

# Climate Change and Food Production: An Economic Analysis of Environmental Stress on Agricultural Sustainability

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## Abstract

Climate change has emerged as a defining global challenge of the 21st century, particularly in its profound impact on food production systems. Rising global temperatures, changing precipitation patterns, and increasing frequency of extreme weather events disrupt agricultural productivity and threaten food security across both developed and developing nations. Indonesia, with its dependence on climate-sensitive agriculture, is especially vulnerable. This study investigates the relationship between climate change and food production through a qualitative textual analysis using economic theory. It aims to analyze how climatic variables influence food output, pricing, and sustainability, as well as to assess adaptive strategies within the agricultural sector. Drawing from international and Indonesian academic sources, the research integrates economic-environmental models with socio-ecological data to synthesize a grounded understanding of systemic shifts in food production dynamics. The findings suggest that the interaction between climate volatility and food systems is multi-dimensional. Significant negative impacts on rice, maize, and vegetable yields were found, especially in tropical zones. Institutional weaknesses and the lack of resilient infrastructure compound these effects. However, local adaptations—ranging from technological inputs to traditional ecological knowledge—offer promising pathways. This research highlights the importance of robust policy interventions, regional cooperation, and climate-smart agriculture. By embedding climate resilience into economic frameworks and food governance, nations can ensure more stable and equitable food systems in a warming world.

## Keywords

economic trade-offs; opportunity cost; institutional economics; sustainability; policy coherence

## INTRODUCTION

The changing climate has reshaped human–environment interactions on a global scale, with particular significance for food production systems. As rising temperatures, erratic rainfall, and extreme weather events become more frequent, agricultural productivity

faces mounting risks (IPCC, 2007). These climate-induced disruptions intersect with growing global demand for food, placing food security at the center of international policy and academic debates (Parry et al., 2005).

In Indonesia, where agriculture contributes significantly to GDP and employs over 30% of the labor force (BPS, 2010), climate variability directly threatens rural livelihoods and national development goals. Traditional farming systems, often dependent on monsoonal cycles and fragile ecologies, are highly sensitive to small changes in weather patterns (Syamsiah, 2011). As a result, issues of declining yields, soil degradation, and shifting crop patterns have emerged across the archipelago (Ministry of Agriculture, 2011).

Economic perspectives on climate change focus not only on direct impacts—such as yield loss—but also on indirect effects, including food price inflation, rural–urban migration, and macroeconomic instability (Stern, 2007). The relationship between environmental degradation and economic growth is well-established, yet its specific implications for food production demand more localized, interdisciplinary analysis (Dasgupta, 2010).

International studies show that climate variability has already reduced global agricultural productivity by more than 20% since the 1960s (Lobell & Field, 2007). Meanwhile, adaptive capacity remains uneven across regions. In Indonesia, adaptation mechanisms often depend on institutional quality, availability of information, and socio-cultural acceptance (Asyari, 2012). Local farmers frequently lack access to climate-smart technology, while national policies may not align with ecological realities (Arifin, 2005).

Given these complexities, how can we better understand the interaction between climate stress and food production? What economic theories help illuminate this relationship? What are the local and global strategies for resilience? And how can policies effectively balance environmental sustainability with food sovereignty?

This paper explores these questions by conducting a qualitative analysis of the interrelationship between climate change and food production in Indonesia and beyond. It aims to provide a comprehensive theoretical and empirical assessment that contributes to scholarly literature and informs sustainable agricultural policies.

## **LITERATURE REVIEW**

Scholarly discourse on climate change and food production has expanded significantly over the past two decades. Much of the global literature converges on the finding that

agricultural productivity is highly susceptible to climate variability, especially in low-latitude countries (Lobell & Gourdji, 2012). Empirical studies suggest that even a 2°C rise in temperature could reduce yields of major staples—such as rice, wheat, and maize—by 10–20% without adaptive measures (Schlenker & Roberts, 2009).

In Indonesia, research has revealed a similar trend. Saptomo (2016) shows how shifts in rainfall patterns have already delayed planting cycles and shortened growing seasons in Java and Sulawesi. Another study by Nugroho and Darmawan (2014) highlights that the combination of floods and droughts has decreased average rice productivity by 7.4% per year in climate-affected regions. Additionally, increased salinity intrusion in coastal areas like North Java has damaged paddy fields, as noted by Syamsiah (2011).

The international literature often employs economic-environmental modeling frameworks such as Computable General Equilibrium (CGE) or Integrated Assessment Models (IAM) to forecast long-term agricultural impacts (Nelson et al., 2014). In contrast, Indonesian scholarship, particularly from Sinta-accredited journals, frequently emphasizes qualitative fieldwork and ethnographic accounts that reveal farmers' adaptive strategies and perceptions (Asyari, 2012). These approaches offer rich, context-specific insights but are often disconnected from broader theoretical models.

Arabic scholarship also provides critical insights. According to al-Ṭabāṭabā'ī (2011), the concept of *al-kifāyah al-ghidhā'īyyah* (food sufficiency) is inherently linked to *ḥifẓ al-bi'ah* (environmental preservation), suggesting a holistic Islamic framework for agricultural stewardship. Meanwhile, Sulaiman (2007, p. 93) discusses the role of zakat-based agricultural investment as a form of community resilience.

Despite these contributions, gaps remain in integrating multi-scalar analysis. There is a lack of synthesis between micro-level farmer responses and macroeconomic policy frameworks. Furthermore, comparative analysis between tropical and temperate zone economies is still limited. This article aims to bridge these gaps by using economic theories to interpret localized responses, thus contributing to a more holistic understanding of climate-food interactions.

## Theoretical Framework

Understanding the nexus between climate change and food production requires grounding in several economic theories. At the core lies Environmental Economics, which examines the externalities of human activity—particularly emissions and resource use—on ecological systems (Perman et al., 2011). Climate change represents a classic case of a negative externality, where the environmental cost of carbon-

intensive development is not internalized in market prices. For agriculture, this implies that climate degradation leads to unpriced damage in the form of lower yields and increased uncertainty (Nordhaus, 1994).

Agricultural Economics, a subfield of applied economics, offers models for analyzing the supply-demand behavior in the agricultural sector. The classical model by Schultz (1964) on “Transforming Traditional Agriculture” posits that technology adoption plays a pivotal role in increasing productivity under stress. As climate shocks reduce land productivity, economic incentives for innovation—like drought-resistant crops and precision farming—gain importance.

Another relevant theory is Risk and Uncertainty in Production (Just & Pope, 1978). This model distinguishes between technical efficiency and environmental stochasticity, asserting that farmers operate under asymmetric information and climate risk. In this context, climate change increases the variance of outcomes rather than simply lowering average productivity. Policymakers must thus consider not only expected losses but also variance-induced instability.

The Theory of Adaptive Expectations, originating from Friedman (1957), also informs agricultural decision-making under climate variability. Farmers often rely on past weather trends to make planting and investment decisions. As climate becomes less predictable, this model breaks down, highlighting the need for real-time climate services and forecasting tools to support rational economic behavior.

From a developmental perspective, Sen’s Entitlement Approach (1981) stresses that food insecurity is not only a result of production failure but also a failure of access and distribution. Even in regions where total food availability remains stable, climate shocks may erode purchasing power, disrupt transport infrastructure, and lead to localized famines. Thus, food systems must be analyzed not just by aggregate outputs, but by their social and economic accessibility.

Lastly, Islamic economic principles such as *al-maslahah al-‘ammah* (public benefit) and *al-‘adl* (justice) emphasize ecological balance and equity. According to al-Ghazālī (2000, p. 217), maintaining environmental harmony is a divine obligation, making sustainable agriculture not only economically prudent but also ethically imperative.

## Previous Research

Several studies conducted before 2012 offer substantial insight into the intersection of climate change and food production. First, Parry, Rosenzweig, and Livermore (2005) conducted global simulations and found that climate change could cause yield

reductions of 10–20% in major cereals by 2050, disproportionately affecting tropical developing countries. Their work emphasized the uneven geographical impacts of climate stress on agriculture.

Second, Naylor et al. (2007) analyzed rice production systems in Asia and found that temperature increases of even 1–2°C could significantly reduce harvests, particularly during critical growth stages like flowering and grain filling. The study also stressed the vulnerability of lowland paddy systems, which dominate food supply in Southeast Asia.

Third, Stern (2007) highlighted the economic costs of inaction on climate change, with a dedicated chapter on agriculture showing that climate variability could affect GDP growth via reduced agricultural productivity, food price volatility, and heightened rural poverty. His use of a cost-benefit framework reinforced the importance of proactive adaptation.

Fourth, in Indonesia, research by Arifin (2005) examined institutional adaptation to climate risks. He found that local governance and farmer cooperatives played a crucial role in mediating access to information and resources. However, many smallholders lacked adequate institutional support, increasing their vulnerability to climatic shocks.

Fifth, Asyari (2012) provided an ethnographic study of indigenous farming practices in Kalimantan. He found that traditional systems such as rotational swidden agriculture and local weather forecasting (based on signs from flora and fauna) were still used effectively to buffer climate uncertainties. His findings underscored the potential for integrating indigenous knowledge into national adaptation strategies.

Sixth, Zulfikar (2010) conducted a study on the effects of prolonged drought in Nusa Tenggara Timur. He observed that household food insecurity rose sharply due to crop failure and water scarcity. Local governments struggled to deliver timely assistance due to limited resources and bureaucratic delays, which compounded the crisis.

Despite these valuable insights, gaps remain in synthesizing these studies through a unified economic framework. Many studies adopt either a biophysical or social lens, often neglecting the economic theories that could bridge micro-level adaptation behaviors with macroeconomic implications. Furthermore, Arabic and Islamic perspectives on climate ethics and food governance remain underrepresented in global discourse. This study seeks to fill these gaps by integrating classical economic theory with qualitative field data, Islamic values, and Indonesian case studies to generate a comprehensive understanding of climate-induced changes in food production.

## RESEARCH METHODS

This study employs a qualitative research design centered on textual data analysis. The qualitative approach is chosen due to its capacity to explore complex, context-dependent interactions between climate change and food production, particularly in the Indonesian setting. Qualitative methods allow the researcher to interpret meanings, motivations, and socio-cultural factors that are often overlooked by quantitative models (Denzin & Lincoln, 2005, p. 10).

The primary sources of data include peer-reviewed journal articles, academic books (international, Indonesian, and Arabic), government reports, and publications from international institutions such as the FAO and IPCC (up to the year 2012). Indonesian policy documents from Bappenas and the Ministry of Agriculture are used to contextualize national-level responses. Arabic books related to Islamic economic ethics and environmental principles, such as al-Ghazālī's *Iḥyā' 'Ulūm al-Dīn*, provide the normative framework for interpreting sustainability concepts.

The data analyzed are predominantly textual and include descriptions of climate events, institutional responses, and theoretical discourse. These data types are classified into three categories: (a) theoretical-economic literature, (b) climate impact and agricultural production reports, and (c) local adaptation and religious-ethical texts. This triangulation ensures a comprehensive understanding across scientific, policy, and cultural domains.

Data were collected using purposive sampling. Relevant literature published before 2012 was selected based on its scholarly credibility and relevance to the themes of climate change and food systems. Indonesian sources were drawn from Sinta-accredited journals and university publications. Arabic texts were translated and interpreted according to the Joint Decree of the Minister of Religion and the Minister of Education and Culture No. 158/1987 and 0543b/U/1987, ensuring linguistic and contextual accuracy.

Textual content was coded thematically. The coding framework followed grounded theory principles, allowing themes to emerge from the data rather than imposing pre-existing categories (Strauss & Corbin, 1998, p. 13). Codes were grouped under three overarching domains: (1) climate-related stressors, (2) economic responses and theories, and (3) adaptive practices and institutional frameworks. These domains were then synthesized into analytical narratives aligned with the research questions.

Conclusions were drawn through interpretative synthesis. Patterns, contrasts, and linkages among texts were examined to construct coherent narratives. The researcher ensured consistency between theoretical propositions and empirical observations. Triangulation with Indonesian and Arabic sources added cultural and ethical depth to

the interpretation. Ultimately, conclusions reflect a balance between economic logic, climate science, and socio-religious values relevant to food production under environmental stress.

## RESULTS AND DISCUSSION

The findings reveal a multifaceted relationship between climate change and food production, marked by both direct and indirect impacts. Directly, increased temperature variability, erratic rainfall, prolonged droughts, and unexpected floods have led to reduced agricultural yields, especially in rice and maize production across Indonesia. Satellite data and field reports from regions like Central Java and South Sulawesi indicate consistent year-on-year fluctuations in harvest outcomes between 2005 and 2012 (BPS, 2012; Ministry of Agriculture, 2011).

Indirectly, climate-related disruptions have triggered food price volatility, reduced rural employment, and increased household vulnerability. Markets respond to climate shocks with inflationary pressure on staples, which disproportionately affects low-income consumers. Furthermore, institutional responses have often lagged, with adaptation policies being reactive rather than proactive, and infrastructure projects—such as irrigation modernization—suffering from budgetary and bureaucratic constraints.

However, the findings also underscore emerging adaptation mechanisms. Traditional farming communities have continued to use *pengetahuan lokal* (local wisdom) such as lunar planting calendars and crop diversity as buffers. Meanwhile, a few districts have piloted *pertanian cerdas iklim* (climate-smart agriculture), integrating early warning systems and organic practices with promising results.

The interplay between modern economic tools and Islamic ethical frameworks is evident. Several pesantren-based cooperatives have adopted sustainable farming models rooted in *al-maslahah* and *hifz al-bi'ah*, blending theological imperatives with ecological responsibility. These innovations provide potential pathways for localized, faith-driven agricultural resilience.

### Climatic Stress and Agricultural Yields

Climate-induced changes in temperature and rainfall patterns have severely disrupted planting and harvesting cycles. In Central Java, a delay of the monsoon season by 4–6 weeks has caused misalignment between soil readiness and seed availability (Nugroho,



2011). As a result, rice yields declined by 6% between 2009 and 2011. Similar trends were noted in West Nusa Tenggara, where maize productivity dropped from 4.1 tons/ha to 3.4 tons/ha due to increasing aridity and poor rainfall distribution (BPS, 2011).

The decline in yields is not merely a function of climate, but also the inability of current farming systems to adapt. Many Indonesian farmers still use rain-fed irrigation and are dependent on fixed cropping calendars. This rigidity becomes problematic under climate volatility. According to Asyari (2012), without accurate, localized climate forecasting, farmers remain vulnerable to timing errors that cost entire planting seasons.

From an economic theory standpoint, this highlights the limits of traditional expectations models. When past weather patterns are no longer reliable, farmers face higher uncertainty and tend to underinvest in inputs such as fertilizers and improved seeds (Just & Pope, 1978). This creates a feedback loop of declining productivity and increasing economic insecurity.

Moreover, institutions like Badan Meteorologi, Klimatologi, dan Geofisika (BMKG) have yet to fully tailor their forecasting to agricultural needs. Government programs like *Program Ketahanan Pangan Nasional* often fail to integrate climate projections, treating food security and environmental adaptation as separate policy domains. This administrative fragmentation reduces overall system resilience (Arifin, 2005).

In Arabic-based scholarship, the concept of *ḥifẓ al-bi'ah* supports ecological preservation as a religious obligation. Al-Ghazālī (2000, p. 217) argues that balance in natural systems (*tawāzun al-ṭabī'ah*) is essential for sustaining human life, including food systems. Ignoring these principles is a violation of *al-amānah*, undermining both faith and function in agrarian societies.

In sum, the evidence confirms that while climatic stress disrupts agricultural output, its impact is exacerbated by structural rigidity, lack of localized adaptation, and fragmented policy integration.

## **Economic Consequences and Food Security**

The economic ramifications of climate-induced stress on food production extend beyond the farm level, infiltrating national markets, household incomes, and macroeconomic stability. Price spikes in essential food commodities have become increasingly common in Indonesia, particularly after poor harvest seasons. For



instance, between 2007 and 2010, the average price of medium-quality rice rose by more than 38%, significantly impacting household food expenditures (BPS, 2010).

These inflationary trends are partly driven by reduced domestic supply and compounded by import dependency. During El Niño years, Indonesia has frequently turned to international markets to meet demand, exposing consumers to volatile global prices. This situation reflects Sen's (1981, p. 45) "entitlement failure" framework, where food insecurity arises not from absolute scarcity, but from unequal access and affordability. In urban areas, price-sensitive groups such as informal workers and the unemployed are most affected.

From a macroeconomic perspective, declining agricultural productivity reduces GDP contributions from the sector and increases fiscal pressure on food subsidy programs. According to Arifin (2005, p. 122), climate-related production shocks have increased the government's short-term spending on rice importation and emergency aid, diverting resources from long-term agricultural investment.

Moreover, household income diversification has not always succeeded in reducing food insecurity. In rural West Kalimantan, where palm oil expansion has replaced traditional food farming, communities became more exposed to market volatility. When palm oil prices fell in 2009, purchasing power dropped, but local food production was insufficient to provide a safety net (Zulfikar, 2010). Thus, agricultural mono-cropping under market liberalization, when coupled with climate volatility, poses significant food access risks.

Ethically, this contradiction is addressed in Arabic literature through the concept of *al-kifāyah al-ghidhā'iyyah* (food sufficiency) as a communal obligation. As stated by al-Ṭabāṭabā'ī (2011), ensuring collective food security is a priority for both states and communities. Disruptions in food access violate the Islamic principle of *'adl* (justice), making economic inequality during climate crises not just a policy failure but a moral breach.

This section illustrates that climate change acts as a multiplier of economic risks within the food system. Without structural reform and targeted subsidies for both production and consumption sides, food security remains vulnerable to external shocks. Integrating economic resilience with religious and cultural imperatives offers a richer, more holistic basis for sustainable policy interventions.

## **Institutional Responses and Local Adaptation**

Institutional responses to the challenges of climate change and food production in Indonesia have been varied, often reactive, and fragmented across administrative levels. Nationally, the *Rencana Aksi Nasional Adaptasi Perubahan Iklim* (RAN-API) was initiated in the late 2000s to align sectoral development plans with climate adaptation. However, implementation at the provincial and district levels has faced bureaucratic hurdles, unclear authority divisions, and limited funding (Bappenas, 2011).

A major institutional challenge lies in the disconnect between agricultural and environmental agencies. While the Ministry of Environment and Forestry focuses on climate mitigation and biodiversity, the Ministry of Agriculture concentrates on food output and market logistics. Arifin (2005, p. 130) criticized this “silo mentality,” noting that climate-smart agriculture initiatives often struggle due to inconsistent policy objectives and competition over budget allocations.

Despite national-level limitations, local institutions—especially community-based organizations and farmer groups—have demonstrated adaptive innovation. In Central Java, *Kelompok Tani* (farmer collectives) have revived traditional water-sharing systems like *subak* and adopted diversified cropping strategies to reduce climate risk exposure. These practices resonate with the resilience principles found in Just and Pope’s (1978) theory, where diversity in input usage mitigates environmental variance.

In West Sumatra, *nagari*-based governance structures have successfully integrated customary laws (*hukum adat*) into climate adaptation strategies. As reported by Asyari (2012), the integration of local wisdom and participatory decision-making enhanced social cohesion and resource management. Moreover, faith-based organizations such as *Nahdlatul Ulama* have promoted organic farming and conservation practices rooted in *ḥifẓ al-bi’ah* (environmental preservation), framing sustainable agriculture as a religious duty.

Islamic jurisprudence provides additional conceptual tools. The principle of *al-maslahah al-‘ammah* (public interest) legitimizes state intervention in agriculture to prevent hunger and ecological degradation. Al-Ghazālī (2000, p. 217) emphasized the necessity of maintaining natural balance to achieve spiritual and material well-being. In this context, zakat funds and waqf assets can be directed toward sustainable agriculture and food distribution, as explored by Sulaiman (2007, p. 93).

These adaptive responses show that while institutional weaknesses exist at higher policy levels, localized mechanisms—particularly when aligned with ethical-religious norms—offer practical solutions. However, scalability remains an issue. Without formal support structures, successful pilot programs often remain isolated. Bridging traditional practices with scientific knowledge, and decentralization with strategic coordination, is essential for long-term climate resilience in food production.

In conclusion, this subsection emphasizes the dual role of institutions—as both obstacles and enablers. Aligning formal structures with informal adaptive capacity, grounded in local and Islamic values, presents a promising yet underutilized path toward climate-resilient food systems in Indonesia.

### **Core Findings and Pathways Forward**

The study's findings coalesce around a central reality: climate change imposes systemic stress on food production through multiple, interlinked pathways. These include climatic variability, economic instability, institutional fragmentation, and socio-cultural limitations. However, amidst these challenges, there are emerging adaptive responses and normative frameworks that offer resilient alternatives—especially in Indonesia's diverse and decentralized agricultural landscape.

Firstly, the direct biophysical effects—such as temperature rise, drought, and rainfall shifts—reduce crop yields, disrupt planting calendars, and intensify pest pressures. These impacts are well-documented, but their actual consequences depend significantly on how communities and institutions respond. This points to a core insight: vulnerability is as much a function of weak adaptation capacity as it is of climatic exposure.

Secondly, the economic consequences of climate impacts extend into macro and micro scales. At the macro level, food price volatility and increased public spending strain national budgets. At the micro level, income loss, food insecurity, and market exclusion exacerbate rural poverty. These outcomes highlight the need for integrated economic strategies that cushion both producers and consumers during environmental shocks.

Thirdly, institutional responses have been uneven. National frameworks like RAN-API are theoretically sound but suffer in practice due to coordination issues and limited funding. Meanwhile, local communities demonstrate innovative adaptive capacities rooted in local wisdom and collective action. Farmer groups, adat institutions, and Islamic organizations have responded to climatic threats using both traditional and spiritual tools—underscoring the potential of culturally grounded adaptation.

What distinguishes this study is the integration of Islamic economic thought—particularly the principles of *al-maslahah al-'ammah*, *hifz al-bi'ah*, and *al-'adl*—into the analysis of agricultural adaptation. These ethical frameworks are not only spiritually compelling but practically relevant, offering moral justification for state intervention, community action, and environmental conservation.

Overall, the climate-food nexus in Indonesia is not merely a technical or economic challenge; it is a societal test of resilience, ethics, and strategic governance. Building climate-resilient food systems requires not only technology and policy reform but also a deep engagement with cultural and religious values that shape behaviors and institutions.

## CONCLUSION

This study has explored the complex interplay between climate change and food production, particularly in the Indonesian context. It has shown that while climate variability directly affects yields and agricultural cycles, the broader consequences extend into economic systems, household food security, and institutional effectiveness. The findings underscore that vulnerability is not solely the result of climatic exposure but is amplified by policy fragmentation, limited infrastructure, and weak adaptation mechanisms. Local communities, however, continue to demonstrate remarkable resilience through traditional knowledge, diversified farming practices, and ethical commitments rooted in Islamic values.

The integration of economic theory with Islamic ethical principles has proven to be a valuable approach. Concepts such as *al-maslahah al-'ammah* and *ḥifẓ al-bi'ah* provide both normative and practical foundations for sustainable agricultural governance. Ultimately, ensuring food production in a climate-challenged future requires a multi-layered strategy: policy coherence, economic resilience, technological innovation, and culturally grounded ethics. Indonesia and other developing nations stand at a critical juncture where aligning spiritual values with scientific approaches can drive a more equitable and sustainable food system.

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