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Article 02

Climate Change and Agricultural Land Use in the Gin River Basin: A Critical Review of Trends, Impacts, and Adaptation Strategies

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Abstract

This literature review examines the impacts of climate change on agricultural land use patterns in the Gin River Basin, Sri Lanka. A systematic search of peer-reviewed journals, government reports, and institutional publications was conducted using databases including Google Scholar, Scopus, and Web of Science, covering literature from 2000 to 2025 with search terms such as 'climate change,' 'agricultural land use,' 'Gin River Basin,' 'Sri Lanka agriculture,' and 'rainfall variability.' A total of 45 sources were reviewed in accordance with PRISMA guidelines. The review finds that rising temperatures, increasingly erratic rainfall, and more frequent flood events have substantially disrupted traditional farming systems in the basin, particularly paddy cultivation in the lower catchment and plantation agriculture in the upper reaches. Farmers have responded by adjusting cropping calendars, diversifying crops, and shifting to more flood-tolerant varieties, though these adaptations remain constrained by limited institutional support and poor access to credit. A key research gap is the absence of integrated basin-scale models linking climate variability, hydrological change, and field-level land-use decisions. Addressing this gap is essential for developing effective climate-resilient agricultural policies for the Gin River Basin.

Keywords: *Agricultural land use, climate change, Gin River Basin, rainfall variability, Sri Lanka, adaptation strategies.*

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Introduction

Climate change is widely regarded as one of the most pressing environmental challenges of the 21st century. The scientific community has documented consistent increases in global temperatures, shifting precipitation patterns, rising atmospheric carbon dioxide concentrations, and growing frequency of extreme weather events, all of which are reshaping both natural and human systems at an unprecedented rate (IPCC, 2021). Agriculture is among the sectors most immediately affected by these changes, given its direct dependence on climate variables such as temperature, rainfall, and soil moisture conditions.

Agricultural systems are particularly sensitive to even modest shifts in long-term climatic patterns. Changes in temperature regimes and precipitation can disrupt crop production cycles, alter soil moisture availability, intensify pest and disease pressure, and reduce the reliability of irrigation (FAO, 2016). While technological innovations and improved crop varieties have improved productivity in many parts of the world, climate change is progressively eroding those gains, especially in developing countries where adaptive capacity remains limited (Morton, 2007). This makes climate change not only an environmental concern but also a serious threat to food security, rural livelihoods, and sustainable land management.

The impacts of climate change unevenly distributed. Tropical countries tend to face greater risks because of already high baseline temperatures and their heavy dependence on rain-fed agriculture closely tied to seasonal climate patterns (Lobell et al., 2011). In these regions, climate change does not simply reduce yields; it also alters long-term land use decisions, including which crops farmers choose to grow, how much land remains under cultivation, and whether agricultural land is eventually abandoned or converted to other uses. These transitions have far-reaching consequences for rural development and environmental sustainability.

Sri Lanka illustrates these dynamics well. Despite its relatively small land area, the country supports diverse agro-ecological zones and a range of farming systems. Paddy, tea, rubber, and coconut remain central to employment, food supply, and export earnings. Recent climate trends, including rising temperatures, greater rainfall variability, and more intense floods and droughts, have already begun to disrupt agricultural systems across the island (Department of Meteorology, 2020). The consequences are being felt not just in reduced harvests but also in how farmers choose to use their land and plan for the future.

River basins offer a useful spatial unit for examining these dynamics because they integrate land use, hydrology, and human activity within a defined physical boundary (Eriyagama et al., 2018). The Gin River Basin in the Southern Province is particularly relevant to this analysis. Located in the wet zone, the basin supports intensive agricultural activity across a range of elevations, from tea and rubber cultivation in the upper catchment to paddy farming in the flood-prone lowlands. Studies have shown that hydrological changes linked to climate variability are already affecting agricultural productivity and livelihoods in the basin, and those socio-cultural changes in the area may also be contributing to these hydrological shifts alongside climatic drivers (Eriyagama et al., 2018).

Despite growing recognition of the connections between climate and agriculture, research on how climate change leads to specific changes in agricultural land use at the river-basin level in Sri Lanka remains comparatively scarce. Most existing studies focus on either national-level crop impacts or broad assessments of water resources, without examining the spatial and social complexity of land use change in individual basins. This gap is particularly significant for the Gin River Basin, which remains understudied compared to larger river systems despite being one of the most flood-prone basins in the country.

The present review addresses this gap by synthesising global, national, and basin-level evidence on the relationship between climate change and agricultural land use. The specific research question guiding this review is: How has climate change affected agricultural land use patterns and practices in the Gin River Basin, and what adaptation responses have emerged? Three sub-questions support this inquiry: (1) What are the observed and projected climate trends relevant to agricultural land use in the basin? (2) How have these trends altered cropping systems, land suitability, and farming decisions? (3) What institutional and policy responses have been developed, and what gaps remain in the literature?

The significance of this review lies in its contribution to both academic understanding and practical policy development. By bringing together evidence across scales and disciplines, the review establishes a theoretical and empirical foundation for future basin-level research and supports the design of climate-resilient agricultural strategies in Southern Sri Lanka.

Materials and Methods

This study relied on secondary data collected through a systematic review of existing literature. The systematic review approach was chosen because it offers a structured, transparent, and reproducible method for synthesising evidence on a defined research question (Moher et al., 2009).

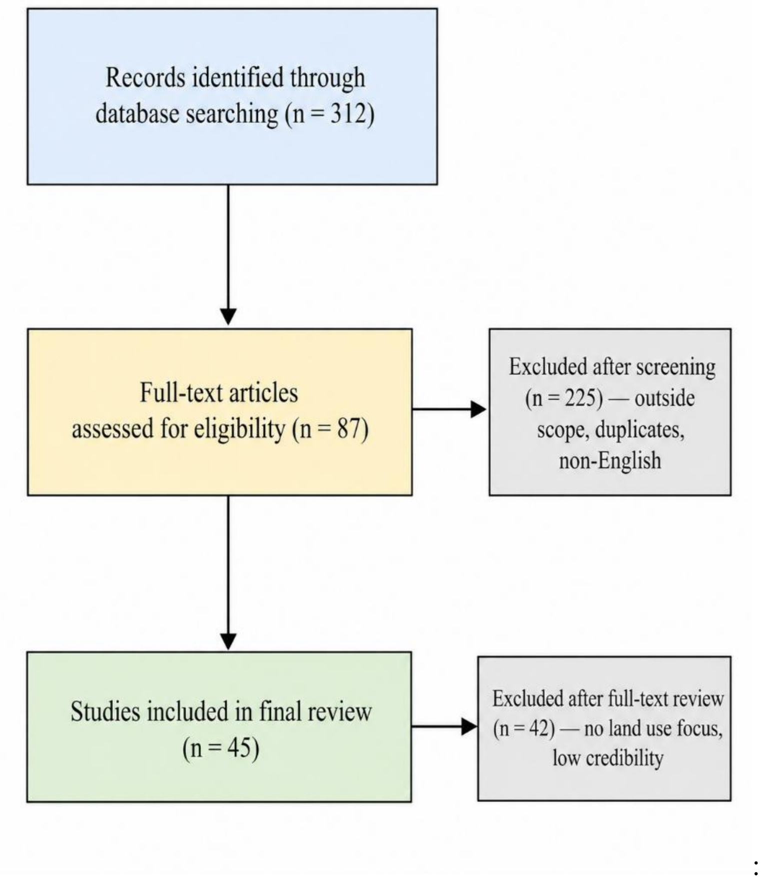
Literature was sourced from five academic databases: Google Scholar, Scopus, Web of Science, JSTOR, and PubMed. In addition, grey literature, including government reports, institutional publications, and NGO documents, was reviewed to capture policy-relevant information not always found in academic journals. The search covered publications from 2000 to 2025 to ensure contemporary relevance while including foundational studies from earlier in this period.

The primary search terms used were: 'climate change Sri Lanka agriculture,' 'Gin River Basin land use,' 'rainfall variability crop production,' 'agricultural adaptation Sri Lanka,' 'flood impacts paddy Sri Lanka,' and 'climate change wet zone hydrology.' These were combined with Boolean operators (AND, OR) to refine the results.

Inclusion criteria required that sources: (1) addressed climate change or climate variability; (2) discussed agriculture or land use; (3) were relevant to Sri Lanka or comparable tropical contexts; and (4) were published in peer-reviewed journals, institutional reports, or government documents. Sources were excluded if they were not in English, were outside the specified time range, or were not traceable to credible institutions. Studies focused solely on biophysical modelling without implications for land use were also excluded.

Following the initial database searches, a total of 312 sources were identified. After removing duplicates and screening titles and abstracts, 87 full texts were assessed for eligibility. Of these, 45 sources met the inclusion criteria and were retained for the final review. The selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure methodological transparency (Moher et al., 2009).

Figure 01: PRISMA Flow Diagram of Literature Selection Process



Source: Created by Authors, 2026

The collected literature was analysed thematically, organised around four areas: (1) global climate change trends and their agricultural implications; (2) climate change impacts on agriculture in Sri Lanka; (3) characteristics and vulnerabilities of the Gin River Basin; and (4) adaptation strategies and policy responses. Critical analysis was applied throughout to evaluate the quality, consistency, and relevance of findings across studies.

Results and Discussion

Global View of Climate Change

According to the IPCC (2021), climate change refers to long-term shifts in the state of the climate, including changes in temperature, precipitation, and other climate variables, resulting from a combination of natural variability and human activities. While greenhouse gas emissions represent a major driver of the current warming trend, it is important to recognise that the IPCC does not attribute climate change to a single cause; the process involves complex interactions between anthropogenic and natural factors.

Atmospheric carbon dioxide concentrations reached over 415 ppm by 2020, levels not seen in at least 800,000 years (NOAA, 2020). Alongside CO2, methane and nitrous oxide emissions from land use change and agriculture have added further radiative forcing, destabilising the climate system (Smith et al., 2014).

Global mean surface temperatures have increased by approximately 1.1 degrees Celsius above pre-industrial levels, with warming accelerating over recent decades (WMO, 2022). This warming has contributed to widespread cryosphere loss, including shrinking glaciers and declining snow cover, which in turn drives sea level rise through both ice melt and thermal expansion of ocean water (IPCC, 2021).

Alongside these gradual changes, extreme climate events have become more frequent and severe. Heat waves, droughts, and floods are occurring more frequently worldwide, directly threatening water availability, ecosystem stability, and agricultural productivity (UNEP, 2021). These developments reinforce the need to understand how climate change interacts with land use at local and regional scales.

Land use plays a dual role in the climate system. Deforestation and land degradation reduce carbon sequestration capacity and contribute to greenhouse gas emissions, thereby amplifying climate change (FAO, 2020). At the same time, climate change itself alters the suitability of land for agriculture and other uses, creating feedback loops that make integrated land management increasingly critical (Vermeulen et al., 2012).

Agriculture also contributes to global greenhouse gas emissions through methane from rice cultivation and livestock, and nitrous oxide from synthetic fertilisers (Smith et al., 2014). These complex interactions between climate change and agricultural land use underscore the need for strategies that simultaneously address both mitigation and adaptation.

In terms of food security, the evidence is concerning. Changes in precipitation patterns and rising temperatures have already reduced yields of major crops, including wheat, maize, and rice, particularly in tropical and subtropical regions (Lobell & Gourdji, 2012; Challinor et al., 2014). These productivity losses are compounded by growing pest pressure, soil degradation, and water scarcity, and they fall most heavily on smallholder farmers in developing countries who have the least capacity to adapt (Morton, 2007).

Climate Change and Its Impacts on Agriculture

Temperature is one of the most direct climatic influences on crop growth and yield. Even modest increases in average temperature can significantly affect photosynthesis, respiration, and evapotranspiration, with consequences for agricultural output (De Costa, 2010). In tropical regions, where many crops already operate near their thermal tolerance limits, this risk is especially acute.

Research by Zhao et al. (2017) demonstrates that elevated temperatures shorten crop growing periods, accelerate phenological development, and reduce grain filling, particularly in cereals like rice and wheat. Heat stress during critical growth stages such as flowering and pollination can cause irreversible yield losses. Lobell et al. (2011) also found that increased night-time temperatures raise respiration rates, thereby reducing net carbon assimilation and limiting overall biomass accumulation. Beyond crop plants, rising temperatures affect livestock production by reducing feed intake, reproductive success, and milk yields while increasing susceptibility to disease (Rojas-Downing et al., 2017).

These temperature-related impacts translate into changes in agricultural land use in several ways. Declining productivity in heat-stressed environments pushes farmers to shift cropping systems, adopt more heat-tolerant varieties, or, in some cases, abandon marginal lands altogether. This makes temperature a central factor in understanding agricultural vulnerability and land use change across tropical farming systems.

Rainfall variability is another critical dimension of climate change that has received considerable research attention. As Huntington (2006) demonstrates, shifts in the volume, timing, and intensity of precipitation affect soil moisture availability, groundwater recharge, and irrigation reliability. In developing countries where most farming systems are rain-fed, this variability directly translates into agricultural risk.

Panabokke et al. (2014) show that prolonged dry spells and delayed monsoon onset in Sri Lanka have disrupted normal planting schedules and reduced cultivation rates. Conversely, intensified rainfall events have increased the frequency of waterlogging, crop damage, and soil erosion. These extremes reduce agricultural stability and compound the risks already faced by smallholder farmers, who often have limited means to recover from production losses.

Changes in rainfall patterns also affect surface water availability for irrigation. Reduced river flows during dry seasons and declining reservoir storage capacity restrict irrigation potential, forcing farmers to either reduce the area under cultivation or shift to crops with lower water requirements (Eriyagama et al., 2018). These hydrological constraints directly shape agricultural land use decisions and long-term land management strategies.

Extreme weather events including floods, droughts, heat waves, and cyclones have become more frequent and intense under changing climate conditions (Field et al., 2012). These events cause immediate crop losses and long-term degradation of the productive capacity of agricultural land.

Floods destroy standing crops, erode fertile topsoil, and deposit sediment that alters soil structure and nutrient content. Repeated flooding in vulnerable areas discourages continued cultivation and may lead to land abandonment or conversion to other uses (Nandalal & Ratnayake, 2010). Droughts, by contrast, deplete soil moisture and increase crop failure rates, especially in rain-fed systems. The cumulative effect of increasing climate extremes is to raise production risks, reduce farmers' investment in land improvements, and shift agricultural land-use patterns across the landscape.

Elevated atmospheric CO2 concentrations can stimulate photosynthesis and improve water-use efficiency in some crops, a phenomenon known as the CO2 fertilisation effect. Under controlled conditions, crops such as rice and wheat have shown increased biomass in response to higher CO2 levels (FAO, 2016). However, field-based research suggests that these benefits are frequently offset by nutrient deficiencies, water stress, and simultaneous temperature increases (Porter et al., 2014). A study by Myers et al. (2014) also found that higher CO2 concentrations are associated with reduced protein and micronutrient content in staple foods, raising concerns about food quality and human nutrition. The CO2 fertilisation effect, therefore, does not provide a reliable buffer against the broader adverse effects of climate change on agricultural systems.

Taken together, the evidence on temperature stress, precipitation variability, extreme events, and CO2 dynamics points to significant land use consequences. Vermeulen et al. (2012) document that farmers in many regions are already responding by diversifying crops, shifting planting calendars, reducing cropping intensity, and transitioning to more climate-resilient land-use systems. In some areas, marginal agricultural lands are being abandoned or converted to non-agricultural uses, while remaining productive lands are being intensified or diversified in response to climate uncertainty.

Climate Change Trends in Sri Lanka

Meteorological records analysed by the Department of Meteorology (2020) indicate a clear warming trend across Sri Lanka over the past several decades. Long-term data show that average temperatures have increased by approximately 0.8 to 1.2 degrees Celsius since the mid-20th century, with warming evident across all climatic zones.

De Costa (2010) found that rising temperatures have had significant consequences for Sri Lankan agricultural systems, including physiological changes in crops, increased evapotranspiration, and greater demand for irrigation water. Studies by Basnayake et al. (2015) show that elevated temperatures during sensitive crop development stages, particularly during rice, have been linked to poor grain formation and unstable yields in lowland paddy-growing regions. The same study demonstrates that temperature increases have affected yield consistency in highland plantation crops such as tea.

Temperature increases also interact with other climate variables to intensify their effects. During dry seasons, higher temperatures accelerate soil moisture depletion, further restricting agricultural land use options. These patterns suggest that temperature change is a key mediating factor in Sri Lanka's climate-driven transformation of agricultural land use.

Rainfall in Sri Lanka is highly variable and largely determined by the Southwest and Northeast monsoon systems. While total annual rainfall has not shown a consistent long-term decline, its distribution, intensity, and seasonality have changed considerably (Chandrapala, 1996). Rain events have become more concentrated, with shorter high-intensity periods and longer dry intervals between them.

These shifts have disrupted agricultural calendars that depend closely on the predictable arrival and duration of monsoon rains. Delayed onset and early cessation of the Southwest Monsoon have reduced the reliability of cultivation seasons, especially the Yala season, in many farming areas (Panabokke et al., 2014). For rain-fed farming systems, such disruptions increase the risk of crop failure and discourage full use of available agricultural land.

The paradox is that, despite increased rainfall intensity in some instances, actual water availability for agriculture has not improved in proportion. Higher-intensity rainfall leads to faster runoff, reduced infiltration, and lower groundwater recharge, resulting in less water during dry seasons. Rainfall variability has thus become a major constraint on stable agricultural land use in Sri Lanka.

Sri Lanka has also experienced a notable rise in the frequency and intensity of extreme weather events including floods, droughts, landslides, and cyclones (Department of Meteorology, 2021). Floods have become more common in the wet zone, while droughts have intensified in the dry and intermediate zones.

Nandalal and Lakshman (2018) found that floods destroy extensive agricultural areas, erode topsoil, and damage irrigation infrastructure. Repeated flooding discourages continued cultivation in vulnerable lowland areas and reduces long-term land productivity. Droughts simultaneously deplete soil moisture and increase pressure on irrigation systems, often beyond the capacity of existing water storage infrastructure. These events also affect farmer decision-making over longer time horizons. As production risks increase, farmers are less willing to invest in land improvements and tend to favour short-term coping over long-term sustainable land management. Extreme weather events, therefore, play a decisive role in shaping agricultural land use dynamics under climate change.

Rising sea levels represent a growing threat to low-lying coastal agricultural lands in Sri Lanka (Wijeratne & Ranasinghe, 2015). Combined with storm surges and coastal erosion, higher sea levels have contributed to saline intrusion into freshwater supplies and agricultural soils. This process reduces soil fertility and limits the suitability of coastal land for traditional crops such as paddy and coconut.

In affected areas, farmers have been compelled to change their land use practices, shifting to salt-tolerant crops, reducing cultivation, or abandoning agricultural land entirely. Some farmlands have been converted to aquaculture or other non-agricultural uses, reflecting the declining viability of traditional farming systems amid changing coastal environments. These transitions illustrate how sea-level rise interacts with other climate impacts to reshape agricultural land use along the coast of Sri Lanka.

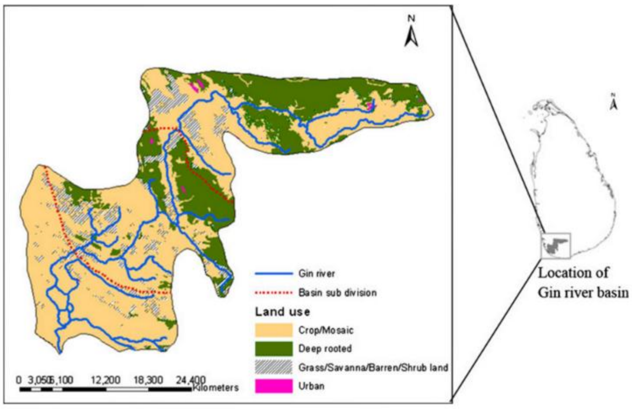
Climate projections for Sri Lanka indicate continued warming and increasing climate variability throughout the 21st century (Eriyagama et al., 2018; IPCC, 2021). Under high-emission scenarios, mean temperatures are expected to rise by up to 3.5 degrees Celsius by the end of the century, with more pronounced warming in inland and upland areas. Projected changes in rainfall include greater seasonal variability, more intense rainfall events, and extended dry periods. These changes are expected to amplify flood and drought risks, placing additional pressure on agricultural systems and water resources. Current agricultural land use patterns may become increasingly unsustainable in the absence of targeted adaptation and land use planning. Understanding these projections is therefore essential for anticipating long-term land-use shifts and designing climate-resilient strategies at both national and subnational levels.

Gin River Basin Characteristics

The Gin Ganga River Basin is located in the Galle District of the Southern Province of Sri Lanka and covers approximately 932 km^2 (Eriyagama et al., 2018). Elevation ranges from upper catchment areas above 1,000 m above mean sea level down to Tawalama Station at 190 m and Baddegama Station at below 10 m (Jayapadma et al., 2024, 2025). The basin has a tropical rainforest climate, characterised by high humidity and substantial rainfall throughout the year, with particularly heavy precipitation during the monsoon seasons (De Silva, 2006).

Agricultural land accounts for approximately 38.5% of the total land area in the basin, while homestead land covers about 51.5% (JICA, 2016; Dissanayake et al., 2019). Tea cultivation and forestry dominate the upper catchment, with large-scale tea estates particularly prominent in the Deniyaya and Neluwa areas. The middle catchment supports a mix of plantation crops, home gardens, and smallholder systems, with perennial crops such as rubber, cinnamon, and banana commonly integrated into agroforestry systems (Eriyagama et al., 2018). Paddy cultivation is concentrated in the lower basin, in areas below 30 m above mean sea level-including Baddegama, Bope-Poddala, and Nagoda, where approximately 38% of land is under paddy and vulnerability to flooding during the Southwest Monsoon is high (Department of Irrigation, 2020).

Figure 02: Map of the Gin River Basin Showing Land Use Zones and Elevation Gradient



Source: Created by Authors, 2026

The basin receives more than 3,500 mm of annual rainfall in some upstream areas, with precipitation highly seasonal and strongly influenced by the Southwest Monsoon (Department of Meteorology, Sri Lanka, 2021). Hydrological research indicates a trend towards higher peak flows during monsoon periods and lower base flows during dry months, reflecting the combined influence of climate variability and land-use change. (Eriyagama et al., 2018).

Agriculture is the primary livelihood activity in the basin, supporting both subsistence and commercial production. Paddy in the lower basin depends on river water and smaller irrigation canals, while upland farming relies mainly on rainfall (Samaraweera et al., 2024). Changes in precipitation and temperature have already begun to disrupt cropping schedules, reduce harvests, and increase production risks for basin farmers (SLJSSH, 2020).

The Gin River Basin is one of the more flood-prone river systems in Sri Lanka, with the frequency and intensity of flooding increasing in recent decades (Nandalal & Ratnayake, 2010). Sedimentation, riverbank erosion, and the silting of irrigation canals further reduce agricultural productivity and water-use efficiency. These characteristics make the basin particularly vulnerable to climate change and highlight the importance of integrated river basin management and climate-resilient land use planning.

Agricultural Land Use in Sri Lanka: Climate Change Effects

Climate change has emerged as a significant driver of agricultural land-use change in Sri Lanka, influencing cropping patterns, land suitability, and farming decisions across different agro-ecological zones. Rising temperatures, altered rainfall patterns, and more frequent climate extremes have collectively disrupted traditional farming systems and forced farmers to make new land-use choices amid increasing production risks (Eriyagama et al., 2018).

One of the clearest manifestations of climate change on agricultural land use has been the shift in crop suitability zones. Temperature increases and changes in rainfall have reduced the productive suitability of certain crops in previously high-performing areas, while opening up possibilities in others (De Costa, 2010). Paddy, for example, has shown declining productivity in both rain-fed and irrigated systems due to erratic rainfall and elevated evapotranspiration rates (Basnayake et al., 2015). As a result, marginal paddy fields have increasingly been abandoned or converted to less water-demanding crops.

Changes in rainfall distribution have also affected cropping intensity and seasonal land use. Late monsoon onset and early withdrawal have disrupted planting calendars across many regions, resulting in reduced cultivation during the Yala season (Panabokke et al., 2014). Extended dry periods in rain-fed systems have discouraged double cropping, leading to underutilization of available agricultural land. By contrast, intensified rainfall during cultivation periods has caused significant flood damage, particularly in wet-zone river basins such as the Gin River, where repeated crop failures have undermined confidence in continued cultivation (Nandalal & Ratnayake, 2010).

Land degradation processes have also been accelerated by climate change, with direct implications for agricultural land use. Increased rainfall intensity has contributed to accelerated soil erosion, nutrient loss, and sedimentation, particularly on sloped soils under plantation agriculture (Dissanayake et al., 2019). These processes progressively reduce land productivity and erode the agricultural suitability of upland areas. Along the coast, sea level rise and saline intrusion have rendered formerly fertile land unsuitable for conventional crops, including paddy and coconut (Wijeratne & Ranasinghe, 2015).

Socio-economic factors interact with these climatic stressors to shape land-use outcomes. Smallholder farmers, who predominate in the Sri Lankan agricultural sector, often lack the financial resources, access to technology, and institutional support needed to adapt effectively (Esham & Garforth, 2013). Climate change has therefore reinforced existing pressures, including land fragmentation, rural labour migration, and the conversion of agricultural land to non-agricultural uses, particularly in peri-urban and flood-prone areas.

Understanding these climate-driven changes in agricultural land use is essential for developing effective land-use planning strategies that balance productivity, sustainability, and livelihood security across Sri Lanka's diverse agro-ecological contexts.

Agricultural Land Use Change and Adaptation in the Gin River Basin

The Gin River Basin shows clear evidence of climate-driven changes in agricultural land use, reflecting both biophysical pressures and socio-economic constraints. Increasing rainfall variability, rising temperatures, and frequent flooding have collectively altered conventional farming systems and reshaped land use decisions throughout the basin (Eriyagama et al., 2018).

The impacts of climate change have been particularly pronounced in paddy farming in the lower catchment. Heavy rains associated with the Southwest Monsoon regularly inundate lowland paddy fields, causing crop losses and soil erosion (Department of Irrigation, 2020). In response, farmers have reduced cultivation intensity, delayed planting dates, or temporarily abandoned flood-prone areas. In some locations, paddy land has been converted to seasonal crops or non-agricultural uses, reflecting declining confidence in paddy-based livelihoods (SLJSSH, 2020).

Plantation agriculture in the middle and upper catchment areas has also undergone notable changes. Tea and rubber cultivation on hillside slopes has become more vulnerable to soil erosion, landslides, and moisture stress from both heavy rainfall and extended dry periods (Dissanayake et al., 2019). These pressures have encouraged a shift toward mixed cropping, agroforestry arrangements, and the incorporation of perennial crops such as cinnamon and fruit trees, which tend to be more resilient to climatic variability (Samaraweera et al., 2024).

Farmers in the Gin River Basin have adopted a range of adaptation measures in response to these pressures. These include adjustments to cropping calendars, diversification of crop types, the adoption of short-duration and flood-tolerant crop varieties, and improved water management practices. However, these strategies are not uniformly adopted across the basin. Access to credit, extension services, and institutional support remains uneven, and these gaps significantly constrain the effectiveness of adaptation (Esham & Garforth, 2013). Traditional knowledge continues to play an important role in local adaptation, especially in managing flood risk and maintaining soil fertility, though the pace of climate change is increasingly challenging the relevance and sufficiency of inherited farming practices.

Hydrological changes in the basin also complicate agricultural adaptation. Increasing monsoon peak flows and declining dry-season base flows have reduced the reliability of surface water for irrigation (Eriyagama et al., 2018). Sedimentation and reduced storage capacity in irrigation canals and tanks have further exacerbated water shortages during critical periods for crop production. These factors undermine the stability of farming systems and shape long-term land use decisions across the basin.

Despite these challenges, there are opportunities for climate-resilient land use planning in the Gin River Basin. Integrated river basin management, improved flood forecasting, promotion of climate-smart agricultural practices, and stronger institutional coordination have all been identified as pathways to enhanced resilience (Eriyagama et al., 2018). Understanding the land-use changes and adaptation strategies already underway in the basin is therefore critical to designing targeted interventions that can sustain agricultural livelihoods under changing climatic conditions.

Policy Frameworks and Institutional Responses in Sri Lanka

Sri Lanka has developed a multilayered policy and institutional framework to address climate change in the agriculture and land use sectors. Sri Lanka's Nationally Determined Contributions (NDC), revised in 2021, commit the country to implementing climate-smart agriculture on 500,000 hectares by 2030 and to reducing agricultural greenhouse gas emissions by 10% (Ministry of Environment, 2021). The National Adaptation Plan (NAP) for 2018 to 2025 prioritises water management and requires the integration of climate risk considerations into Agricultural Master Plans (Ministry of Environment, 2018).

At the sector level, the Agriculture Sector Modernisation Program has allocated LKR 15 billion toward climate resilience measures, including micro-irrigation subsidies and research into heat-tolerant crop varieties (Ministry of Agriculture, 2020). The National Agriculture Policy (2019) promotes crop diversification and organic production to reduce dependence on water-intensive paddy farming (Ministry of Agriculture, 2019). A dedicated Climate Smart Agriculture Strategy is also being developed to support value chain financing and the scaling of climate-adaptive practices (Department of Agriculture, 2021).

At the institutional level, governance is being decentralised through District Climate Cells that localise national climate plans. In the Galle District, which encompasses the Gin River Basin, vulnerability assessments covering 50 Grama Niladhari divisions have been conducted (Weerasinghe, 2020). Although formal River Basin Organisations are still in development, ad hoc Basin Task Forces have taken on coordination roles for flood management and infrastructure rehabilitation in the Gin River area (Jayapadma et al., 2022; Eriyagama et al., 2018). Research institutions, including the Tea Research Institute and the Rubber Research Institute, have contributed by developing climate-resilient crop varieties suited to the basin's specific agro-ecological conditions (Eriyagama et al., 2018).

In terms of financing, the Green Climate Fund approved a USD 30 million Climate Smart Agriculture pilot project that includes the Gin Basin as one of its target areas (GCF, 2021). Weather-indexed insurance pilots have been implemented to protect farmers against specific drought and flood risks, and concessional credit schemes worth LKR 5 billion have been made available to support investment in climate-smart practices. The National Climate Change Secretariat coordinates these initiatives by aligning sector plans through multi-agency consultations. Public-private partnerships, including co-investment by plantation estates in precision agriculture pilots and digital advisory services, have also been identified as promising mechanisms for strengthening market connections and environmental resilience in the Gin Basin.

Research Gaps in the Existing Literature

Despite growing attention to climate change and agriculture in Sri Lanka, a number of significant research gaps remain, particularly regarding how climate variability translates into changes in agricultural land use at the river basin scale.

The most significant gap is the absence of integrated basin-scale models that link climate variability, hydrological change, and agricultural land use decisions within a single analytical framework. While global climate projections (IPCC, 2021) and plot-level crop models exist, no high-resolution model couple’s climate, hydrology, and crop growth across the full landscape of a heterogeneous basin like the Gin River Basin. This limits planners' ability to anticipate land-use shifts and design targeted adaptation interventions.

Land use monitoring also remains constrained by the resolution of available remote sensing data. Most published studies rely on 30-metre Landsat imagery, which cannot capture the complexity of smallholder field patterns or intercropping systems common in the basin (Smith et al., 2014; Lal et al., 2020). Higher-resolution satellite data and drone-based monitoring are needed to track microscale land-use changes and their relationship to climate events.

Longitudinal socio-economic studies are also largely absent. Most existing research is based on cross-sectional surveys conducted at a single point in time (Weerasinghe, 2020; Department of Agriculture, 2019). Panel studies that follow households over multiple seasons or years are needed to distinguish between short-term coping responses and genuine long-term adaptive transitions in land use behaviour.

The effectiveness of existing policy interventions has also not been rigorously evaluated. Although policy frameworks are well documented (Ministry of Environment, 2021; Ministry of Agriculture, 2020), there is little empirical evidence on whether subsidies, insurance pilots, and extension programs are improving farmers' climate resilience. This limits the ability to refine policies based on observed outcomes.

Ecosystem service valuation represents another underexplored area. While provisioning and regulating services in the Gin Basin have received some attention (Eriyagama et al., 2018; Jayapadma et al., 2022), quantitative assessments of services such as carbon sequestration and soil retention under future climate scenarios remain largely absent. This gap constrains the design of Payment for Ecosystem Services schemes that could incentivise climate-resilient land management.

Finally, gender and equity dimensions of climate adaptation are poorly represented in the existing literature. Intersectional analysis of how gender, land tenure status, age, and social class shape access to resources and adaptation options is needed to avoid reinforcing social inequalities through climate interventions (FAO, 2016; Weerasinghe, 2020).

Additional gaps include the limited analysis of market dynamics in relation to climate-driven land use change, the connections between agricultural transitions and nutrition outcomes, and socio-cultural barriers to technology adoption. The role of regional climate teleconnections, particularly ENSO, in driving interannual variability in the Gin Basin also deserves more systematic attention.

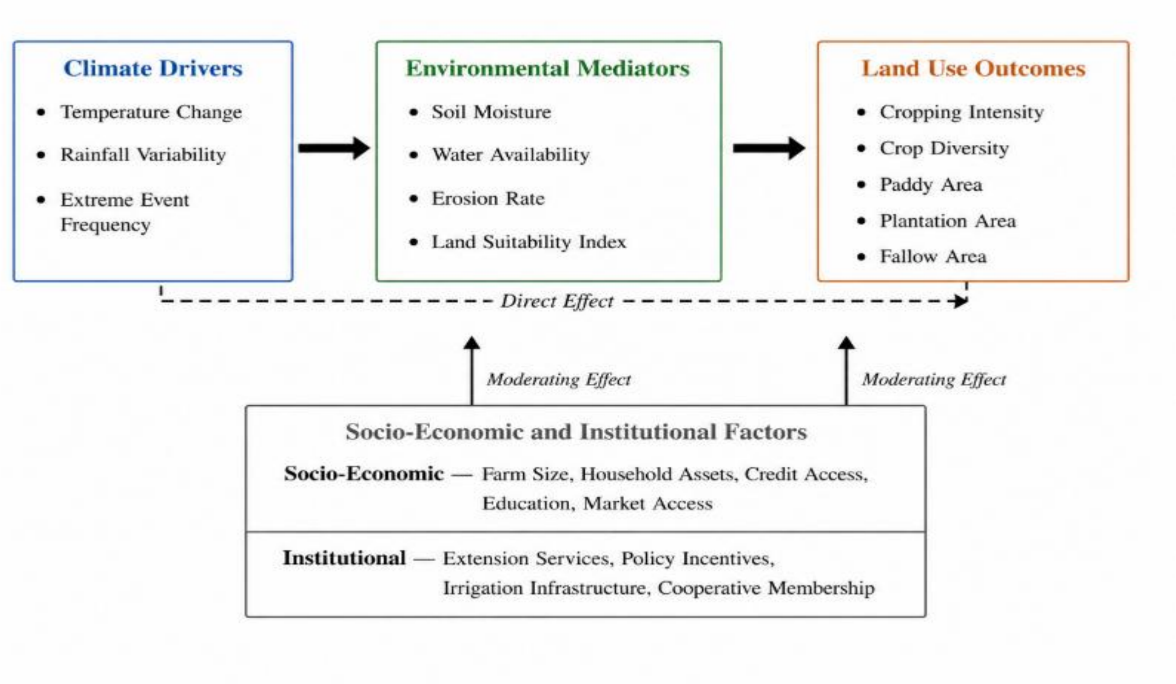
Conceptual Framework

The conceptual framework proposed for this study integrates climate change drivers, environmental mediators, and agricultural land-use outcomes in the specific context of the Gin River Basin. It draws on three theoretical traditions: the Vulnerability and Resilience Theory, which understands land use change as a product of exposure, sensitivity, and adaptive capacity (Adger, 2006); Land Change Science, which examines the interaction between environmental drivers and human decision-making (Turner et al., 2007); and the Socio-Ecological Systems framework, which treats the basin as a coupled system of resource users and governance institutions that co-evolve over time (Ostrom, 2009).

The framework identifies five categories of variables. Climate Drivers include temperature change, rainfall variability, and extreme event frequency. Environmental Mediators include soil moisture, water availability, erosion rates, and land suitability indices. Socio-Economic Factors include farm size, household assets, access to credit, education level, and market proximity. Institutional Factors include extension services, policy incentives, irrigation infrastructure, and cooperative membership. Land Use Outcomes include cropping intensity, crop diversity, and the area under paddy, plantation, fallow, and other land use categories.

Five hypothesised relationships structure the analytical approach. First, climate drivers are expected to have a direct negative effect on cropping intensity and crop diversity (Lobell & Gourdji, 2012; Altieri et al., 2015). Second, climate drivers also affect land use indirectly by modifying soil moisture and erosion rates; for example, extreme weather events may increase erosion, which in turn expands fallow area (Jayapadma et al., 2022). Third, socio-economic factors such as farm size and household assets are expected to buffer the negative effects of climate stress; market access also moderates sensitivity by enabling crop switching in response to economic signals (Morton, 2007). Fourth, strong irrigation infrastructure and appropriate policy incentives are expected to support adaptation and reduce land abandonment. Fifth, combined access to credit and cooperative membership is expected to yield significantly better outcomes for crop diversity and adaptive capacity than either factor alone.

Figure 03: Conceptual Framework Diagram Showing Climate Drivers, Environmental Mediators, Socio-Economic and Institutional Factors, and Land Use Outcomes



Source: Created by Authors, 2026

The framework is operationalised through measurable indicators assigned to each variable, as presented in Table 1.

Table: 01: Operationalization and Measurement of Key Variables

Variable	Measure / Indicator	Data Source	Scale
Temperature change (DeltaT)	Change in degrees C per decade (1950-2020)	Meteorological records	Continuous
Rainfall variability (sigmaP)	Coefficient of variation of monthly rainfall	Meteorological records	Continuous
Extreme event frequency (f_ext)	Number of days per year with rainfall above 95th percentile; number of heatwave days	Station extreme indices (ETCCDI)	Count
Soil moisture (SM)	Volumetric soil moisture (%)	In-situ sensors; SWAT model output	Continuous

Variable	Measure / Indicator	Data Source	Scale
Water availability (WA)	Baseflow volume (m3 per month)	River gauge records; SWAT output	Continuous
Erosion rate (ER)	Suspended sediment yield (tons/ha/year)	Sediment sampling; SWAT	Continuous
Land suitability index (LSI)	Composite index of soil, slope, and climatic suitability	Multi-criteria analysis in GIS	Continuous (0 to 1)
Cropping intensity (CI)	Number of crop cycles per year	Farmer survey; remote sensing	Continuous
Crop diversity (CD)	Shannon's diversity index of crops grown	Survey: land use maps	Continuous
Land use area (AP, AT, AF)	Hectares under paddy, plantation, and fallow	Remote sensing classification; survey	Area (ha)
Farm size / Assets (FS, HA)	Land holding size (ha); household asset index	Household survey	Continuous
Credit access (AC)	Access to formal credit (yes/no)	Survey	Binary
Education level (ED)	Years of formal education completed	Survey	Continuous
Market access (MA)	Distance to nearest market; frequency of market use	GIS; survey	Continuous
Institutional factors (ES, PI, II, CM)	Likert-scale indices of extension services, policy incentives, irrigation infrastructure, and cooperative membership	Key informant interviews; survey	Ordinal (1 to 5)

Source: Created by Authors, 2026

To test the relationships proposed in the framework, the study uses four analytical methods. Structural Equation Modelling is used to measure both direct and indirect (mediated) effects among latent constructs (Byrne, 2013). Multilevel Regression accounts for hierarchical data structure (fields within households, within villages) and tests moderation effects (Gelman & Hill, 2007). Spatial Analysis using GIS visualises land use outcomes and land suitability indices to compare spatial patterns against model predictions. Qualitative Comparative Analysis identifies combinations of socio-economic and institutional conditions that are associated with positive adaptive outcomes (Ragin, 2008).

This framework makes three main contributions. It brings together biophysical and socio-institutional dimensions to explain complex climate-land use interactions. It guides empirical data collection through clearly measurable indicators. It identifies leverage points, such as credit access and the quality of extension services, that can be targeted through policy to strengthen climate adaptation.

Conclusion

This review has synthesised evidence from global, national, and basin-level research to examine how climate change is affecting agricultural land use in the Gin River Basin, Sri Lanka. Three key findings emerge from the analysis.

First, rising temperatures, increasingly erratic rainfall, and more frequent flood events are already disrupting agricultural systems in the basin, particularly paddy cultivation in the flood-prone lower catchment and plantation agriculture in the upper reaches. These changes are translating into reduced cropping intensity, shifts in crop composition, and in some areas, land abandonment or conversion to non-agricultural uses.

Second, farmers in the Gin River Basin are actively responding to climate pressures through a range of adaptation strategies, including crop diversification, calendar adjustments, adoption of flood-tolerant varieties, and shifts toward agroforestry. However, the effectiveness of these strategies is constrained by unequal access to credit, extension services, and institutional support, limiting many small-holders farmer’s ability to make sustainable, long-term adjustments.

Third, the existing research base has significant gaps, most notably the absence of integrated basin-scale models, limited longitudinal data on farmers' adaptation, insufficient evaluation of policy effectiveness, and inadequate attention to the gender and equity dimensions of climate-driven land-use change.

In terms of policy implications, the findings suggest that interventions need to operate at multiple levels simultaneously. Improving access to weather-indexed insurance and concessional credit can reduce production risk for smallholder farmers and encourage longer-term investment in land management. Strengthening extension services and agricultural advisory systems can improve the uptake of climate-adaptive practices. At the basin level, integrated water management and early flood warning systems are needed to protect lowland paddy areas. National climate adaptation frameworks need to be translated into locally relevant, spatially targeted action plans that take into account the specific vulnerabilities of wet-zone river basins.

For future research, three priorities stand out. The development of integrated, high-resolution climate-hydrology-land use models for the Gin River Basin would substantially improve the evidence base for adaptation planning. Longitudinal studies tracking farmers' land-use decisions over multiple seasons would clarify the pathways from climate exposure to land-use outcomes. Research that explicitly addresses gender, equity, and social differentiation in adaptation would help ensure that interventions reach the most vulnerable farming households.

Taken together, this review establishes a foundation for empirical research on climate change and agricultural land use in the Gin River Basin, and contributes to the broader effort of building climate-resilient agricultural systems in Sri Lanka's wet zone.

References

Adger, W. N. (2006). Vulnerability. *Global Environmental Change, 16*(3), 268–281. https://doi.org/10.1016/j.gloenvcha.2006.02.006

Altieri, M. A., Nicholls, C. I., Henao, A., & Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agronomy for Sustainable Development, 35*(3), 869–890. https://doi.org/10.1007/s13593-015-0285-2

Basnayake, B. R. S. B., Punyawardena, B. V. R., & Wijeratne, M. A. (2015). *Assessment of impact of climate change on productivity of tea (Camellia sinensis L.) plantations in Sri Lanka*. Tea Research Institute of Sri Lanka.

Byrne, B. M. (2013). *Structural equation modeling with Mplus: Basic concepts, applications, and programming*. Routledge.

Chandrapala, L. (1996). Long term trends of rainfall and temperature in Sri Lanka. In Y. P. Abrol, S. Gadgil, & G. B. Pant (Eds.), *Climate variability and agriculture* (pp. 153–162). Narosa Publishing House.

Challinor, A. J., Watson, J., Lobell, D. B., Howden, S. M., Smith, D. R., & Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change, 4*(4), 287–291. https://doi.org/10.1038/nclimate2153

De Costa, W. A. J. M. (2010). Adaptation of agricultural systems to climate change: A review of mechanisms, options and limits. *Journal of the National Science Foundation of Sri Lanka, 38*(2), 73–88. https://doi.org/10.4033/jnsfsr.v38i2.2023

De Silva, R. P. (2006). *Hydrological studies in the Gin Basin*. Department of Irrigation Research, Government of Sri Lanka.

Department of Agriculture Sri Lanka. (2019). *Annual report on agricultural extension and development*. Government of Sri Lanka.

Department of Agriculture Sri Lanka. (2021). *Annual report on agricultural extension and development*. Government of Sri Lanka.

Department of Irrigation Sri Lanka. (2020). *Hydrological annual of Sri Lanka 2019/2020*. Ministry of Irrigation, Government of Sri Lanka.

Department of Meteorology Sri Lanka. (2020). *Annual climate report 2019*. Government of Sri Lanka.

Department of Meteorology Sri Lanka. (2021). *Performance report 2021*. Ministry of Defense, Government of Sri Lanka.

Dissanayake, D. M. S. L. B., Morimoto, T., Murayama, Y., Ranagalage, M., & Perera, E. N. C. (2019). Impact of land use/land cover changes on surface water quality in the Kelani River Basin, Sri Lanka. *Environmental Monitoring and Assessment, 191*(3), 114. https://doi.org/10.1007/s10661-019-7253-1

Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlomer, S., von Stechow, C., Zwickel, T., & Minx, J. C. (Eds.). (2014). *Climate change 2014: Mitigation of climate change*. Cambridge University Press.

Ekanayake, E. M. G. S., Jayawardena, L. N. A. C., & Munas, M. M. (2020). Climate change impacts and adaptations: A case study of paddy cultivation in the dry zone of Sri Lanka. *Environmental Development, 36*, 100558. https://doi.org/10.1016/j.envdev.2020.100558

Eriyagama, N., Smakhtin, V., Chandrapala, L., & Fernando, K. (2018). *Impacts of climate change on water resources and agriculture in Sri Lanka: A review and preliminary vulnerability assessment* (IWMI Research Report 135). International Water Management Institute.

Esham, M., & Garforth, C. (2013). Agricultural adaptation to climate change: Insights from a farming community in Sri Lanka. *Mitigation and Adaptation Strategies for Global Change, 18*(5), 535–549. https://doi.org/10.1007/s11027-012-9374-6

FAO. (2016). *Climate change and food security: Risks and responses*. Food and Agriculture Organization of the United Nations.

FAO. (2020). *Global forest resources assessment 2020: Main report*. Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/ca9825en

Field, C. B., Barros, V., Stocker, T. F., Qin, D., Dokken, D. J., Kristie, L. E., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S. K., Tignor, M., & Midgley, P. M. (Eds.). (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation: Special report of the Intergovernmental Panel on Climate Change (SREX)*. Cambridge University Press. https://www.ipcc.ch/report/srex/

Gelman, A., & Hill, J. (2007). *Data analysis using regression and multilevel/hierarchical models*. Cambridge University Press.

Green Climate Fund. (2021). *Funding proposal: Climate-smart agriculture in Sri Lanka*. GCF.

Huntington, T. G. (2006). Evidence for intensification of the global water cycle: Review and synthesis. *Journal of Hydrology, 319*(1–4), 83–95. https://doi.org/10.1016/j.jhydrol.2005.07.003

IPCC. (2021). *Climate change 2021: The physical science basis*. Cambridge University Press.

Jayapadma, M., Souma, K., & Ishidaira, H. (2022). The effect of incorporation of embankment information for flood simulation of the Gin River, Sri Lanka. *Journal of Disaster Research, 17*(3), 475–486.

Jayapadma, M., Souma, K., & Ishidaira, H. (2024). Hydrological analysis of the Gin River Basin under changing climate conditions. *Journal of Hydrology: Regional Studies, 51*, 101658.

Jayapadma, M., Souma, K., & Ishidaira, H. (2025). Land use and hydrological interactions in the Gin River Basin. *Environmental Research Letters, 20*(1), 014031.

JICA. (2016). *Study on flood risk assessment and land use planning in the Gin River Basin*. Japan International Cooperation Agency.

Lal, M., Seneviratne, S. I., & Ekanayake, E. M. G. S. (2020). Agro-ecological zone shifts under climate change in Sri Lanka. *Climate Risk Management, 27*, 100204.

Lobell, D. B., & Gourdji, S. M. (2012). The influence of climate change on global crop productivity. *Plant Physiology, 160*(4), 1686–1697. https://doi.org/10.1104/pp.112.208298

Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science, 333*(6042), 616–620. https://doi.org/10.1126/science.1204531

Ministry of Agriculture. (2019). *National agriculture policy*. Government of Sri Lanka.

Ministry of Agriculture. (2020). *Agriculture sector modernization program*. Government of Sri Lanka.

Ministry of Environment. (2018). *National adaptation plan for climate change 2018–2025*. Government of Sri Lanka.

Ministry of Environment. (2021). *Sri Lanka's updated nationally determined contribution*. Government of Sri Lanka.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine, 6*(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences, 104*(50), 19680–19685. https://doi.org/10.1073/pnas.0701855104

Myers, S. S., Zanobetti, A., Kloog, I., Huybers, P., Leakey, A. D., Bloom, A. J., Carlisle, E., Dietterich, L. H., Fitzgerald, G., Hasegawa, T., Holbrook, N. M., Nelson, R. L., Ottman, M. J., Raboy, V., Sakai, H., Sartor, K. A., Schwartz, J., Seneweera, S., Tausz, M., & Usui, Y. (2014). Increasing CO2 threatens human nutrition. *Nature, 510*(7503), 139–142. https://doi.org/10.1038/nature13179

Nandalal, K. D. W., & Lakshman, A. (2018). *Assessing potential loss and damage for flood hazard using an econometric modelling technique*. Asia-Pacific Network for Global Change Research.

Nandalal, K. D. W., & Ratnayake, U. R. (2010). Event-based analysis of an unsteady flow resulting in a flood: Gin River case. *Engineer: Journal of the Institution of Engineers Sri Lanka, 43*(3), 11–18.

NOAA. (2020). *Global climate report – annual 2020*. National Centers for Environmental Information.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science, 325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Panabokke, C. R., Tennakoon, T. M. J., & Ariyaratne, R. M. (2014). *Climate change and its impact on the rice-based cropping systems of the Dry Zone of Sri Lanka*. National Science Foundation of Sri Lanka.

Porter, J. R., Xie, L., Challinor, A. J., Cochrane, K., Howden, S. M., Iqbal, M. M., & Travasso, M. I. (2014). Food security and food production systems. In C. B. Field et al. (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability* (pp. 485–533). Cambridge University Press.

Ragin, C. C. (2008). *Redesigning social inquiry: Fuzzy sets and beyond*. University of Chicago Press.

Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptations, and mitigations. *Climate Risk Management, 16*, 145–163. https://doi.org/10.1016/j.crm.2017.02.001

Samaraweera, H., Perera, K., & Fernando, R. (2024). Vulnerability of wet zone agriculture to climate variability in Sri Lanka: Field evidence from Galle District. *Sri Lanka Journal of Social Sciences and Humanities, 12*(2), 45–59.

Turner, B. L., Lambin, E. F., & Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. *Proceedings of the National Academy of Sciences, 104*(52), 20666–20671. https://doi.org/10.1073/pnas.0704119104

UNEP. (2021). *Adaptation gap report 2021*. United Nations Environment Programme.

Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. (2012). Climate change and food systems. *Annual Review of Environment and Resources, 37*(1), 195–222. https://doi.org/10.1146/annurev-environ-020411-130608

Weerasinghe, P. (2020). Climate-resilient agriculture in Sri Lanka: Challenges and prospects. *Journal of Environmental Management, 275*, 111218.

World Meteorological Organization. (2022). *State of the global climate 2021* (WMO-No. 1290). World Meteorological Organization. https://library.wmo.int/idurl/4/58111

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D. B., Huang, Y., Huang, M., Yao, Y., Bassu, S., Ciais, P., Durand, J. L., Elliott, J., Ewert, F., Janssens, I. A., Li, T., Lin, E., Liu, Q., Martre, P., Muller, C., & Asseng, S. (2017). Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences, 114*(35), 9326–9331. https://doi.org/10.1073/pnas.1701762114