTERS

Sangita Saha

Natural or man-made, environmental disasters have a terrible impact on people's mental health as well as the physical environment. Disaster response planning and scientific study are focusing on psychological toll from the rise of natural disasters like floods, wildfires, cyclones, earthquakes, and industrial catastrophes as the result of climate change and anthropogenic activities. Environmental disasters frequently occur without much notice, leaving victims feeling terrified, helpless, and deeply lost. Numerous mental health issues, such as anxiety, depression, PTSD, and substance abuse, might result from these events. In certain instances, the trauma may endure for a long time, even after physical healing and infrastructural reconstruction. Psychological discomfort is frequently caused by the uncertainty that occurs during and after such occurrences, especially for vulnerable groups like children, the elderly, individuals with disabilities, and low-income communities.

Typical Mental Health Issues after a Disaster

- **Post-traumatic stress disorder (PTSD):** One of the most researched and documented consequences of environmental disasters is PTSD. Flashbacks, nightmares, hyperarousal, and avoiding reminders of the catastrophe are some of the symptoms. Recovery and day-to-day functioning are hampered by survivors of natural disasters like earthquakes and tsunamis, who frequently replay the experience in their minds.
- **Anxiety and Depression:** In the wake of a calamity, it's normal to have feelings of anxiety, fear, hopelessness, and grief. People who find it difficult to deal with loss and the daunting process of rebuilding their life may experience depression. Additionally common are anxiety disorders, particularly in people who are frequently exposed to calamities or who worry about the future.
- **Behaviour Changes and Substance Use:** Some people use drugs or alcohol as a coping mechanism for stress, which can result in long-term dependency problems. Adolescents and children in particular may exhibit behavioural abnormalities such withdrawal, aggressiveness, or subpar academic achievement.



Long-Term Psychological Effects: Even after the acute physical harm has been rectified, environmental disasters can still have an impact on people's mental health. Long-lasting emotional pain can result from ongoing stress, ongoing sadness, and a sense of uncertainty about what lies ahead. Residents of disaster-prone places may experience ongoing worry, which over time may impair their immune systems, cognitive abilities, and general quality of life. Furthermore, environmental catastrophes have the power to uproot individuals from their communities, resulting in the creation of environmental refugees. Psychological discomfort can worsen when the stress of relocation is combined with the loss of cultural ties and identity.

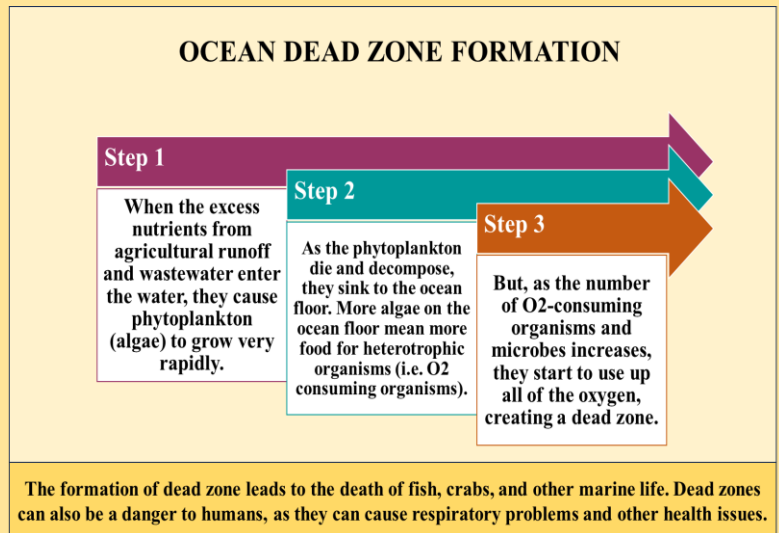
Despite increased awareness of the mental health problems associated with environmental disasters. Mental health services are frequently inadequate or absent in environments with limited resources. Additionally, people may be discouraged from getting care due to the societal stigma associated with mental illness. It is crucial to incorporate mental health services into plans for disaster preparedness and response through community-based interventions, campaigns for public awareness, school-based programs, and long-term mental health services.

SILENT OCEANS: HOW NUTRIENT RUNOFF IS SUFFOCATING OUR OCEANS

Shreya Mitra

"What we do on land is mirrored in the ocean. Nutrient runoff is not just an agricultural issue – it's an ecological crisis." — Dr. Nancy Rabalais (Marine ecologist and hypoxia expert)

Ocean dead zones are regions with significantly low oxygen levels where aquatic life cannot survive. These dead zones, also known as hypoxic zones, are becoming more prevalent due to nutrient runoff from agricultural and urban areas. Mostly, unsustainable agriculture and wastewater treatment contribute significantly, mainly through excess nitrogen and phosphorus from fertilizers and animal waste. When these nutrients enter waterways, particularly after heavy rainfall, they reach coastal waters and cause algal blooms. Some of these blooms are toxic, posing risks to marine life and human health. The cycle of eutrophication starts with nutrient enrichment, leading to high algal blooms that prevent sunlight for underwater plants. As the algae decay, they deplete oxygen, creating hypoxic environments that result in dead zones. These zones force migratory marine species, including fish and shrimp, to escape, and can kill less migratory species like shellfish, disrupting food webs, reducing fishery productivity, and affecting coastal livelihoods. Additionally, the changed water chemistry may discharge toxic materials like ammonia and methane, increasing the environmental load.



As of 2024, scientists have identified 415 dead zones worldwide. Most are found along the eastern coast of the United States and the coastlines of the Baltic States, Japan, and the Korean Peninsula. The Black Sea, once home to the world's largest dead zone, largely disappeared between 1991 and 2001 after fertilizers became too costly to use. One of the best-documented and currently the world's second-largest dead zone is in the Gulf of Mexico, where excess nutrient runoff from the Mississippi River Basin, which drains 31 U.S. states, produces a hypoxic zone every summer, spanning more than 6,000 to 8,000 square miles, damaging significant fisheries and threatening marine biodiversity. According to NOAA (National Oceanic and Atmospheric Administration), the 2024 Gulf dead zone was approximately 6,705 square miles, or the size of Delaware, and was mostly caused by upstream nutrient pollution.

However, mitigating nutrient runoff and the resulting ocean dead zones needs a comprehensive approach. In agriculture, adopting best management practices (BMPs), including precision fertilizer applications, buffer strips along waterways, cover cropping, and crop rotation, can significantly reduce nutrient runoff. Urban areas can benefit from advanced wastewater treatment facilities and minimize the use of phosphorus-based detergents to limit nutrient discharge into water bodies. Globally, international institutions like the UN Environment Programme encourage integrated coastal zone management (ICZM) and sustainable land use practices to address the issue. Public awareness, strong policy implementation, and regulations like the U.S. Clean Water Act and the European Union's Water Framework Directive aim to control nutrient pollution. Additionally, advanced technologies like satellite monitoring and water quality sensors are being used more for monitoring nutrient pollution levels and supporting mitigation efforts. Through these combined practices, it is possible to combat nutrient pollution and protect our marine ecosystems for future generations.

DERAILED BY DECIBELS: NOISE POLLUTION DISRUPTING ANIMAL MIGRATION

Sneha Mistri

Humans live on an increasingly populous planet, pulsing with generated noise of every kind. The most common noise-making structures created; traffic-laden roads, which already crisscross much of the Earth and are projected to increase in length by approximately 25 million km by mid-century, enough to encircle the planet more than 600 times. For wildlife, the challenges of living in a world increasingly overwhelmed by such infrastructures are only going to worsen.

Noise pollution is increasingly imperilling migratory species such as whales, birds, and ungulates, interfering with how they communicate, covering up the sounds natural to the environment, and modifying their behaviour. These disturbances throw animals off their migratory paths, lower their chances of reproducing, and heighten the threat from predators. Many species rely on the natural sounds of their environment to find their way, communicate, and survive. However, the noise pollution we create from shipping, traffic, and industrial activities is on the rise, disrupting these vital cues and potentially leaving animals disoriented and using up more energy. For example, marine mammals are altering their vocalisations and steering clear of areas with ship noise. As noise pollution continues to escalate globally, we must act swiftly. It's essential to grasp the implications of this issue and to put regulations and quieter technologies in place to protect migration patterns and maintain the balance of our ecosystems.



Noise pollution is steadily affecting the natural migration patterns of various species, including birds, whales, and land mammals. This is an alarming prospect in a world ever more beset by human-induced noises. For example, nowhere in Costa Rica's iconic La Selva Biological Reserve can one avoid hearing the incessant thrum of a nearby highway. By interfering with essential behaviours such as communication and navigation, noise pollution poses a growing threat to biodiversity and ecosystem stability. As human development expands, so does the urgency to address this issue. Implementing noise regulations, preserving quiet habitats, and investing in quieter technologies are crucial steps toward protecting migratory species and maintaining the delicate balance of our natural world.

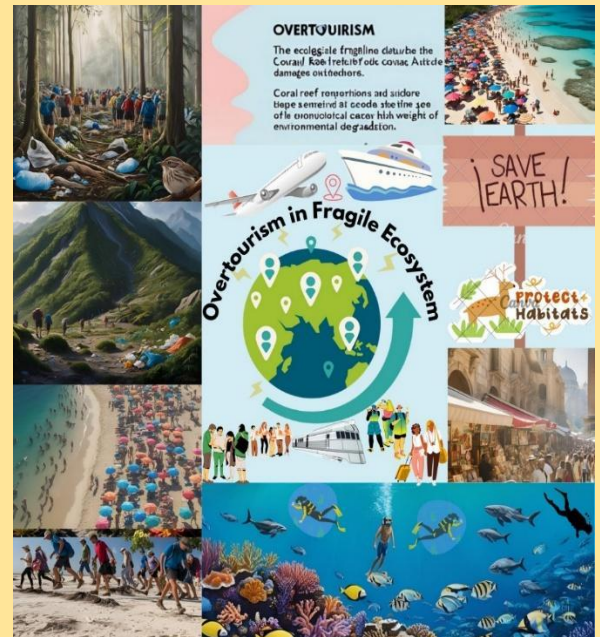
OVER-TOURISM IN FRAGILE ECOSYSTEMS: CHALLENGES AND RESOLUTION

Soheli Saha

“The more clearly we can focus our attention on the wonders and realities of the universe about us, the less taste we shall have for destruction.” ~ Rachel Carson – Marine Biologist & Author of "Silent Spring"

In the era of Instagram travel goals and bucket-list adventures, tourism has gone up. For many destinations, it is their lifeline, opening the way for local economies to grow and diverse cultures to meet and share meaningfully. But what happens when too much love starts hurting the very places we admire? This is the reality of over-tourism, and nowhere is it more acutely felt than in the world's fragile habitats. Over-tourism, which gained global attention in 2016 when the travel industry news site, Skift, wrote an article titled *“Exploring the Coming Perils of Overtourism”* that covered the dangers of mass tourism in high-traffic destinations, is now quickly degrading some of the world's most fragile environments.

Imagine a centuries-old settlement situated on a volcanic island, a coral reef with an abundance of life, or a valley in the Himalayas fed by glaciers. Though fragile, these locations are stunning. The irony is bitter; tourism flourishes on the beauty of these environments, yet that very popularity becomes their downfall. Fragile ecosystems are not resilient enough to withstand millions of footprints, plastic bottles, motor fumes, and continuous noise, in contrast to busy cities. In Antarctica, even the icy sanctuary of penguins and seals isn't safe. Even as it is subject to regulations, increased tourism is adding non-native microbes and pollutants, further imperilling the ecosystem upon which climate change is already bearing down. When the Galápagos Islands first opened to tourists in the 1970s, there were fewer than 20,000 visitors annually. Fast forward to today, and that figure has swelled to more than 275,000. Every footprint it makes disturbs the earth, sends wildlife fleeing, and drives native species to the brink. In India, the once-pristine Himalayan towns are drowning in garbage and gridlock.



The surge of domestic tourists in recent years has brought with it not just economic activity, but rising pollution and deforestation. Similar challenges face Thailand's Maya Bay, which had to shut down completely in 2018 due to coral reef destruction. Over-tourism does not just harm nature, but it erodes communities. Local cultures are often commodified, traditions repackaged for tourist appetites, and daily life disrupted. The problem isn't tourism itself, but its unmanaged tourism. Cheap travel, lack of visitor caps, and an economy built on numbers over nuance have pushed many ecosystems to a breaking point. The desire for “authentic” experiences often overlooks how intrusive visitors can be in someone else's backyard.

Can Tourism and Conservation Coexist? Yes, but only with intention, innovation, and restraint. Some destinations are setting examples. Bhutan, for instance, enforces a “high-value, low-impact” tourism policy, charging daily fees that fund conservation efforts and limit visitor numbers. In Costa Rica, tourism revenues are redirected to protect rainforests and national parks, turning tourists into indirect stewards. Technology is also stepping up. Visitor caps, real-time tracking, and virtual tourism experiences are being explored to help manage human impact. But the most crucial shift has to come from travellers. Conscious choices, from choosing off-peak travel dates to respecting local guidelines, can make a significant difference. Over-tourism is a wake-up call; not just for governments and tour operators, but for all of us. While the Earth offers us its wonders, it doesn't come with unlimited bandwidth.

BIO-FORTIFICATION AND MALNUTRITION: A PATH TO SECURE FOOD

Sravana Chanda

Malnutrition is an ongoing worldwide public health concern, especially in developing countries where millions are afflicted by "hidden hunger"—a type of malnutrition due to the lack of consumption of key micronutrients like iron, zinc, vitamin A, and iodine. In contrast to caloric hunger, which is outwardly visible, hidden hunger goes unnoticed but has severe health implications, such as stunted growth, impaired immunity, reduced cognitive development, and higher mortality rates, particularly among children and pregnant women. To address this silent emergency, bio-fortification has arisen as a sustainable, cost-effective, and food-based approach designed to enhance the nutrient value of food crops. This improvement is made through conventional plant breeding, agronomic management, or new biotechnology. The aim is to naturally fortify widely eaten crops with essential nutrients to enhance the quality of diets without necessitating drastic changes in eating patterns or use of supplements.

One of the most important benefits of bio-fortification is that it can reach low-income and rural populations who typically have limited access to commercially fortified foods and dietary supplements. Once nutrient-enriched crop varieties are adopted and embedded in normal production and consumption patterns, they can bring long-term returns for a negligible recurring expense. Some of the successful experiences highlight the potential of bio-fortification. Golden Rice, which is genetically modified with beta-carotene—a vitamin A precursor—has been created to deal with vitamin A deficiency, a primary reason for avoidable blindness among children. In the same vein, iron-enriched beans and pearl millet, zinc-enriched wheat, and orange-fleshed sweet potatoes with high beta-carotene content are being introduced in areas throughout Africa, Asia, and Latin America. Institutions such as HarvestPlus, in partnership with Consultative Group on International Agricultural Research (CGIAR) institutions, have been leading the way in developing and disseminating these bio-fortified crops, benefiting millions of smallholder farmers and enhancing global nutrition efforts.

Even with its advantages, the mass production of biofortified crops is hampered by various challenges. Low public awareness and the reluctance of farmers to plant new crop varieties, especially when market demand is unclear, are among the issues. The application of genetically modified organisms (GMOs) in certain biofortified crops has also raised concerns about safety, environmental effects, and ethics, creating regulatory barriers in some nations. In order to cross these barriers, multi-sector and collaborative action is required. Governments, research, NGOs, and private sector players must collaborate in the inclusion of bio-fortification in national agricultural and nutritional policy, provision of incentives and training for farmers, and initiating consumer acceptability campaigns. Additional research is also imperative to develop more high-yielding crops that are more resistant, as well as more resistant crops with less loss of nutrients during processing and cooking. As one of a wider nutritional approach comprising dietary diversification, food fortification, and supplementation, bio-fortification is very promising in solving micronutrient deficiency. Through continuous support and innovation, it can be a revolutionary tool against malnutrition, opening the way towards a healthier and more food-secure future.

"Let food be thy medicine and medicine be thy food"

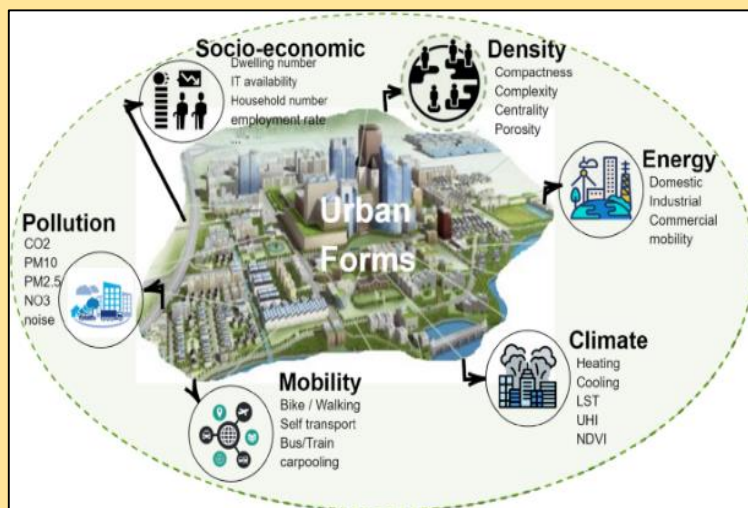
- Hippocrates, Greek physician

SUSTAINABLE URBAN PLANNING AMIDST RAPID POPULATION GROWTH

Tazmin Sultana

Population explosions are occurring in cities across every continent due to natural growth and rural-to-urban migration. The UN predicts that by 2050, about 70 percent of the world's population will live in cities, which will increase the pressure on urban residents to grow while maintaining environmental balance, livability, and utility. Sustainable urban planning is a crucial tool for managing this growth for the benefit of both present and future generations.

Environmental appraisal is another key component of sustainable urban planning. By incorporating social justice, urban planning aims to create cities where people can thrive. Effective city planning seeks to achieve a balance that meets the needs of different communities without harming the environment. Rapid population growth often results in urban sprawl, overcrowded housing, traffic congestion, and strained infrastructure. Informal settlements, lacking basic amenities, can emerge at the fringes of cities, overwhelming public services such as waste management, water supply, and healthcare.



Uncontrolled growth has severe environmental consequences, including increased carbon emissions, loss of green spaces, and air and water pollution. The lack of careful planning perpetuates a vicious cycle of environmental degradation and declining living standards. Sustainable urban planning provides a solution to these challenges by promoting more efficient land use, equitable access to housing and services, and incorporating environmental considerations into urban development. Studies show that countries adopting sustainable urban planning achieve lower community stress levels, cleaner air, improved environmental resources, and a better quality of life.

To enhance urban development, urban planners focus on several key strategies, including green energy, sustainable transportation, eco-friendly housing, green spaces, community empowerment, and a sustainable economy. A sustainable urban development agenda should encompass affordable housing policies, participatory decision-making, and infrastructure that meets the needs of marginalized communities. Inclusivity in planning ensures that the benefits of urban growth are equitably distributed, helping to diffuse social tensions.

In India, the government has initiated several projects focusing on sustainable urban planning. One such project is the Smart Cities Mission, launched in 2015, which aims to develop 100 smart cities employing smart solutions to improve infrastructure, efficiency, and sustainability. As of 2024, over 7,000 projects worth ₹1.8 lakh crores have been inaugurated, significantly contributing to green mobility, energy efficiency, and sustainable urban services. Indian cities contribute roughly 30 percent of total CO₂ emissions from transport sources. To reduce emissions and alleviate congestion, various urban mobility solutions, such as metro rail projects, e-buses, and bike-sharing schemes, are being implemented across the country.

Although urban green cover has seen slight improvement, cities like Delhi and Bengaluru are enhancing their climate action plans by incorporating urban forests and rooftop gardens. The Atal Mission for Rejuvenation and Urban Transformation (AMRUT), initiated in 2015, aims to improve infrastructure and green spaces in over 500 cities, with its second phase emphasizing water security and climate resilience.

In conclusion, urban sustainability is not an option in the face of rapid population growth; it is a necessity. As cities expand, they must be designed for greater efficiency, equity, and environmental integrity. The future of urban living will depend on our commitment to sustainability as the guiding principle in all aspects of planning and development.

AGRICULTURE AT RISK: A STUDY OF CLIMATE CHANGE-INDUCED CROP LOSS IN THE INDIAN SUNDARBANS

Abhijit Pal

The Sundarbans, located in the deltaic region of the Ganges-Brahmaputra-Meghna basin, is a UNESCO World Heritage Site (1987) shared between India and Bangladesh. It is ecologically rich and economically fragile. Nearly 59% of the workers are engaged in farming, while 5% are involved in fishing (**Census,2011**). Agriculture in the Sundarbans, primarily rain-fed and mono-cropped, is acutely vulnerable to climate change-induced stressors, resulting in significant agricultural loss.

Agriculture in the Indian Sundarbans is increasingly threatened by climate change, primarily due to **salinity intrusion, cyclone-induced damage, erratic weather patterns, and riverbank erosion**. Rising sea levels and storm surges have significantly increased **soil salinity from 2 dS/m to over 8 dS/m** in the past two decades, rendering land infertile for high-yielding rice varieties (Mondal & Khare, 2022; NRSC, 2011).

Severe cyclones—Aila (2009), Amphan (2020), and Yaas (2021)—have inundated large areas with saline water. Notably, **Cyclone Amphan damaged over 1.7 million hectares of farmland**, resulting in **₹1,500 crores** in crop losses (Government of West Bengal, 2020). Additionally, **temperatures have risen by 0.5–0.8°C** over the last 50 years, disrupting traditional crop calendars and reducing yields (Hazra et al., 2021). Erratic rainfall and extreme weather during sowing and harvesting periods have severely affected rice cultivation.

Furthermore, over 750 sq. km of cultivable land has been lost to riverbank erosion in the last three decades, forcing many farming households to abandon agriculture or migrate (World Bank, 2014). The combined impact of these stressors has made farming in the Sundarbans increasingly unsustainable.

Table: Year-wise Climate Change-Induced Erosion and Land Loss in the Sundarbans

year	Event / Observation	Land Lost / Eroded (sq. km)	Remarks	Source
1990	Rising tidal inundation	64 sq. km lost (1980–1990)	Accelerated erosion observed in Sagar, Ghoramara, and Namkhana areas	Hazra et al. (2021)
2009	Cyclone Aila	35 sq. km submerged	Large-scale breach of embankments, saline ingress	Government of West Bengal (2010); Ghosh (2018)
2020	Cyclone Amphan	26 sq. km submerged	Embankment breaches in 160+ locations; land permanently lost	Government of West Bengal (2020); Hazra et al. (2021)
2023	Rising sea level (2–8 mm/year)	Total loss since 1980: 260+ sq. km	Increasing frequency of tidal surges and cyclonic depressions	IPCC (2021); School of Oceanographic Studies, JU

Key Highlights:

Total Land Loss (1980–2023): Estimated 260+ sq. km, including both erosion and submergence.

Average Annual Loss: Approximately 6–7 sq. km/year, with spikes during cyclone years.

Vulnerable Islands: Ghoramara, Mousuni, Sagar, and southern fringes of Patharpratima and Namkhana blocks.

Agricultural loss in the Sundarbans due to climate change is a multifaceted issue driven by salinization, cyclonic storms, erratic climate patterns, and land erosion. These processes reinforce poverty cycles, threaten food security, and lead to socio-economic dislocation. Adaptive strategies such as saline-resistant crop varieties, embankment reinforcement, and integrated land-water management are crucial for future resilience.

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