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CLIMATE-RESILIENT AGRICULTURE IN INDONESIA AND TÜRKİYE: A COMPARATIVE REVIEW OF POLICY, PRODUCTIVITY, AND SUSTAINABILITY INDICATORS (2000–2023)

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ABSTRACT

Climate change exerts asymmetric pressures on agriculture in emerging economies, where adaptive capacity is constrained by structural fragmentation, fiscal limits, and uneven institutional coverage. This article provides a comparative, descriptive review of agricultural climate resilience in Indonesia and Türkiye over the 2000–2023 period, drawing on harmonized aggregate indicators from FAOSTAT, the World Bank's World Development Indicators, IRENA, and national policy documents. Three analytical axes are examined: (i) the structural profile of the agricultural sector (employment share, value added, land productivity, and total factor productivity proxies); (ii) climate vulnerability patterns proxied by temperature trends, irrigation dependence, and disaster exposure; and (iii) the adaptation–mitigation policy landscape, including the Indonesian Climate Resilience Development Policy under RPJMN 2020–2024 and the Turkish National Climate Change Adaptation Strategy and 12th Development Plan. The review highlights three convergences (the decoupling of agricultural employment from value added, rising input intensity, and incomplete crop insurance penetration) and three divergences (water governance architecture, smallholder versus mid-scale producer dominance, and renewable-energy diffusion in agri-food chains).

Keywords: climate-resilient agriculture; Indonesia; Türkiye; sustainable agriculture; comparative policy review; FAOSTAT; agricultural productivity

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ABSTRAK

Perubahan iklim memberikan tekanan asimetris pada pertanian di negara-negara berkembang, di mana kapasitas adaptasi dibatasi oleh fragmentasi struktural, keterbatasan fiskal, dan cakupan kelembagaan yang tidak merata. Artikel ini menyajikan tinjauan deskriptif komparatif tentang ketahanan iklim pertanian di Indonesia dan Turki selama periode 2000–2023, berdasarkan indikator agregat yang diselaraskan dari FAOSTAT, Indikator Pembangunan Dunia Bank Dunia, IRENA, dan dokumen kebijakan nasional. Tiga sumbu analitis diperiksa: (i) profil struktural sektor pertanian (pangsa lapangan kerja, nilai tambah, produktivitas lahan, dan proksi produktivitas faktor total); (ii) pola kerentanan iklim yang diwakili oleh tren suhu, ketergantungan pada irigasi, dan paparan bencana; dan (iii) lanskap kebijakan adaptasi-mitigasi, termasuk Kebijakan Pembangunan Ketahanan Iklim Indonesia di bawah RPJMN 2020–2024, Strategi Adaptasi Perubahan Iklim Nasional Turki, dan Rencana Pembangunan ke-12. Tinjauan ini menyoroti tiga konvergensi (pemisahan lapangan kerja pertanian dari nilai tambah, peningkatan intensitas input, dan penetrasi asuransi tanaman yang tidak lengkap) serta tiga divergensi (arsitektur tata kelola air, dominasi petani kecil versus produsen skala menengah, dan difusi energi terbarukan dalam rantai agribisnis). Makalah ini tidak memperkirakan parameter kausal; melainkan, menyediakan basis bukti terstruktur untuk memandu pekerjaan ekonometrik panel selanjutnya dan untuk menginformasikan desain kebijakan di kedua negara. Keterbatasan berkaitan dengan harmonisasi data di seluruh sistem statistik nasional yang heterogen serta sifat deskriptif dari analisis tersebut.

Kata kunci: *pertanian tahan iklim; Indonesia; Turki; pertanian berkelanjutan; tinjauan kebijakan komparatif; FAOSTAT; produktivitas pertanian.*

INTRODUCTION

The intensification of climate change has reshaped the conditions under which agriculture is practiced in emerging economies, exposing producers to compounded risks from temperature anomalies, shifting precipitation regimes, and extreme weather events (IPCC, 2022). Two emerging economies, the Republic of Indonesia and the Republic of Türkiye, illustrate the heterogeneity of this exposure and the diversity of policy responses. Despite differing agro-ecological endowments and institutional histories, both countries share a structural reliance on agriculture for employment, foreign exchange, food security, and rural cohesion, and both have committed to climate resilience pathways under the Paris Agreement and the United Nations 2030 Agenda for Sustainable Development.

Indonesia, with a population of approximately 277 million and a tropical, archipelagic geography, hosts one of the world's largest smallholder-based agricultural systems. Agriculture, forestry, and fishing accounted for roughly 12.5 percent of Indonesia's gross value added in 2023, while still absorbing nearly 29 percent of total employment (World Bank, 2024a). Climate change manifests primarily through monsoon variability, sea-level rise affecting coastal paddy zones, and recurrent El Niño–Southern Oscillation (ENSO) events that depress rice and palm-oil yields (Naylor et al., 2007; Caruso et al., 2016). Türkiye, with a population of approximately 85 million and a semi-arid Mediterranean–continental climate, shows a comparable but distinct pattern: agriculture contributed around 6.5 percent of gross value added and 14.5 percent of employment in 2023, with productivity gains concentrated in irrigated horticulture, cereals, and the rapidly expanding hazelnut and pulse sub-sectors (TurkStat, 2024; World Bank, 2024a). Türkiye's vulnerability is dominated by warming-driven water stress, particularly across the Konya Closed Basin and the southeastern Anatolian plains (Şen, 2019).

These overlapping yet differentiated exposures generate a research need: how do two structurally distinct emerging economies organize their agricultural systems for climate resilience, and what comparative lessons can be extracted to inform policy choices? Existing scholarship tends to treat each country in isolation. Studies on Indonesian agriculture have emphasized smallholder vulnerability and adaptive responses (Measey, 2010; Stuart et al., 2016), while research on Türkiye has focused on water governance, irrigation efficiency, and the role of agricultural support payments (Çakmak & Dudu, 2010; Akder, 2010). Comparative work that places both countries within a unified descriptive frame remains scarce.

This article addresses that gap by providing a structured comparative descriptive review of climate-resilient agriculture in Indonesia and Türkiye for the period 2000–2023. The contribution is threefold. First, harmonization aggregate indicators from FAOSTAT, the World Bank, the International Renewable Energy Agency (IRENA), and national statistical agencies to construct a consistent comparative profile. Second, it juxtaposes the two countries' policy architectures — including Indonesia's Rencana Pembangunan Jangka Menengah Nasional (RPJMN) 2020–2024 and Türkiye's National Climate Change Adaptation Strategy and 12th Development Plan (2024–2028) — to identify convergences and divergences in the design of instruments. Third, it lays the groundwork for subsequent econometric work by mapping the data architecture and limitations of cross-country panel analysis in this domain.

The Productivity–Sustainability Nexus

A central tension in the climate-agriculture literature concerns whether productivity gains and sustainability outcomes are complementary or substitutive. Wheeler and von Braun (2013) document how climate-induced yield declines threaten food security; Hertel (2015) shows that supply responses to climate shocks vary substantially across regions; and Vermeulen et al. (2012) emphasize the food-system perspective that extends beyond farm-level adaptation. In the Indonesian context, Naylor et al. (2007) demonstrated the sensitivity of rice production to shifts in monsoon onset, while Caruso et al. (2016) documented the long-run welfare costs of historical temperature shocks. For Türkiye, Dellal et al. (2011) projected substantive yield reductions for wheat under business-as-usual scenarios, and Şen (2019) reviewed observed climatological trends across the Anatolian basins.

Recent evidence reinforces the substitutive reading of this nexus. Jing et al. (2025) show that agricultural

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intensification at the global scale is now associated with habitat loss, agrochemical externalities, and aquifer depletion at intensities sufficient to threaten the biodiversity foundations of long-run agricultural productivity. Their findings situate the productivity-sustainability nexus less as an abstract trade-off and more as an empirically observable pattern in intensified agricultural systems in emerging economies.

Total Factor Productivity and the Ecological Productivity Paradox

The literature on agricultural total factor productivity (TFP) suggests that, over the past two decades, emerging economies have increasingly relied on input intensification rather than on efficiency gains to drive output growth (Fuglie, 2018; USDA ERS, 2023). This pattern raises the concern of an "ecological productivity paradox": short-term output gains may erode the natural capital base — soil, water, biodiversity — on which long-term productivity depends. The paradox echoes the Jevons effect in resource economics, whereby efficiency improvements can be offset by rebound effects in aggregate resource use (Alcott, 2005). For climate-resilient agriculture, this implies that productivity metrics must be complemented by sustainability indicators, including water-use efficiency, fertilizer productivity, and the share of renewable energy in agri-food value chains.

The mechanism behind this paradox is sharpened by Benton and Bailey (2019), who formalize a 'paradox of productivity' in which the same gains that lower per-unit prices and raise output simultaneously generate downstream food-system inefficiency (waste, dietary distortion, and ecological externalities). On the input side, Lassaletta et al. (2014) document fifty-year trends in cropping-system nitrogen-use efficiency, showing that yield gains in most regions of the world have been bought at the cost of declining ratios of nitrogen incorporated in harvested product to nitrogen applied; the productivity wedge thus has a quantifiable ecological counterpart.

Comparative Case-Selection Logic

The selection of Indonesia and Türkiye is not arbitrary. Following the contrast-case design tradition in comparative policy analysis (Lijphart, 1971; Gerring, 2007), both countries occupy the same broad class, such as upper – middle – income emerging economies with substantial agricultural sectors and binding Paris Agreement commitments, yet differ systematically along three dimensions that are

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theoretically expected to shape climate-resilience outcomes: (i) agro-ecological endowment (tropical-archipelagic versus semi-arid-continental), (ii) producer structure (smallholder-dominant versus mid-scale-consolidated), and (iii) water-governance architecture (multi-level versus centralized basin management). This contrast-case configuration permits the analyst to isolate the influence of institutional design from that of climatic endowment, supporting policy learning across heterogeneous frames rather than requiring strict condition comparability

RESEARCH METHODS

1. Scope and Justification

This review adopts a comparative descriptive design covering Indonesia and Türkiye for the 2000–2023 period. The design is intentionally non-causal: the objective is to construct a harmonized evidence base that supports subsequent panel-econometric work, rather than to estimate policy effects. The choice of period reflects the post-2000 expansion of climate-relevant data in the FAO and World Bank repositories, the entry into force of major sustainable development instruments (the Millennium Development Goals and the Sustainable Development Goals), and the maturation of national climate policy frameworks in both countries.

2. Data Sources

Aggregate agricultural indicators are drawn from FAOSTAT (FAO, 2024), including value added, employment, land area, fertilizer use, and agricultural emissions. Macroeconomic indicators, including gross domestic product, agricultural value-added share, employment share, and CO_2 emissions per capita, are sourced from the World Bank's World Development Indicators (World Bank, 2024a). Renewable-energy indicators, including the share of renewables in total final energy consumption, are drawn from IRENA (2024). National policy documents include Indonesia’s RPJMN 2020–2024 (Kementerian PPN/Bappenas, 2020) and the Indonesian Long-Term Strategy for Low Carbon and Climate Resilience 2050 (Government of Indonesia, 2021), and Türkiye’s National Climate Change Adaptation Strategy and Action Plan (T.C. Çevre ve Şehircilik Bakanlığı, 2011), its updated Climate Change Strategy under the Climate Council (2022), and the 12th Development Plan 2024–2028 (Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2023).

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The greenhouse-gas component of the FAOSTAT database, used here for cross-country comparability of agricultural emissions, is documented by Tubiello et al. (2013), who outline its construction, scope, and known uncertainties. The post-2013 series is used here, which incorporates revisions that improve the reliability of cross-country comparisons over the 2000–2023 review window.

3. Analytical Strategy

The analysis proceeds in three stages. The first stage develops harmonized structural profiles of the two agricultural sectors, focusing on employment, value added, productivity, and input intensity. The second stage maps climate vulnerability through observed temperature trends, irrigation dependence, and reported disaster exposure. The third stage compares policy architectures along five dimensions: adaptation strategy, water governance, agricultural support, insurance penetration, and renewable-energy integration. Reported values are presented in aggregate form; where indicators have been harmonized across sources, the harmonization procedure is reported transparently. The article does not estimate regression coefficients; any quantitative comparison presented should be interpreted as descriptive evidence on observed levels and trajectories, not as causal estimates.

The choice of indicators is informed by the resilience-indicator framework of Bizikova et al. (2019), who derive a policy-maker–oriented set that covers the structural, environmental, and institutional dimensions of agricultural climate resilience. The present review does not use that framework as a scoring system; rather, it draws on it to motivate the cross-country juxtaposition of structural, vulnerability, and policy indicators developed in Sections 4–6.

***4.* Methodological Caveats**

Three caveats deserve emphasis. First, agricultural statistics in both countries are subject to revision; the 2023 values incorporate provisional FAOSTAT releases that may be updated. Second, definitions of “agricultural employment" differ between TurkStat and Statistics Indonesia (BPS), with the latter using a broader rural-livelihoods definition that may inflate the headline share. Third, emissions accounting for agriculture in both countries relies on Tier 1 IPCC methodologies, which provide internationally comparable but country-specific estimates (IPCC, 2019). Subsequent econometric work should

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explicitly model these measurement-error structures.

Smallholder coverage in particular is a known source of measurement attenuation. Carletto, Jolliffe, and Banerjee (2015) argue that agricultural data quality in low- and middle-income countries has historically been weakest precisely where smallholder farming is most prevalent, with implications for cross-country productivity comparisons. The present review retains the FAOSTAT and World Bank aggregates as canonical reference series while acknowledging that smallholder-sensitive metrics (insurance penetration, input intensity per holding) are necessarily approximated.

RESULT AND DISCUSSION

1. Sectoral Weight and Structural Transformation

The structural weight of agriculture in the two economies has declined steadily over the 2000–2023 period, consistent with the broader pattern of structural transformation in middle-income economies (Timmer, 2009). In Indonesia, the agricultural share of gross value added fell from approximately 15.6 percent in 2000 to around 12.5 percent in 2023, while the employment share contracted from roughly 45 percent to 29 percent over the same period (World Bank, 2024a). In Türkiye, the corresponding shifts have been sharper: agricultural value added fell from approximately 10.1 percent to 6.5 percent of GDP, and the employment share from around 36 percent to 14.5 percent (TurkStat, 2024; World Bank, 2024a). The faster Turkish transition reflects both higher initial levels of industrialization and the deliberate consolidation of agricultural holdings under the post-2006 Agricultural Law (Tarım Kanunu No. 5488).

A critical observation is that, in both countries, the employment share of agriculture remains substantially higher than its value-added share, implying persistent labor-productivity gaps relative to industry and services. This wedge is a structural feature with implications for adaptation: workers in low-productivity smallholder agriculture have, on average, fewer resources to invest in climate-resilient technologies and face higher exposure to weather-driven income volatility. Figure 1 and 2 summarises the comparative structural profile for the two countries.

Indonesia's structural transformation has unfolded alongside a substantial reorganization of its rural land base. Margono et al. (2014) document that the country lost approximately 6.02 million hectares of primary forest between 2000 and 2012, with conversion concentrated in Sumatra and Kalimantan. This land-cover dynamic has been linked, in subsequent work, to plantation expansion (oil palm and pulpwood) and to the institutional configuration of agricultural property rights. Kubitza et al. (2018) show that, in Indonesian smallholder frontiers, formalized land titling is associated with both intensification and further forest conversion, suggesting that the productivity wedge documented above coexists with a parallel ecological wedge that is not captured in conventional value-added metrics.

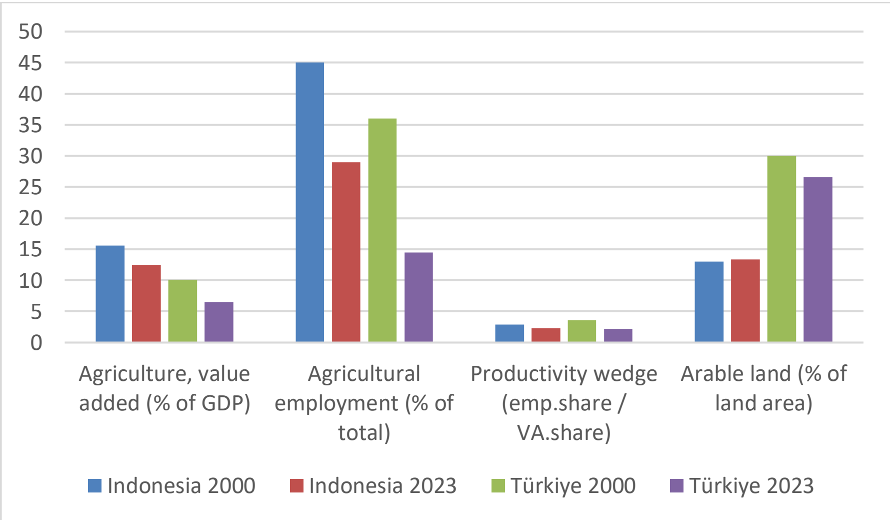

Figure 1. Comparative agricultural structural transformation and land-use indicators in Indonesia and Türkiye (2000 vs. 2023). Note: "Productivity wedge" is an author-calculated ratio of agricultural employment share to agricultural value-added share.

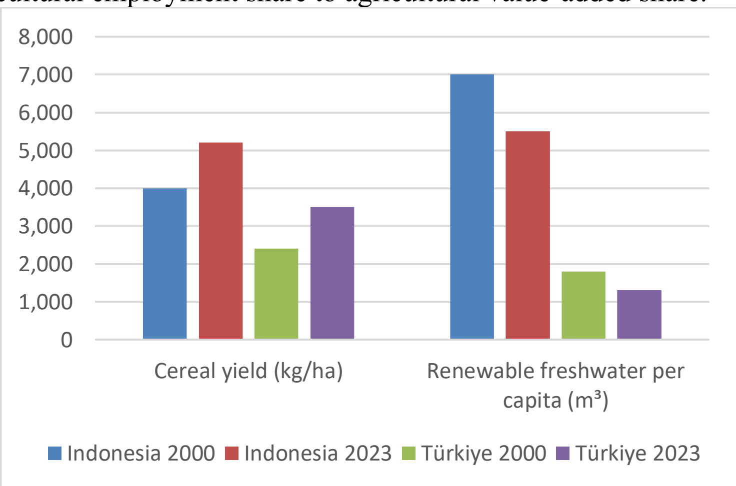

Figure 2. Comparison of land productivity (cereal yield) and renewable freshwater availability per capita in Indonesia and Türkiye (2000 vs. 2023). Notes: *Estimated values based on FAO AQUASTAT database. The "productivity wedge" is calculated as the ratio of agricultural employment share to agricultural value-added share.

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2. Land Use and Productivity

Indonesia's cropland area expanded over the review period, driven principally by oil-palm and rubber estates in Kalimantan and Sumatra, while Türkiye's cropland area has been broadly stable. Land productivity, measured as agricultural value added per hectare, has risen in both countries, but the trajectories differ. Indonesian productivity gains have been concentrated in plantation crops and rice intensification, while Turkish gains have been driven by horticulture, greenhouse production along the Mediterranean coast, and irrigation expansion in the Southeastern Anatolia Project (GAP) region.

3. Input Intensity

Fertilizer use per hectare provides a useful proxy for input intensity. According to FAOSTAT (2024), both countries record fertilizer application rates substantially above the global mean for arable land, although well below the rates observed in East Asian high-intensity systems. The trajectory of nitrogen use efficiency, the ratio of crop nitrogen uptake to nitrogen applied, has been a concern in both contexts, with implications for water quality, nitrous-oxide emissions, and the fiscal cost of input-subsidy programs.

4. Total Factor Productivity Indicators

Estimates from the USDA Economic Research Service International Agricultural Productivity database suggest that both Indonesia and Türkiye have recorded positive but moderating TFP growth in agriculture over the review period (USDA ERS, 2023). The composition of this growth in the two countries appears to differ, with Indonesian gains often associated with cropland expansion and input intensification in plantation crops, and Turkish gains often associated with productivity improvements in irrigated (Sundari et al., 2026) and protected-environmental horticulture. These compositional differences are widely reported in regional descriptions of the two agricultural sectors but warrant formal empirical decomposition in future work. The aggregate pattern of decelerating TFP gains in emerging economies since the mid-2010s, documented by Fuglie (2018), raises concerns about the sustainability of input-led growth strategies under climate stress.

Interpreted alongside Benton and Bailey (2019), the bilateral TFP pattern is consistent with the broader emerging-economy concern that headline productivity growth may

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understate ecological and food-system costs. The present TFP comparison should be read as descriptive of measured output per composite input, not as a welfare-relevant measure of agricultural performance.

5. Climate Vulnerability Patterns

Temperature and Precipitation Trends

Both countries have recorded statistically significant warming over the review period. The Turkish State Meteorological Service has documented average warming trends across all seven geographical regions, with the strongest signals in the southeastern Anatolian and Mediterranean zones (Meteoroloji Genel Müdürlüğü, 2023). The Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) reports comparable warming, with rainfall variability increasing particularly during the secondary cropping season in eastern Indonesia (BMKG, 2023). Precipitation trends are more spatially heterogeneous: Türkiye's central and southeastern regions show declining trends, while Indonesia exhibits intensified extreme rainfall episodes alongside more frequent, prolonged dry spells.

On the Indonesian side, El Niño-Southern Oscillation dynamics shape the rainfall regime in ways that have implications for paddy and palm-oil yields. Hendon (2003) showed that ENSO modulates Indonesian rainfall through both remote atmospheric forcing and local air-sea interaction, producing the dry-season anomalies subsequently linked to rice-yield losses in the agricultural-economics literature. The temperature-rainfall pattern documented for Türkiye and Indonesia thus rests on two qualitatively different climate-system drivers.

Water Stress and Irrigation Dependence

Türkiye's water stress is structurally high: per-capita renewable water resources have declined from above 4,000 cubic meters in the early 1960s to approximately 1,300 cubic meters in the early 2020s, placing the country in the water-scarce category according to the Falkenmark threshold (DSİ, 2023; Falkenmark, 1989); recent global assessments (Mekonnen & Hoekstra, 2016) confirm Türkiye’s position in the severely water-stressed quintile for substantial parts of the year. Irrigation accounts for the majority of total water withdrawals, and the dominant gravity-irrigation infrastructure is increasingly being replaced by pressurized systems under the GAP and Konya Closed Basin programs. Indonesia faces a different water-stress profile: overall renewable resources are abundant, but seasonal and spatial mismatches between water availability and agricultural demand generate localized stress, particularly in Java during the dry season.

Karahasan and Pınar (2023) provide complementary sub-national evidence that climate change is shaping spatial agricultural development within Türkiye in patterns consistent with the basin-level water-stress profile, with the southeastern and central Anatolian provinces exhibiting differential exposure. Their results, although focused on Türkiye, support the broader proposition that aggregate water-stress indicators conceal substantial within-country heterogeneity that single summary statistics cannot capture.

Disaster Exposure

Both countries record substantial agricultural losses from climate-related disasters. The EM-DAT database catalogs recurrent flood, drought, and storm events with substantial agricultural impacts in both contexts (CRED, 2024). Indonesia's exposure is dominated by hydrometeorological events linked to ENSO cycles, while Türkiye's recent decade has been marked by intensifying drought in the southeast and the southern coastal zone, with concomitant pressures on cereal and horticultural production (Bellitürk et al., 2026).

Climate-driven food-loss channels are documented in Ahmed et al. (2022) for the Turkish case, who show that intensifying climate change is associated with substantial post-harvest losses across the food chain, with implications for both food-security indicators and effective producer income. Comparatively smallholder-vulnerability work (Harvey et al., 2014, for Madagascar) provides a reference point: smallholders in tropical low-income settings face a syndrome of co-occurring exposures (yield variability, asset depletion, limited insurance access) that is observable in Indonesia under different climatic forcing but with broadly similar institutional contours.

6. Policy Landscape Comparison

Indonesia: From RAN-API to Climate Resilience Development Policy

Indonesia's climate policy architecture has evolved from the National Action Plan on Climate Change Adaptation (RAN-API), released in 2014, towards an integrated Climate Resilience Development Policy embedded within the RPJMN 2020–2024 (Kementerian PPN/Bappenas, 2020). The agricultural pillar emphasizes seed-system resilience, modernization of water infrastructure, and integrated

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farming-system approaches. Indonesia's Long-Term Strategy for Low Carbon and Climate Resilience 2050 (Government of Indonesia, 2021) further articulates a sectoral pathway in which agriculture contributes to both adaptation and mitigation, particularly through peatland restoration and methane management in paddy production.

Two paddy-specific mitigation pathways merit emphasis, given Indonesia’s position as one of the world's largest rice producers. Alternate wetting-and-drying (AWD) irrigation, validated through a multi-country meta-analysis (Carrijo et al., 2017), substantially reduces methane emissions without yield penalties under moderate-stress drying regimes; Indonesian field trials in West Java and Central Java have confirmed the agronomic feasibility of AWD under smallholder management. The System of Rice Intensification (SRI), promoted in Indonesia since the early 2000s, similarly combines reduced standing-water periods with modified transplanting and weeding practices to lower methane and nitrous-oxide emissions while improving water productivity. The integration of these practices into mainstream agricultural extension beyond demonstration plots remains a policy frontier under both the LTS-LCCR 2050 and the broader rice self-sufficiency program.

Türkiye: From the 2011 Adaptation Strategy to the 12th Development Plan

Türkiye's National Climate Change Adaptation Strategy and Action Plan (2011) provided an initial sectoral framework that has subsequently been updated through the Climate Council process and integrated into the 12th Development Plan 2024–2028 (Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2023). Agricultural priorities encompass water-use efficiency in irrigated systems, climate-tolerant varieties (notably for wheat and pulses), strengthening the agricultural insurance system — the Turkish Agricultural Insurance Pool (TARSİM, Tarım Sigortaları Havuzu) — and expanding agri-photovoltaic and biogas applications. The Climate Change Mitigation Strategy and Action Plan (2024–2030) further articulates the agricultural mitigation pathway in support of the country's 2053 net-zero target.

Comparative Architecture

A side-by-side reading of the two countries’ frameworks suggests three structural similarities and three differences. Similarities include (i) the formal integration of climate resilience into core medium-term planning instruments, (ii) the prioritization of water-related interventions, and (iii) the explicit recognition of smallholders as a primary target group. Table 2 summarises the comparative policy architecture.

Table 2. Comparative climate-resilience policy architecture, Indonesia and Türkiye

Dimension	Indonesia	Türkiye	Source
Anchor adaptation document	RAN-API (2014) → RPJMN 2020–2024	NCCAS-AP (2011) → 12th Development Plan (2024–2028)	Bappenas; Cumhurbaşkanlığı SBB
Long-run climate strategy	LTS-LCCR 2050 (2021)	Climate Council strategy; 2053 net-zero target	KLHK; ÇŞİDB
Lead water authority	National agencies + Provincial/Regency tiers	State Hydraulic Works (DSİ), centralized	Government documents
Agricultural insurance scheme	AUTP (rice) and AUTS/K (cattle)	TARSİM (multi-peril, multi-crop)	Kementan; TARSİM
Approx. insurance penetration	Limited (single-digit % of arable area)	Higher (around 25–30% of insurable area)	TARSİM annual report; OECD ag-policy review
Renewable energy emphasis	Geothermal, hydropower, rooftop solar	Solar PV, wind, agri-PV pilots, biogas	IRENA (2024)
Producer-structure focus	≈ 27 million farmer households (rumah tangga petani)	≈ 3 million consolidating holdings	BPS Sensus Pertanian 2023; TurkStat Agricultural Census

Notes: Penetration figures are approximate and reflect publicly reported aggregate values; exact ratios depend on whether the denominator is total arable land, insurable area, or registered producers. Acronyms: RAN-API = National Action Plan on Climate Change Adaptation; RPJMN = National Medium-Term Development Plan; NCCAS-AP = National Climate Change Adaptation Strategy and Action Plan; LTS-LCCR = Long-Term Strategy for Low Carbon and Climate Resilience; AUTP = Asuransi Usaha Tani Padi; AUTS/K = Asuransi Usaha Ternak Sapi/Kerbau; TARSİM = Tarım Sigortaları Havuzu.

Differences include (i) water governance: Türkiye operates a centralised basin-management model led by the State Hydraulic Works (DSİ), while Indonesia combines national agencies with provincial and Regency-level authorities; (ii) producer structure: Indonesian policy must address a population of approximately 27 million farmer households (BPS, 2024, Hasil Sensus Pertanian 2023: 27.4 million rumah tangga petani) dominated by smallholders, while Turkish policy addresses approximately 3 million more consolidated holdings (TurkStat Agricultural Census); and (iii) insurance: TARSİM in Türkiye covers a broader share of agricultural producers than the Indonesian Asuransi Usaha Tani Padi (AUTP) scheme, though both systems face penetration challenges among the most vulnerable producers.

Renewable Energy in Agri-Food Chains

IRENA data indicate substantial differences in the renewable-energy intensity of the two agricultural systems (IRENA, 2024). Türkiye has rapidly expanded grid-scale solar and wind capacity since 2017 and is pursuing agri-photovoltaic pilots and farm-level biogas digesters. Indonesia retains a high share of biomass and hydropower in its energy mix and is expanding geothermal and rooftop solar capacity, with agri-food applications concentrated in post-harvest processing and cold-chain logistics. The diffusion of renewable energy into agri-food value chains remains incomplete in both countries, representing a clear policy frontier.

Pambudi et al. (2023) provide a recent assessment of Indonesia's renewable-energy status, highlighting the country's comparatively low penetration relative to its potential and the policy gap between announced targets and operational generation. Their account supports the divergence noted here: while Türkiye has scaled grid-connected solar and wind from a low 2017 base, Indonesia's renewable trajectory is constrained by archipelagic grid architecture and the dominance of state-owned utility procurement. A full quantitative comparison of renewable shares for the agri-food chain specifically is beyond the scope of this descriptive review and is flagged in Section 9 as a methodological extension.

Convergences and Divergences

The comparative review reveals patterns that are both encouraging and concerning. Each convergence and divergence identified below is paired with the theoretical mechanism that, in our reading, most plausibly accounts for it.

Three convergences stand out. First, both countries exhibit the classical pattern of structural transformation, in which agriculture's share of value added declines faster than its share of employment, generating a sustained productivity wedge that disproportionately exposes smallholders to climate stress. While the Lewis (1954) dual-economy framework provides the original intuition for labor transfer out of agriculture, the empirical persistence of within-country sectoral productivity gaps in middle-income economies is more precisely characterized by the structural-transformation decomposition of McMillan, Rodrik, and Verduzco-Gallo (2014), who document that labor reallocation across sectors can be growth-reducing when workers move into low-productivity informal services.

The "productivity wedge" indicator reported in Table 1 (defined as the ratio of agricultural employment share to agricultural value-added share) is constructed by the author in the spirit of that decomposition; it is not a standard published metric and should be interpreted as a transparent descriptive summary rather than a benchmarked indicator. Second, both countries have intensified input use without commensurate efficiency gains, raising the specter of an ecological productivity paradox in which short-term output gains erode the natural capital base. The Hayami–Ruttan induced-innovation thesis (Hayami & Ruttan, 1985) explains the bias toward land-saving inputs in scarce-land economies, but, by itself, does not ensure environmental sustainability; the rebound logic of Jevons (Alcott, 2005) closes the explanation. Third, in both jurisdictions, formal climate-insurance schemes have expanded but remain insufficient to cover the most vulnerable producers, leaving an adaptation gap that risks reinforcing rural inequality. The mechanism here is the basis-risk and trust-deficit channel familiar from the agricultural-insurance literature (Carter et al., 2017), in which premium-affordability constraints and uncertain payout triggers depress smallholder uptake.

Three divergences are equally striking. First, water governance: architectures differ substantially, with Türkiye's centralized basin-management approach contrasting with Indonesia's multi-level water administration. Türkiye's centralized model arguably suits a country in which water-stress hotspots cluster in a small number of major basins (GAP, Konya Closed Basin), while Indonesia's multi-level architecture confronts a vastly heterogeneous archipelagic hydrology in which decentralized decision rights may convey informational advantages. The comparative effectiveness of these models remains an open empirical question. Second, producer structure differs in scale and orientation, with implications for the design of extension services, financial products, and risk-management instruments. While the long-run endowment-and-institution literature (Engerman & Sokoloff, 2002) shows how initial endowments shape subsequent institutional paths, the specific divergence here reflects post-independence agrarian reform trajectories in both countries, which are well documented (Çakmak & Dudu, 2010; Stuart et al., 2016), rather than a deeper colonial endowment difference.

Third, renewable-energy Türkiye's agri-food transition is driven by grid-scale solar and farm-level biogas, while Indonesia leverages biomass, geothermal energy, and solar applications in cold-chain logistics. This pattern is consistent with resource-endowment-driven path dependence in the broader energy-transition literature (Sovacool, 2016), although a fuller account would require modeling the policy and price incentives that shape technology adoption.

A recent meta-review (Pret et al., 2025) underscores that research on farm-level resilience to climatic risk remains conceptually and methodologically fragmented, with quantitative integrative assessments still scarce. The comparative review presented here is intentionally one such integrative contribution at the aggregate cross-country scale; the fragmentation noted by Pret et al. is read not as a limitation of the present analysis but as a substantive justification for the bilateral comparative frame adopted here.

CONCLUSION

This article establishes a harmonized comparative profile of agricultural climate resilience in Indonesia and Türkiye (2000–2023). The identified convergences in structural vulnerabilities and divergences in institutional water and energy architectures highlight that climate-resilient agriculture requires both technological adoption and institutional reforms. Future research should utilize this database to conduct causal panel-econometric analyses using cointegration and heterogeneous-slope estimators.

Notwithstanding these limitations, the comparative perspective developed here offers a foundation for both academic research and policy dialogue. The convergent vulnerabilities and divergent institutional responses of Indonesia and Türkiye provide a natural laboratory for the study of climate-resilient agriculture in emerging economies, and the harmonized data architecture mapped in this article can be extended to additional comparator countries in the broader G-20 and ASEAN contexts.

POLICY IMPLICATIONS

Based on the comparative review, we suggest five policy actions:

1. **Climate-Risk Budgeting:** Directly integrate local climate-vulnerability indicators into national agricultural budget allocations.
2. **Enhance Insurance Penetration:** Expand crop insurance subsidies

and lower entry barriers for smallholders, linking index-based insurance with rural credit programs (e.g., KUR in Indonesia).

3. **Modernize Irrigation:** Shift priority from water extraction to water productivity, scaling up pressurized irrigation systems in Türkiye and localized water-harvesting in Indonesia.
4. **Agri-Energy Integration:** Accelerate renewable energy adoption in post-harvest processing and cold storage (solar PV in Türkiye, biomass-geothermal in Indonesia).
5. **Targeted Extension Services:** Develop climate-tolerant crop varieties through participatory systems—emphasizing smallholder adaptation in Indonesia and consolidation-friendly practices in Türkiye.

DECLARATION

The authors declare that this manuscript is original, has not been previously published, and is not under consideration for publication elsewhere.

Author Roles:

The author has made substantial contributions to the research, approved the final version of the manuscript, and agrees to be accountable for all aspects of the work.

Consent to participate

Authors are agreed

Consent to publication

The authors agree to publish this data

Conflict of interest

The author declares no financial or material conflict of interest. The manuscript was prepared independently and without any preferential review pathway. The author has requested that the manuscript be subject to the journal's standard peer-review process.

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