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Editorial

Intensifying Extreme Events and their Implications for Agricultural and Ecosystem Management

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Introduction

Extreme weather events are by definition the outliers of natural climate variability rare, intense, and often catastrophic. However, what was once considered rare is rapidly becoming routine. Advances in extreme event attribution science now allow researchers to link specific extreme events more confidently to human-caused climate change, and the evidence is explicit: climate change significantly intensifies the frequency, intensity, duration, and spatial extent of extreme weather events worldwide (Clarke et al. 2022). As we move forward into the twenty-first century, the question is no longer whether such events will occur, but how prepared our agricultural systems and ecosystems are to withstand them.

This editorial discusses the increasing impact of climate extremes and their effects on agriculture, food security, soil health, and ecosystems. Using global evidence and experiences from countries like Sri Lanka, it highlights the urgent need for practical adaptation measures based on nature-based solutions and interdisciplinary research.

1. Shifting Emerging Risks

Globally, all categories of extreme geophysical, meteorological, hydrological, and climatic phenomena show an upward trend, but the largest increase has been observed in hydrological events such as floods, mudslides, and snow avalanches (Furtak et al. 2023). The most significant shifts are in the amount of precipitation and the duration of droughts, two forces that lie at the heart of agricultural vulnerability. Rising air temperatures are accelerating the hydrological cycle, producing more intense precipitation events interspersed with prolonged dry spells. In the Sri Lankan context, current evidence points to an increasing frequency of extreme wet events (Abeysingha 2022, Abeysingha et al. 2023; Partheepan et al. 2026) due to an intensifying hydrological cycle.

Climate change is leading to more frequent and intense ENSO events. Post-1960 ENSO amplitude has increased by approximately 10%, linked to greenhouse gas forcing (Cai et al., 2023), driving drier or wetter regional conditions, increasing the likelihood of hurricanes and atmospheric rivers, and exacerbating droughts, floods, and heat waves.

Looking ahead, El Niño is forecast with an 82% probability for May to July 2026, persisting through the Northern Hemisphere winter with a 96% probability for December 2026 to February 2027 (CPC/NCEP, 2026). In the Sri Lankan context, the cyclonic disturbance frequency has been shown to increase by 216% (1.3 to 4.1 systems/year, $p < 0.001$) during 1975 to 2025 (Partheepan et al. 2026). Moreover, historical evidence indicates that during El Niño years, the Yala season (April–September) typically experiences below-normal rainfall, leading to yield losses, while the subsequent northeast monsoon can bring anomalously heavy rainfall and flooding in Sri Lanka (Zubair 2002). Abeysingha et al. (2026) further demonstrated using SPI frequency and trend analyses that the Yala season is becoming drier relative to the Maha season, with total annual rainfall increases primarily driven by enhanced precipitation during the northeast monsoon and second inter-monsoon periods, a pattern that is compounding the agricultural risk profile of the island. The agricultural sector must be strategically prepared for these compound risks, especially as natural ENSO variability is further amplified by long-term climate change. On a high-emissions trajectory of IPCC scenarios, climate extremes will continue to intensify, potentially triggering irreversible changes to critical Earth systems (IPCC AR6, 2022).

2. Impacts on Food Security, Agriculture, and Soil Health

Climate change and variability are already causing threatening and devastating effects on human food security and nutrition outcomes (Clarke et al. 2022). For rain-fed agriculture, which accounts for approximately 80% of global farmland, growing uncertainties about rainfall timing, adequacy, and intensity are becoming increasingly common threats (FAO 2021). Flooding influences food security through food, water, and health pathways, impacting both food availability and access while increasing the burden of infectious diseases through contaminated water systems. Modelling studies suggest flooding can progressively degrade food security over time, particularly in sub-Saharan Africa (Reed et al. 2022). Crop model (13 Global Gridded Crop Models) studies suggest that droughts and heatwaves are being systematically underestimated, which implies future losses may be worse than many models project (Heinicke et al. 2022).

For Sri Lanka, the implications of intensifying extreme events are especially important because agriculture is highly exposed to rainfall variability, drought, landslides, heat stress, and flood risk, and these hazards directly affect both rainfed and irrigated production systems. Sri Lanka recently experienced severe climate extremes. In 2016, the country faced its worst drought in 40 years as both monsoon seasons failed to bring enough rainfall. Paddy farming during the main Maha season was badly affected, and the 2017 harvest dropped by about 63%, with total production nearly 40% lower than the previous year (FAO/WFP, 2017). As a result, nearly 900,000 people faced food insecurity. Soon after, heavy rainfall in May 2017 caused major floods and landslides, killing at least 246 people and displacing more than 600,000. Due to these disasters, Sri Lanka was ranked the second most vulnerable country in the 2017 Global Climate Risk Index (Eckstein et al. 2019). More recently, Cyclone Ditwah (November 2025) caused widespread destruction of paddy fields in Trincomalee and Batticaloa, affecting tens of thousands of hectares and threatening livelihoods across multiple districts. These events are not isolated: statistical analyses show significant shifts in the intensity and distribution of extreme precipitation in Sri Lanka across recent decades (Naveendrakumar et al. 2018; Nisansala et al. 2020; Abeysingha et al. 2023).

Beyond crop losses, extreme events degrade the ecosystem services that agriculture depends upon. Extreme precipitation reduces soil biological function, accelerates waterlogging and soil erosion, and heightens susceptibility to salinisation (Bezner Kerr et al. 2022). Pollinator populations are increasingly stressed by heat extremes and phenological mismatches between flowering and pollinator activity (Gérard et al. 2019).

Crucially, intensifying extreme rainfall accelerates soil erosion through elevated rainfall erosivity, the capacity of rain to detach and transport soil particles. A comprehensive review of future soil erosion in river basins found that 73% of the world’s river basins are projected to experience increasing soil erosion and sedimentation under a changing climate, driven primarily by intensifying precipitation, with a positive correlation between precipitation trends and soil erosion in 83% of case studies (Abeysingha and Ray 2025). Climate projections using RUSLE indicate a potential 30 to 66% increase in global water erosion by 2070 (Borrelli et al. 2020). Since more than 95% of global food production depends on soil's productive capacity (FAO, 2015), addressing soil erosion is a fundamental dimension of climate adaptation.

3. Adaptation Pathways

Addressing increasing climate extremes requires solutions that both protect and support productivity. Nature-based solutions (NbS) can reduce climate impacts while improving ecosystem resilience. Effective adaptation should also be tailored to different agro-ecological zones, farming systems, and climate risks rather than using one common approach (Assad et al. 2022).

Agroforestry is a well-known nature-based solution. Integrating trees into croplands can reduce temperature extremes, control runoff and erosion, lessen flood impacts, and protect farms from cyclone damage (Dobhal et al. 2024). Moreover, studies suggested that drought-induced low rainfall damages many crops, but integrating trees can improve microclimate and maintain crop yield by providing shade, windshield, and prolonged soil moisture retention (Dobhal et al. 2024). Other approaches, such as cover cropping, conservation tillage, riparian buffer restoration, and watershed vegetation management, also help reduce erosion and improve resilience. Eco-holistic soil conservation further supports sustainable landscape management by treating soil as a living system (Albaladejo et al. 2021).

Biodiversity plays an important role in reducing climate impacts. Ecosystems with higher biodiversity are better able to withstand climate extremes, while biodiversity loss can weaken ecosystem stability (Mahecha et al. 2024). Therefore, protecting and restoring biodiversity is essential for climate adaptation. Actions that support both nutrition and climate resilience, such as climate-smart agriculture, early warning systems, and community-based risk management, should be given priority.

Despite the growing body of knowledge, several important gaps continue to constrain effective policy and practice. Long-term data on the combined and cumulative impacts of repeated climate extremes on agriculture and soil health remain limited, particularly in tropical and developing countries. The effectiveness of existing soil conservation measures under future climate conditions has not been widely evaluated, and many studies fail to simultaneously consider changes in land use and management practices. In addition, future projections of soil erosion are constrained by the limited availability of Global Climate Models (GCMs) capable of accurately simulating future rainfall intensities, frequencies, and durations (Abeysingha & Ray 2025).

The social and economic consequences of extreme events, including gender vulnerability, nutrition, and livelihoods, are also insufficiently studied, especially in developing countries. Climate-related malnutrition among vulnerable communities remains particularly difficult to quantify (Clarke et al. 2022). Furthermore, local and indigenous knowledge is inadequately integrated into adaptation planning, while economic evaluations of nature-based soil conservation approaches remain scarce. The application of crop models for assessing the impacts of extreme events is also limited in developing countries such as Sri Lanka due to the lack of reliable datasets for model calibration and validation.

Addressing these gaps requires long-term, interdisciplinary, and internationally collaborative research focused on climate-vulnerable farming communities. In some countries, including Sri Lanka, climate policies are already in place; however, implementation at district and local levels remains weak (Perera et al. 2025). Studies indicate that effective climate change adaptation and disaster risk reduction depend on stronger institutional frameworks, improved coordination, enhanced data systems, decentralised decision-making, adequate financial support, and greater empowerment of local actors (Perera et al. 2025).

4. Conclusions

The increasing impacts of climate extremes on agriculture, food security, soil health, and ecosystems were discussed using global examples and experiences from Sri Lanka. Extreme weather events are no longer future possibilities; they are already affecting farming systems and ecosystems around the world. Events such as the drought–flood crisis that damaged rice production in Sri Lanka during 2016 to 2017 and the impacts of Cyclone Ditwah in 2025 show that farming communities are facing growing extreme climate-related pressures. Three major challenges need urgent attention: increasing floods and drought linked to ENSO that are changing rainfall patterns and cropping seasons; ongoing soil degradation that reduces agricultural productivity and food security; and the heavy impacts faced by vulnerable farming communities, which are often overlooked in research and policy.

Addressing these issues requires moving from short-term disaster response to long-term, location-specific adaptation strategies. Greater emphasis should be placed on nature-based solutions, stronger institutions, and continued investment in climate-resilient agriculture.

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