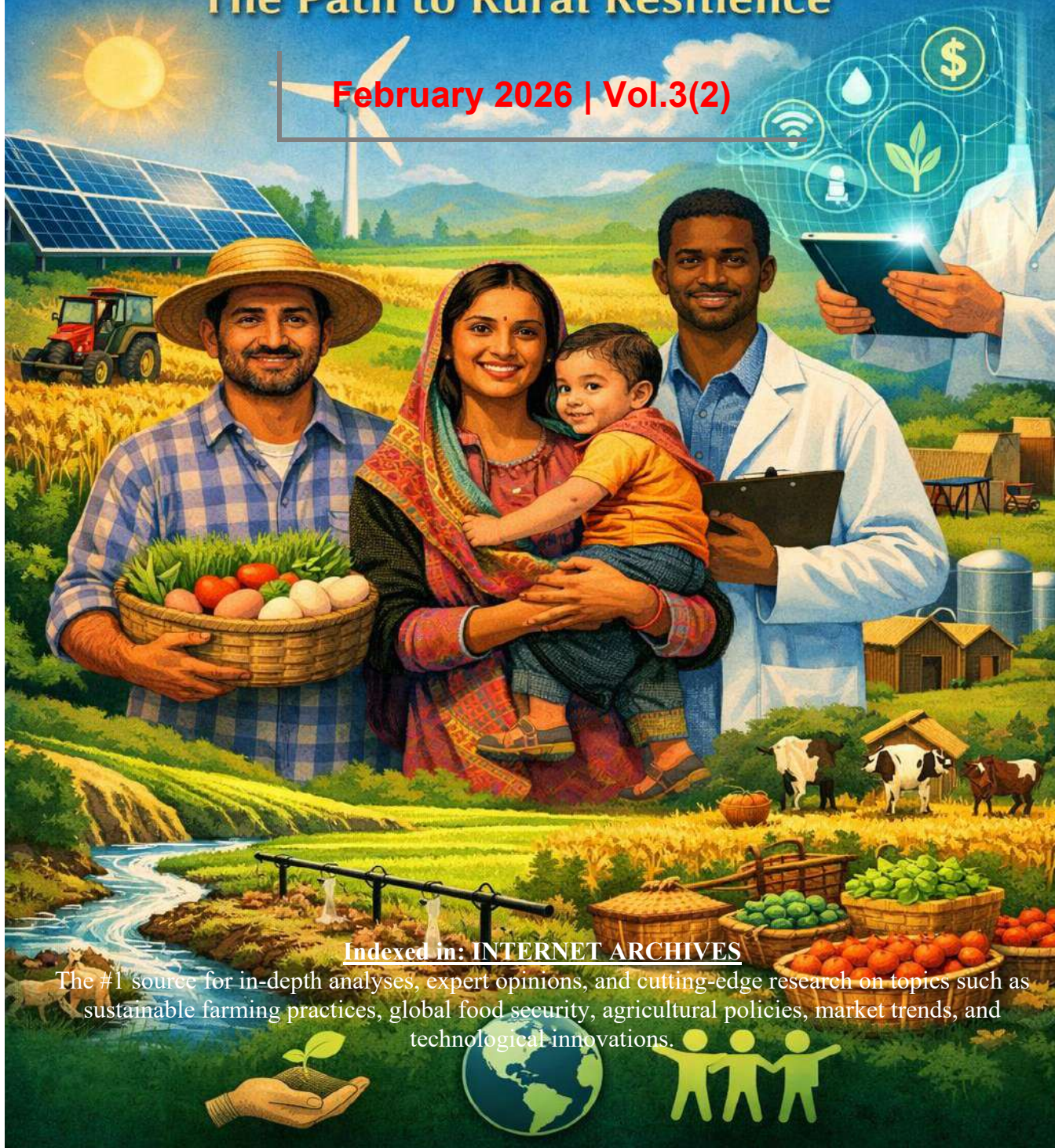


# Equity, Innovation, and Sustainability

## The Path to Rural Resilience

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## Rural Resilience: A Call for Integrated Approaches

Explore how rural resilience in 2026 hinges on equity, inclusive innovation, and sustainable agricultural practices. Learn about the interconnected challenges of gender inequality, climate shocks, health and nutrition challenges.

Muhammad Khalid Bashir

2/2/2026

As we step into February 2026, the global development community is confronted with a defining question: how can rural economies remain resilient in an era marked by climate uncertainty, widening inequalities, technological disruption, and persistent health and nutrition challenges? This month's international observances ranging from World Wetlands Day on February 2, to the International Day of Women and Girls in Science on February 11, and the World Day of Social Justice on February 20 are not symbolic footnotes. Together, they form a powerful thematic framework that speaks directly to the future of rural areas and agri-food systems worldwide.

Rural regions remain the backbone of global food security and economic stability. Agriculture alone supports the livelihoods of nearly 2.5 billion people, most of whom reside in low- and middle-income countries. Yet this foundation is increasingly fragile. The past year has underscored the scale of the challenge: 2025 witnessed record climate-induced displacement, disproportionately affecting farming and pastoral communities, while global food price volatility continued to erode purchasing power among the rural poor. These pressures have exposed the limits of fragmented, sector-by-sector responses. The path to rural resilience in 2026 demands a holistic paradigm, one that places equity, inclusive innovation, and environmental sustainability at the center of policy, investment, and institutional reform.

Equity is the cornerstone of resilient rural economies. Despite decades of development efforts, structural inequalities continue to constrain productivity, livelihoods, and adaptive capacity. Women, who account for more than 40 percent of the agricultural labor force,

remain systematically disadvantaged. They farm smaller plots, have weaker land tenure security, and face significant barriers to credit, extension services, and modern technology. The persistent gender gap in landownership is not only a social injustice; it is economic inefficiency that limits yields, incomes, and intergenerational well-being.

The World Day of Social Justice serves as a reminder that acknowledging inequity is no longer sufficient. In 2026, advancing rural equity requires deliberate institutional change. Digital land registries can formalize tenure and protect women's rights to land. Gender-responsive climate finance can ensure that adaptation and mitigation funds reach those most exposed to climate risks. Expanding social protection to cover informal agricultural workers who form most of the rural labor force can buffer households against shocks and prevent negative coping strategies such as distress sales of assets or withdrawal of children from school.

Equity is also linguistic and cultural. International Mother Language Day highlights an often-overlooked dimension of inclusion: access to information. Agricultural extension, market intelligence, weather advisories, and financial services are far more effective when delivered in indigenous languages and culturally relevant formats. Inclusion, in this sense, is not a marginal concern; it is the engine of sustainable and broad-based rural growth.

Innovation is the second pillar of rural resilience, but its promise can only be realized if it is inclusive. Scientific and technological advances from digital agriculture and biotechnology to artificial intelligence and precision farming are reshaping food systems at an

unprecedented pace. Yet large segments of the rural population remain excluded from both the creation and the benefits of these innovations. The underrepresentation of women and girls in agricultural science, technology, engineering, and mathematics is particularly concerning, given the centrality of these fields to food security and climate adaptation.

The International Day of Women and Girls in Science underscores a critical insight: diversity in innovation leads to better outcomes. Evidence increasingly shows that women-led agri-tech solutions are more likely to be socially embedded, environmentally conscious, and responsive to community needs. Across Africa and South Asia, women entrepreneurs are developing AI-enabled pest management tools, climate-resilient seed systems, and nutrition-sensitive value chains that directly address local constraints.

In 2026, closing the gender gap in agricultural innovation must be treated as a strategic investment. This means expanding STEM education for rural girls, particularly at secondary and tertiary levels; creating dedicated venture capital and blended finance instruments for women agripreneurs; and building mentorship networks that link established research institutions with emerging female scientists and innovators. The next phase of agricultural transformation, often described as a new Green Revolution, cannot afford to leave half of humanity on the sidelines. Innovation that excludes is not innovation at all.

Sustainability forms the third, indispensable pillar of rural resilience. Agriculture today sits at the heart of the climate crisis: it is both highly vulnerable to climate change and a significant contributor to greenhouse gas emissions,

biodiversity loss, and land degradation. The latest scientific assessments reinforce an urgent imperative food system that must transition from extractive models to regenerative ones.

February's global observances offer practical entry points for this transformation. World Pulses Day draws attention to crops that are emblematic of sustainable agriculture. Pulses improve soil fertility through biological nitrogen fixation, require relatively low water inputs, and provide affordable, nutrient-dense protein. Scaling up pulse production and consumption supports climate mitigation, soil health, and nutrition simultaneously.

World Wetlands Day further reminds us that sustainability extends beyond farms. Wetlands are among the most productive ecosystems on Earth, providing water regulation, flood control, carbon sequestration, and habitats for an estimated 40 percent of global species. Yet wetlands are disappearing at an alarming rate, undermining agricultural water security and ecosystem resilience. Restoring and protecting wetlands is not a conservation luxury; it is a foundational investment in climate adaptation for rural landscapes.

Sustainability in 2026 must therefore be redefined as stewardship. Policies need to reward farmers for ecosystem services such as carbon sequestration, biodiversity conservation, and water management. Incentive structures must shift away from practices that degrade soils and water resources toward those that regenerate them. Farmers are not merely producers; they are custodians of natural capital essential to long-term rural prosperity.

Health and nutrition underpin all dimensions of resilience. A productive rural economy cannot exist without healthy people. The interlinkages between agriculture, environment, and health are increasingly evident. World Cancer Day and International Childhood Cancer Day highlight heightened rural vulnerabilities, where exposure to hazardous agrochemicals, unsafe water, and limited healthcare access intersect.

Integrating health and agriculture policies is no longer optional. In 2026, innovative models that link agricultural extension with primary healthcare through telemedicine, mobile clinics, and trained community health workers offer scalable solutions. Such integration can improve early detection of disease, promote safer input use, and enhance overall well-being.

Nutrition remains equally urgent. Despite sufficient global food production, more than 3.1 billion people still cannot afford a healthy diet. Promoting the cultivation and consumption of nutrient-rich, locally adapted crops is a direct pathway to improving both food security and public health. A resilient farm begins with a healthy farmer and a well-nourished household.

Looking ahead, the path to rural resilience in 2026 is clear, even if the journey is complex. Three imperatives stand out. First, policy coherence is essential. Governments must align agricultural subsidies, climate commitments, and nutrition strategies. With nearly USD 700 billion in annual agricultural support still classified as potentially harmful, repurposing public finance toward green, equitable, and nutrition-sensitive

investments is one of the most powerful levers available.

Second, innovation must be hyper-localized. Frugal, context-specific solutions such as solar-powered cold storage, community seed banks, and low-cost digital advisory platforms can deliver outsized impacts when designed with and for rural communities. Top-down technologies without local ownership are unlikely to endure.

Third, radical collaboration is required. No single actor can deliver rural resilience alone. Governments, private investors, researchers, civil society, and farming communities must form new partnerships to de-risk investment, scale innovation, and ensure accountability.

At *The Agricultural Economist*, we see 2026 as a decisive year. Incremental change will not suffice. This edition is both an invitation and a challenge, to researchers, policymakers, practitioners, and community leaders. Share your evidence, your experiences, and your solutions. Together, we can help build rural economies that are not merely coping with change, but actively shaping a more equitable, innovative, and sustainable future.

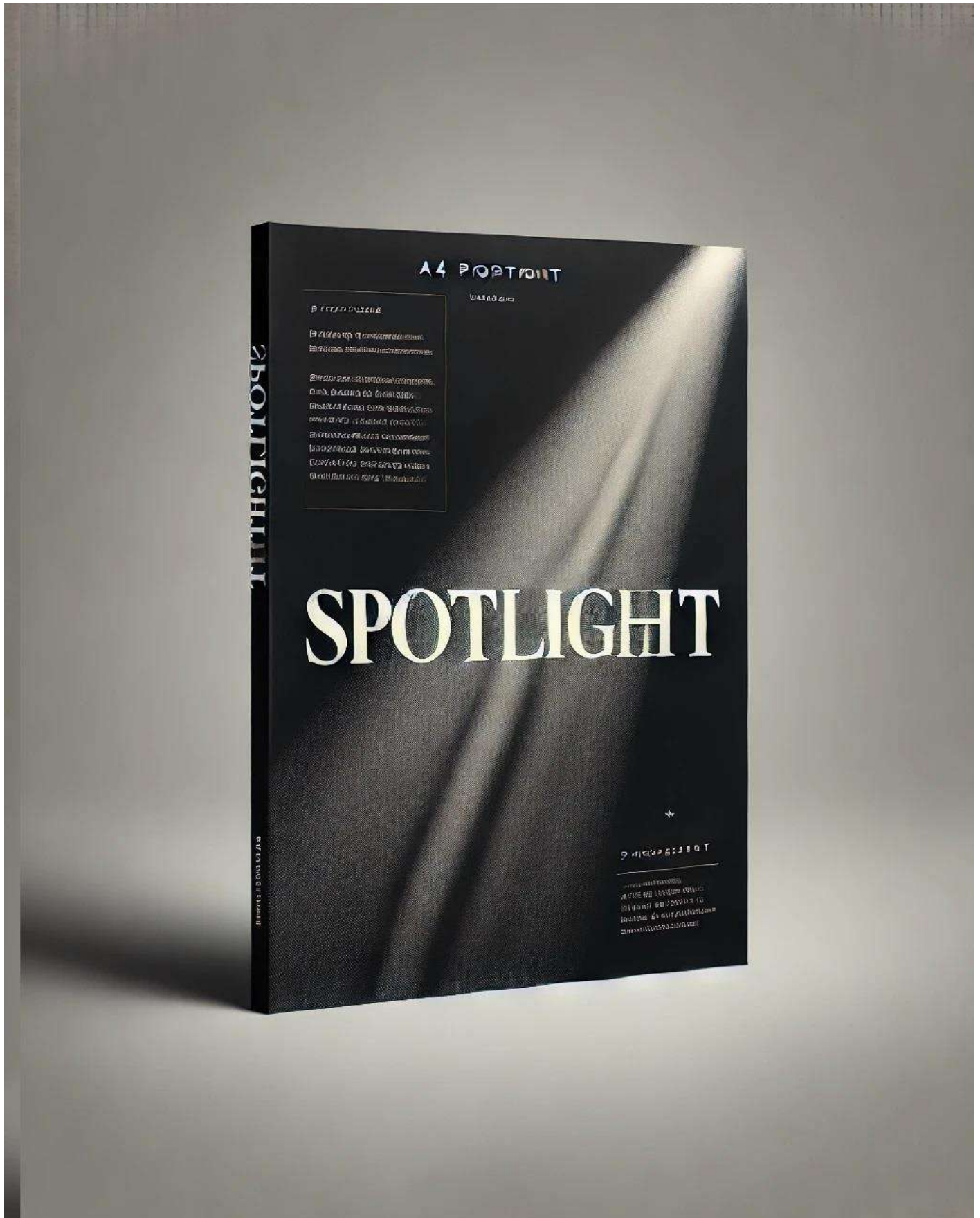
The imperative for transformative resilience is now. Together, let us build it.

**Together, let us build it.**

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**Muhammad Khalid Bashir,**  
Managing Editor, *The Agricultural Economist*





## Türkiye's Thriving Poultry Sector: A Key to Protein Access

Explore how Türkiye's poultry sector has become a vital part of the agri-food system, enhancing productivity and meeting the growing demand for affordable animal protein. Discover its impact on food security, employment, and export earnings.

Mithat Direk

2/6/2026

In an era of mounting pressure on global animal protein supplies, poultry production stands out as a strategically vital sector due to its efficient feed conversion, rapid production cycle, and cost-effectiveness relative to red meat. Poultry meat and eggs require significantly less land, water, and feed per unit of protein produced, making the sector particularly well-suited to meeting the dietary needs of growing populations under conditions of resource scarcity and climate uncertainty. Consequently, Türkiye's poultry industry has solidified its role as a cornerstone of national food security, employment, and economic growth, while also contributing to price stability in domestic protein markets.

The sector has undergone a profound transformation since the 1980s, largely driven by the adoption of vertically integrated production models. Prior to this shift, poultry farming in Türkiye was dominated by small, fragmented operations with limited technological capacity and weak market linkages. Integration enabled firms to coordinate all stages of production from grandparent and parent stock breeding to feed formulation, commercial farming, processing, cold storage, and distribution within a single managerial framework. This structural evolution improved biosecurity, reduced transaction costs, enhanced productivity, and facilitated compliance with international quality and food safety standards.

Today, Türkiye's poultry industry is characterized by highly organized and technologically advanced production chains, managed by over 14,000 integrated enterprises operating across diverse regions of the country. These enterprises ensure consistent quality control, traceability, and uninterrupted supply, even during periods of market or input

price volatility. Beyond its direct economic contributions, the sector generates substantial spillover benefits through demand for maize, soybean meals, veterinary services, logistics, packaging, and retail. As a result, poultry production directly and indirectly supports an estimated 2.5–3 million livelihoods, making it one of the most employment-intensive segments of Türkiye's agri-food system (BESD-BİR, 2024; FAO, 2023).

### Production and Consumption Dynamics

Türkiye ranks among the world's top ten poultry meat producers, reflecting the sector's strong productive capacity and its strategic importance within the national agri-food system. In 2023, poultry meat production reached approximately 2.45 million tons, while egg output exceeded 20.5 billion units, firmly positioning the country as one of the leading global producers of both commodities (TÜİK, 2024; USDA, 2024). This scale of production is supported by modernized farms, improved genetics, efficient feed formulations, and well-developed processing and cold-chain infrastructure, which together enable year-round supply and stable market availability.

On the demand side, poultry products occupy a central place in Turkish consumption patterns. Per capita poultry meat consumption has remained consistently high, stabilizing at around 21–22 kg per year. This reflects consumer preferences shaped by affordability, cultural acceptance, and nutritional considerations, particularly in comparison with red meat, which has become increasingly expensive due to rising input and energy costs. Poultry meat and eggs thus play a critical role in ensuring access to high-quality animal protein for low- and middle-income households, reinforcing

their contribution to food security and dietary diversity.

Beyond domestic consumption, the poultry sector exerts a substantial economic impact through strong backward and forward linkages. It stimulates demand in feed manufacturing, maize and oilseed production, veterinary pharmaceuticals, equipment supply, transportation, packaging, and retail, thereby amplifying its multiplier effects across the wider economy. Export performance has become an increasingly important growth driver. In 2023, Türkiye emerged as a leading global egg exporter and significantly expanded poultry meat exports, generating approximately USD 1.2 billion in export revenue. Major destination markets include Iraq, Gulf Cooperation Council countries, and several nations in Africa and Central Asia (USDA, 2024). However, heavy reliance on a limited number of regional markets exposes the sector to geopolitical risks, trade disruptions, and exchange rate volatility, highlighting the need for greater market diversification.

### Structural Challenges and Risks

Despite its considerable strengths and scale, Türkiye's poultry sector faces a range of structural challenges that pose significant risks to its long-term sustainability and competitiveness. Foremost among these is the sector's heavy dependence on imported feed raw materials. More than 60 percent of protein-rich feed inputs, particularly soybean meals, are sourced from international markets. This dependency exposes producers to volatility in global commodity prices, shipping costs, and exchange rate fluctuations, which directly translate into higher and less predictable production costs (USDA, 2024). Given that feed accounts for the largest share of total production expenses, even modest

price shocks can severely erode profitability.

Animal health risks constitute another critical vulnerability. Recurrent outbreaks of Highly Pathogenic Avian Influenza (HPAI) have imposed substantial biosecurity costs and periodically triggered domestic movement controls and international trade restrictions. Between 2021 and 2023, HPAI outbreaks resulted in the loss of more than 10 million birds in Türkiye, underscoring persistent weaknesses in disease prevention, surveillance, and emergency response systems (WOAH, 2023). These events not only disrupt supply chains but also undermine export credibility in sensitive markets.

Macroeconomic pressures further compound these challenges. Elevated domestic inflation, particularly in energy, fuel, and logistics, has significantly increased operational costs across the production and distribution chain. Smaller and medium-scale producers are especially vulnerable, as they often lack the financial buffers to absorb sustained cost increases. Finally, rising sustainability demands add a new layer of complexity. Growing scrutiny of environmental impacts, waste management practices, and animal welfare standards, coupled with heightened consumer expectations for food safety and traceability, necessitates continuous investment in technology, compliance, and innovation, placing additional strain on already tight margins.

### **Strategic Priorities for Sustainable Growth**

Ensuring the long-term viability and global competitiveness of Türkiye's poultry sector requires a coherent strategic shift that addresses structural vulnerabilities while leveraging existing strengths. A central priority is feed security. Reducing dependence on imported feed inputs necessitates targeted policies to expand domestic production of key crops such as soybean and maize. This can be achieved through improved seed varieties, irrigation support, contract farming arrangements, and sustained investment in agricultural

research and development. Strengthening local feed supply chains would not only stabilize production costs but also enhance resilience against external price and exchange rate shocks.

Equally critical is the fortification of biosecurity systems across the sector. Enhanced national disease surveillance, early warning mechanisms, and rapid response frameworks, aligned with World Organization for Animal Health (WOAH) standards, are essential to mitigating the recurring risks posed by avian diseases. At the farm level, stricter hygiene protocols, controlled farm access, and capacity building for producers can significantly reduce outbreak probabilities, safeguard animal health, and protect export market access.

Another strategic lever lies in value-added diversification. Moving beyond bulk poultry meat and shell egg exports toward processed, branded, and certified products such as halal, organic, and ready-to-cook items can generate higher margins and reduce exposure to price competition. This approach also facilitates entry into premium and more diversified markets, strengthening Türkiye's positioning in global poultry value chains.

Finally, building climate resilience must become an integral component of sectoral strategy. Investments in energy-efficient housing, renewable energy solutions, and environmentally sound waste and by-product management systems can lower operating costs while addressing environmental and regulatory pressures. Together, these strategic priorities can underpin a more resilient, innovative, and sustainable poultry industry.

### **Conclusion**

Türkiye's poultry sector has emerged as a central pillar of the national agri-food system, combining scale, efficiency, and organizational maturity to meet rising domestic and international demand for affordable animal protein. Its evolution toward vertically integrated production has strengthened productivity, quality assurance, and market resilience, enabling the sector to make substantial contributions

to food security, employment generation, and export earnings. With poultry meat and eggs firmly embedded in household consumption patterns, the industry plays a critical role in stabilizing protein access, particularly for low- and middle-income consumers.

However, the analysis also underscores that continued success is not guaranteed. Structural vulnerabilities most notably dependence on imported feed inputs, recurring animal health risks, macroeconomic cost pressures, and rising sustainability expectations pose significant constraints on future growth. These challenges have implications not only for producer profitability but also for export competitiveness and long-term sectoral resilience. Addressing them requires coordinated policy action, strategic investment, and institutional strengthening rather than piecemeal responses.

Looking ahead, the sector's sustainability will hinge on its ability to transition from cost-driven expansion toward resilience-driven and value-oriented growth. Enhancing domestic feed security, reinforcing biosecurity frameworks, diversifying export products and markets, and integrating climate-smart technologies are no longer optional but strategic imperatives. If effectively implemented, these measures can position Türkiye's poultry industry to remain competitive in global markets while aligning with evolving environmental, welfare, and consumer standards. In this way, the sector can continue to support inclusive economic growth and national food security in an increasingly uncertain global environment.

**References:** BESD-BİR; FAO; TÜİK; USDA; World Organization for Animal Health.

*Please note that the views expressed in this article are of the author and do not necessarily reflect the views or policies of any organization.*

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## Türkiye's Agro-Ecological Diversity and Challenges

Explore Türkiye's unique agro-ecological diversity and the pressing challenges of climate stress, water scarcity, and land degradation. Understand the need for integrated policies focusing on sustainability, productivity, and social equity to address these urgent issues.

Mithat Direk

2/13/2026

Agriculture represents humanity's foundational technological and social transformation, the decisive shift from mobile hunter-gatherer bands to sedentary, food-producing societies. Archaeological evidence from the Fertile Crescent dates the domestication of cereals and legumes to approximately 9500–8500 BCE, marking the onset of the Neolithic Revolution (Barker, 2021). This transition, however, was gradual and regionally differentiated rather than abrupt. Independent centers of domestication emerged across the globe, including Mesoamerica, the Yangtze and Yellow River basins of China, the African Sahel, and the New Guinea highlands (Larson et al., 2022). These parallel developments underscore that agriculture was not a singular invention but a convergent adaptive response to climatic stabilization following the Last Glacial Maximum.

Recent archaeogenomic research has substantially refined domestication chronologies. Emmer wheat (*Triticum dicoccum*) was first cultivated in the Karacadağ mountains of southeastern Türkiye around 8800 BCE, while rice (*Oryza sativa*) domestication in the Yangtze Valley is now dated to roughly 6000 BCE, earlier than prior archaeological estimates suggested (Allaby et al., 2021; Fuller et al., 2023). Such findings reinforce the centrality of Anatolia as a reservoir of genetic diversity and a diffusion corridor through which farming systems spread into Europe and Central Asia via Neolithic migrations.

The agricultural transition catalyzed demographic expansion by stabilizing food supplies and increasing caloric yields per unit area. Sedentism facilitated architectural innovation, storage technologies, and surplus accumulation,

which in turn supported occupational specialization and emergent governance structures. Sites such as Çatalhöyük in present-day Türkiye, inhabited between 7100 and 5900 BCE, demonstrate early forms of dense settlement, ritual architecture, craft production, and long-distance exchange networks (Hodder, 2020). Agriculture thus functioned not merely as an economic adaptation but as the structural precondition for urbanization, social stratification, and the institutional complexity that defines early civilization.

### Pre-Industrial Agriculture and the Guano Era

For nearly ten millennia following the Neolithic transition, agriculture remained predominantly organic, labor-intensive, and structurally yield-constrained. Productivity depended on ecological nutrient recycling rather than synthetic inputs. Farmers maintained soil fertility through crop rotations, extended fallow periods, intercropping, livestock integration, and the application of animal manure. In riverine civilizations, such as those nourished by annual flood regimes, nutrient replenishment occurred through alluvial silt deposition (Mazoyer & Roudart, 2019). Despite incremental innovations such as the heavy plough, three-field rotation systems, and selective breeding agricultural output per hectare remained modest. Consequently, global population growth was slow and periodically reversed by famine, epidemic disease, and conflict. By 1800, the world population had reached roughly one billion, constrained by what economic historians describe as the Malthusian ceiling of pre-industrial productivity (Galor, 2022).

The nineteenth century marked the first major disruption to this equilibrium

through the globalization of nutrient extraction. Vast seabird guano deposits along the arid coasts of Peru and Chile, accumulated over centuries, were discovered to contain exceptionally high concentrations of nitrogen, phosphorus, and potassium, critical macronutrients for crop growth. Between 1840 and 1880, Peru exported approximately 20 million tons of guano to agricultural economies in the United Kingdom, France, and the United States, dramatically boosting yields (Cushman, 2021). Yet this trade was environmentally unsustainable and socially exploitative, relying on coercive labor systems akin to debt peonage, while rapidly exhausting finite reserves.

By the late nineteenth century, concern over nitrogen scarcity intensified. In 1898, Sir William Crookes warned that reliance on Chilean sodium nitrate deposits could not indefinitely sustain Europe's wheat supply (Smil, 2021). This looming nitrogen bottleneck framed food security as a scientific challenge and set the stage for the industrial fixation of atmospheric nitrogen, ushering agriculture into the chemical age.

### The Haber–Bosch Revolution and the Transformation of Global Food Production

The decisive turning point in modern agricultural productivity occurred in 1909, when Fritz Haber successfully demonstrated the catalytic synthesis of ammonia ( $\text{NH}_3$ ) from atmospheric nitrogen and hydrogen under conditions of high temperature and pressure. Carl Bosch subsequently engineered the process for industrial-scale production in 1913 at BASF's Oppau facility in Germany, converting a laboratory reaction into a cornerstone of industrial chemistry (Erisman et al., 2022). This innovation effectively severed

agriculture's historic dependence on naturally occurring nitrogen sources.

The Haber–Bosch process reconfigured the global nitrogen cycle. Prior to its development, bioavailable nitrogen originated exclusively from biological fixation or limited mineral deposits such as guano and Chilean nitrates. Today, synthetic ammonia production exceeds 150 million metric tons annually, with roughly 80 percent allocated to fertilizer manufacturing (FAO, 2024). Although energy-intensive, consuming approximately 1–2 percent of global energy supply, the process underpins contemporary food systems. Demographic analyses suggest that without synthetic nitrogen, the planet's carrying capacity would be limited to roughly half the current global population of 8.1 billion (Smil, 2022).

The productivity response was unprecedented. Global cereal yields rose from historically stagnant levels below 1.2 tonnes per hectare to over 4 tonnes per hectare by 2023. This nitrogen-enabled yield surge provided the agronomic foundation for the Green Revolution and fundamentally reshaped global food security trajectories.

### **Mechanization, Structural Transformation, and Environmental Repercussions**

The postwar period witnessed a dual transformation of agriculture through mechanization and chemical intensification. The global tractor fleet expanded from roughly 5 million units in 1950 to 28 million in 2023, reflecting accelerated capital deepening in farming systems (World Bank, 2024). Adoption was particularly rapid in emerging economies. In Türkiye, tractor numbers increased from just 1,750 in 1948 to approximately 1.4 million in 2023, facilitating mechanized cultivation across 95 percent of arable land (TurkStat, 2024). Mechanization compressed planting and harvesting windows, raised labor productivity, and reduced dependence on animal draft power.

However, rising capital intensity precipitated profound structural change.

Agriculture's share of global employment declined from 44 percent in 1991 to 26 percent in 2023, displacing an estimated 1.2 billion workers into manufacturing and services (ILO, 2024). In Türkiye, agricultural employment fell from 41.7 percent of the workforce in 1990 to 15.8 percent in 2023. This labor reallocation fueled rapid urbanization; Türkiye's urban population increased from 25 percent in 1950 to 77.5 percent in 2023 (World Bank, 2024). Yet urban infrastructure and housing supply lagged demographic influxes, generating large informal settlements around major metropolitan centers. These compressed transitions mirrored earlier industrialization experiences in Europe and North America but unfolded under weaker welfare protections and planning capacity.

Simultaneously, chemical intensification generated mounting environmental externalities. Global nitrogen fertilizer applications rose from 11 million tonnes in 1961 to 118 million tonnes in 2023 (FAO, 2024). Because crops absorb only a fraction of applied nitrogen, substantial losses occur through volatilization, leaching, and nitrous oxide emissions, contributing to groundwater contamination, eutrophication, and climate forcing (IPCC, 2023). Organic agriculture emerged as a corrective framework, institutionalized through IFOAM and policy support mechanisms such as the EU's Common Agricultural Policy. Although organic acreage has expanded globally, price premiums and yield differentials continue to limit widespread substitution, underscoring the enduring trade-off between productivity and environmental sustainability.

### **Global Crop Concentration, Investment Trends, and the Paradox of Food Insecurity**

Contemporary agricultural production is highly concentrated in a narrow set of staple commodities. In 2023, global cereal output reached approximately 2.8 billion tonnes, with maize leading at 1.21 billion tonnes, followed by wheat (789 million tonnes), rice (788 million tonnes), and soybean (405 million tonnes) (FAO,

2024). Together, these four crops occupy nearly half of global cropland and underpin both direct human consumption and industrial livestock feed systems. Their dominance is reinforced by research and capital allocation patterns.

Global agricultural research and development expenditure reached \$35.2 billion in 2022, of which 62 percent originated from private firms concentrating on maize, soybean, and wheat genetics (Pardey et al., 2023). Since their commercialization in 1996, genetically modified crops have expanded to 190 million hectares worldwide. Adoption rates are especially high for soybean, maize, and cotton, primarily featuring herbicide-tolerant and insect-resistant (Bt) traits (ISAAA, 2024). Regulatory divergence persists, however. Türkiye, under Biosafety Law No. 5977, permits GM imports for feed but prohibits domestic cultivation, reflecting precautionary alignment with European Union standards while increasing feed import dependency (Gul & Cengiz, 2023).

Despite aggregate abundance, food insecurity remains pervasive. In 2023, global food availability averaged 2,950 kilocalories per capita per day, adequate at the aggregate level, yet 735 million people experienced chronic hunger (FAO et al., 2024). This coexistence of surplus and deprivation reflects income inequality, conflict, and price volatility rather than absolute scarcity. Recent spikes in global food prices, compounded by energy costs and geopolitical disruptions, have intensified access constraints, particularly for low-income households in import-dependent economies.

### **Geopolitical Shocks, Climate Stress, and Strategic Imperatives for Türkiye**

The war between Russia and Ukraine exposed the structural fragility of globally integrated food supply chains. Prior to 2022, the two countries jointly supplied roughly 30 percent of global wheat exports, 20 percent of maize exports, and 80 percent of sunflower oil exports (FAO, 2023). Conflict-related disruptions triggered a 46 percent surge in global

wheat prices in March 2022, destabilizing import-dependent economies across North Africa and the Middle East (Glauber & Laborde, 2023). The episode demonstrated how geographic concentration of export capacity magnifies systemic risk in staple markets.

Climate change compounds these geopolitical vulnerabilities. Global temperatures have risen approximately 1.2°C above pre-industrial levels, with measurable impacts on crop productivity and water availability (WMO, 2024). Empirical projections indicate yield declines of 6–10 percent per 1°C warming for major cereals, alongside significant contractions in climate suitability for perennial crops (Jägermeyr et al., 2023). Türkiye is particularly exposed. The 2021 Marmara drought reduced national wheat output substantially, while the 2023 Kahramanmaraş earthquakes disrupted irrigation and storage infrastructure across multiple provinces (MoAF, 2024). Long-term projections suggest declining surface water availability in key irrigated plains, threatening production stability.

Simultaneously, land degradation and urban encroachment continue to erode agricultural capacity. Türkiye's rich biodiversity, positioned at the intersection of Euro-Siberian, Mediterranean, and Irano-Turanian zones, offers strategic genetic advantages for adaptation. Yet conservation gaps, insufficient R&D investment, fragmented landholdings, and low irrigation efficiency constrain resilience. Integrated policy responses, linking research funding, water management reform, land consolidation, strategic reserves, and targeted social

protection, are essential to safeguard national food security under accelerating climatic and geopolitical uncertainty.

### Conclusion

The historical trajectory of agriculture demonstrates an extraordinary continuum of human innovation, adaptation, and societal transformation. From the Neolithic domestication of cereals and legumes in the Fertile Crescent and Anatolia to parallel developments across Mesoamerica, China, Africa, and New Guinea, agriculture fundamentally reshaped human settlements, social organization, and demographic capacity. Pre-industrial farming, while labor-intensive and ecologically constrained, established the foundation for sustenance and incremental technological improvements over millennia. The nineteenth-century guano trade highlighted early interventions in nutrient management but exposed environmental and social vulnerabilities, signaling the need for more sustainable, scalable solutions.

The twentieth century ushered in the Haber-Bosch revolution, mechanization, and chemical intensification, dramatically expanding global food production and enabling the Green Revolution. These advances supported population growth, urbanization, and structural economic transformation but also generated profound social dislocation and environmental externalities, including nitrogen pollution, groundwater contamination, and biodiversity loss. Contemporary agriculture remains highly concentrated in a narrow set of staple

commodities, with significant investment focused on maize, wheat, rice, and soybean. Despite abundant global production, food insecurity persists due to income inequality, price volatility, and geopolitical shocks, exemplified by the Russo-Ukrainian War.

Türkiye exemplifies the intersection of these historical, technological, and ecological dynamics. Its agro-ecological diversity, combined with exposure to climate stress, water scarcity, and land degradation, underscores the urgency for integrated policy strategies that prioritize research, irrigation efficiency, land consolidation, conservation, and social protection. Overall, the evolution of agriculture illustrates a persistent tension between productivity, sustainability, and equity, an imperative for future policy and innovation.

**References:** Allaby et al; Barker; Bayram & Önsoy; Bunn et al; Cengiz; Cushman; Defra; DSI; Erisman et al; Eurostat; Evenson & Gollin; FAO; IFAD; UNICEF; WFP; WHO; Fuller et al; Galor; Glauber & Laborde; Gul & Cengiz; Hodder; ILO; IPCC; ISAAA; Jägermeyr et al; Karpat; Kurnaz; Larson et al; Lockeretz.

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## Pulses: Essential for Pakistan's Agriculture

Pulses are a strategic necessity in Pakistan's agriculture, addressing soil degradation, water scarcity, and nutritional insecurity. They improve soil health, enhance dietary diversity, and provide affordable plant-based protein, making them vital for sustainable farming.

Muhammad Ather Nadeem

2/3/2026

Pakistan's agricultural sector is facing mounting pressure from interconnected challenges that threaten both productivity and sustainability. Severe soil degradation, growing water scarcity, rising input prices, and intensifying climate variability have placed traditional farming systems under strain (FAO, 2023). The long-standing dominance of cereal-based cropping patterns, particularly wheat and rice, has contributed to declining soil fertility, inefficient use of water and nutrients, and increased vulnerability to climatic shocks. These systems have also narrowed dietary diversity, reinforcing nutritional deficiencies at the national level. Within this context, pulses emerge as a scientifically sound yet persistently neglected option for rebalancing Pakistan's agricultural landscape.

Pulse crops offer multiple agronomic and environmental advantages that directly address current constraints. Through biological nitrogen fixation, pulses can contribute between 40 and 170 kilograms of nitrogen per hectare per season, reducing reliance on synthetic fertilizers that are increasingly costly and environmentally damaging (Stagnari et al., 2017). This not only lowers production expenses for farmers but also curtails nitrous oxide emissions associated with chemical fertilizer use. Pulses are also inherently water efficient. Their water footprint is roughly half that of major cereals, making them particularly suitable for Pakistan's water-stressed and rainfed regions, where groundwater depletion and erratic rainfall are already undermining crop reliability (Mekonnen & Hoekstra, 2011).

Beyond resource efficiency, pulses play a critical role in improving soil structure, breaking pest and disease cycles, and enhancing farm-level resilience when integrated into crop rotations. Nutritionally,

they provide affordable plant-based protein, iron, and micronutrients, offering a pathway to address widespread malnutrition. Despite these clear benefits, pulses account for only about 5.4 percent of Pakistan's total cropped area, and domestic production satisfies just 65 percent of national demand, forcing reliance on imports that strain foreign exchange reserves (PBS, 2023; FAO STAT, 2022).

This policy brief argues that expanding pulse cultivation is not merely an agronomic choice but a strategic necessity. It outlines the role of pulses in enabling sustainable, climate-resilient agriculture, identifies institutional and policy bottlenecks limiting adoption, and presents actionable, SDG-aligned recommendations for policymakers, researchers, and development practitioners seeking durable solutions for Pakistan's food and farming systems.

### Pulses as a Foundation for Sustainable Agriculture in Pakistan

Pulses occupy a unique and strategic position in the pursuit of sustainable agriculture in Pakistan, offering measurable benefits across soil health, water use, nutrition, and climate resilience. One of their most significant contributions lies in biological nitrogen fixation. Pulse crops can fix between 40 and 170 kilograms of nitrogen per hectare, substantially enriching soil fertility and reducing the need for synthetic fertilizers in subsequent crops by an estimated 25 to 30 percent (Stagnari et al., 2017). This not only lowers production costs for farmers but also reduces environmental damage associated with excessive fertilizer use, including greenhouse gas emissions and soil degradation.

Water efficiency is another critical advantage. Pulses require roughly half the water consumed by major cereals such as

wheat and rice, making them especially suitable for Pakistan's increasingly water-scarce agro-ecologies (Mekonnen & Hoekstra, 2011). As groundwater tables decline and surface water becomes more unreliable, crops with lower water demands are no longer optional but essential. Despite this suitability, pulses currently occupy only about 5.4 percent of Pakistan's total cropped area, reflecting long-standing policy and market biases toward cereals (PBS, 2023).

This limited domestic production has direct economic consequences. Pakistan spends more than 200 million US dollars annually on pulse imports to meet domestic demand, placing additional pressure on foreign exchange reserves (Trade Development Authority of Pakistan, 2023). Expanding local pulse production could reduce this import bill while strengthening farmer incomes. From a nutritional perspective, pulses provide 20 to 25 percent protein by weight, along with essential micronutrients, offering an affordable and culturally acceptable protein source for low-income households.

Importantly, pulses enhance climate resilience. When integrated into diversified cropping systems, they can improve yield stability by up to 30 percent during climate shocks such as droughts (Campbell et al., 2022). These combined agronomic, economic, and nutritional benefits position pulses as a cornerstone for a more resilient and sustainable agricultural future in Pakistan.

### Strategic Importance of Pulses in Pakistan's Agricultural Transition

Agriculture continues to anchor Pakistan's economy, employing more than 37 percent of the labor force and sustaining rural livelihoods across diverse agro-ecological zones (Pakistan Economic Survey, 2022–23). Yet the sector's productive base is

under growing threat from entrenched, unsustainable practices. The long-standing dominance of cereal monocropping, reinforced by heavy reliance on chemical fertilizers and intensive irrigation, has steadily degraded soil health. In many regions, soil organic matter has fallen below 0.5 percent, a level at which soils lose their capacity to retain nutrients and water effectively (Ahmad et al., 2022). These biophysical stresses are now being amplified by climate change, which is manifesting through more frequent heatwaves, erratic monsoon rainfall, and extended drought periods, further destabilizing already fragile production systems (IPCC, 2022).

Within this context, pulses represent a strategic but underutilized pathway toward agricultural recovery and resilience. Their contribution extends well beyond nitrogen fixation. Pulse crops increase soil organic carbon, stimulate microbial activity, and improve soil aggregation, resulting in 20 to 35 percent gains in water infiltration and moisture retention, benefits that are particularly critical in rainfed and semi-arid areas (Gan et al., 2015). These processes help reverse long-term degradation and create the conditions necessary for sustainable intensification without escalating input use.

Pulses also play a central role in addressing Pakistan's nutritional and food security challenges. National protein intake remains below recommended levels, and micronutrient deficiencies are widespread. Increasing the availability of affordable, domestically produced pulses beyond the current per capita level of roughly 6.5 kilograms per year offers a practical strategy to combat hidden hunger while reducing dependence on imports (FAO, 2022). From a climate perspective, pulses enhance system resilience through their inherent drought tolerance, short growth cycles, and adaptability to marginal lands. Crops such as mungbean, with growth cycles of 60 to 75 days, allow farmers to adjust planting windows, diversify incomes, and buffer households against climate-induced shocks, making pulses a cornerstone of a more resilient agricultural future.

### **Promoting Pulse Crops for Sustainable and Climate-Resilient Agriculture in Pakistan**

Several pulse crops hold promise for Pakistan due to their adaptability, nutritional value, and compatibility with existing farming systems. Chickpea remains a cornerstone rabi crop in rainfed areas of Punjab and Khyber Pakhtunkhwa, where it fits naturally into low-input systems. The release of high-yielding, disease-resistant varieties such as NIFA-2023 demonstrates that productivity gains are achievable if improved seed is widely disseminated. Mungbean is another strategic crop, especially for Punjab and Sindh, where its heat tolerance and short growth cycle allow it to diversify the dominant rice-wheat system. Its ability to mature quickly makes double-cropping feasible, improving land use efficiency and farm incomes. Lentil, typically grown on marginal lands, offers significant scope for yield improvement, as current average yields remain below 700 kilograms per hectare. Better agronomic practices and improved varieties could substantially raise productivity without expanding cultivated area.

Despite these advantages, pulses remain marginalized within Pakistan's agricultural policy framework. They are often treated as minor crops, resulting in weak institutional support. Certified seed availability is limited, with adoption of improved varieties estimated at less than 15 percent. Market volatility further discourages farmers, as the absence of price stabilization mechanisms and structured value chains exposes producers to high risk. Research and development investment in pulses remains minimal compared to major cereals, while extension services provide limited guidance on improved pulse management practices.

Addressing these constraints requires a coherent, policy-driven shift. Pulses must be integrated into core agricultural and climate strategies such as climate-smart crops aligned with food security and adaptation goals. Targeted incentives, including minimum support prices, insurance schemes, and input subsidies for rainfed regions, can reduce farmer risk. Strengthening public-private research partnerships and seed systems is essential to

scale up climate-resilient and bio-fortified varieties. Finally, embedding pulses within crop diversification programs and strengthening value chains through farmer organizations, storage infrastructure, and agro-processing linkages can reduce post-harvest losses and create sustainable market demand.

### **Conclusion**

Pulses are not a peripheral component of Pakistan's agricultural system but a strategic necessity for addressing the interlinked challenges of soil degradation, water scarcity, nutritional insecurity, and climate vulnerability. The continued dominance of cereal-based monocropping has undermined soil health, intensified resource depletion, and narrowed dietary diversity, leaving farming systems increasingly exposed to climatic and economic shocks. In contrast, pulses offer a rare combination of agronomic, environmental, and nutritional benefits. Their ability to fix atmospheric nitrogen, improve soil structure, and use water efficiently provides a low-cost pathway to restore productivity while reducing dependence on synthetic inputs. At the same time, pulses contribute directly to food and nutritional security by supplying affordable plant-based protein and essential micronutrients, particularly for low-income households.

Despite these advantages, pulses remain underrepresented in cropped areas and under-supported in policy, research, and market development. This disconnect reflects institutional bias rather than agronomic unsuitability. Correcting requires a deliberate shift in agricultural priorities, recognizing pulses as climate-smart crops central to sustainable intensification rather than minor alternatives. Integrating pulses into national food security strategies, strengthening seed and research systems, stabilizing markets, and embedding pulses within crop diversification programs can generate wide-ranging benefits for farmers, consumers, and the environment. Ultimately, scaling up pulse cultivation offers Pakistan a practical, evidence-based route toward resilient agriculture that aligns productivity goals with ecological sustainability and long-term food security.

**References:** Ahmad et al; Campbell et al; FAO; Gan et al; IPCC; Mekonnen & Hoekstra; Pakistan Bureau of Statistics; Stagnari et al; Trade Development Authority of Pakistan.

*Please note that the views expressed in this article are of the author and do not necessarily reflect the views or policies of any organization.*

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## Pakistan's Inflation-Unemployment Nexus Analysis

An evidence-based analysis of Pakistan's inflation–unemployment nexus, highlighting cost-push pressures, structural labor market challenges, and recurring stagflation. The study argues that monetary and fiscal stabilization alone is insufficient and calls for coordinated reforms.

Maha Nisar

2/12/2026

Unemployment and inflation remain among the most central and persistently challenging concerns in macroeconomic policymaking worldwide. For developing economies such as Pakistan, this relationship assumes heightened complexity due to structural rigidities, external vulnerability, and entrenched macroeconomic imbalances (Haque & Qayyum, 2023; Khan & Ahmed, 2025). This article examines the inflation–unemployment nexus in Pakistan through the integrated lens of economic theory, historical dynamics, and structural characteristics. By synthesizing these perspectives, it underscores the necessity of coordinated monetary, fiscal, and structural reforms to secure sustainable price stability alongside inclusive employment generation.

Inflation and unemployment function as core indicators of macroeconomic performance and social welfare. Policymakers typically confront a perceived short-run trade-off, often framed through the Phillips Curve, which posits an inverse relationship between inflation and unemployment. However, Pakistan's experience deviates from this conventional framework. Episodes of stagflation characterized by elevated inflation concurrent with sluggish growth and high unemployment have recurred, particularly during periods of exchange rate depreciation, energy price adjustments, and IMF-supported stabilization programs (SBP, 2025; PIDE, 2024). These dynamics suggest that cost-push pressures and structural bottlenecks dominate demand-driven cycles.

Unlike advanced economies where excess aggregate demand frequently drives inflation, Pakistan's inflationary process is largely supply-constrained. Energy shortages, import dependence, administered price revisions, indirect

taxation, and currency volatility transmit into generalized price increases (Ahmed & Mustafa, 2024). Simultaneously, unemployment remains persistent due to limited industrial diversification, low productivity growth, skills mismatches, and rapid demographic expansion approximately 2.5 million new labor force entrants annually (PBS, 2025; ILO, 2024). The coexistence of structural inflation and structural unemployment indicates that orthodox stabilization tools alone are insufficient. A calibrated mix of macroeconomic stabilization, export-oriented industrialization, human capital investment, and institutional reform is therefore indispensable for breaking this cyclical constraint.

### Inflation and Unemployment Trends in Pakistan

Pakistan's recent macroeconomic trajectory reflects persistent inflationary pressures alongside structurally elevated unemployment, reinforcing the complexity of stabilization efforts.

Pakistan has experienced chronic inflation, punctuated by sharp accelerations during episodes of external account stress, exchange rate depreciation, and fiscal consolidation (SBP, 2025). Average headline inflation reached 23.4 percent in FY2023–24 before moderating to approximately 17.2 percent in FY2024–25 still far above the State Bank of Pakistan's medium-term target range of 5–7 percent (SBP, 2025; Ministry of Finance, 2025). Core inflation, which excludes volatile food and energy components, remained elevated at 16.8 percent in early 2025, signaling entrenched inflationary expectations and second-round effects.

Several structural and policy-driven factors underpin this inflationary persistence. Energy price rationalization

under IMF-supported programs has resulted in repeated upward revisions in electricity and gas tariffs, while domestic fuel prices have cumulatively increased by approximately 135 percent since 2022 (Ministry of Energy, 2025). Simultaneously, the rupee has depreciated by nearly 65 percent against the US dollar since 2021, amplifying import costs through exchange rate pass-through (SBP, 2025). Fiscal dominance, particularly pre-2024 monetization of deficits, expanded liquidity pressures (Haque & Qayyum, 2024). Global commodity price volatility and supply chain disruptions further compounded imported inflation (World Bank, 2025a). Additionally, expanded sales tax coverage and higher indirect taxation under fiscal consolidation have elevated production and distribution costs (FBR, 2025).

Food inflation, carrying a 34.6 percent weight in the consumer price index, averaged 28.3 percent in 2023–24, disproportionately burdening low-income households whose expenditure shares on food exceed 50 percent (PBS, 2025; UNDP, 2024). Importantly, Pakistan's inflation is predominantly cost-push in nature. Rising input prices (energy, imported raw materials, transportation, and taxation) compress firm margins and reduce output, rather than stimulating demand-driven employment expansion (Ahmed & Mustafa, 2024; PIDE, 2024).

Parallel to inflationary stress, unemployment remains structurally embedded. The overall unemployment rate rose to 8.2 percent in FY2024 from 6.9 percent in FY2022 (PBS, 2025). Youth unemployment stands at 14.5 percent, affecting approximately 3.8 million individuals (ILO, 2025). Female labor force participation remains critically low at 23.7 percent, with female

unemployment at 16.2 percent (PBS, 2025; World Bank, 2025b). Educated unemployment is particularly acute, reaching 17.3 percent among degree holders (HEC, 2025), reflecting pronounced skill mismatches.

Each year, 2.5–2.8 million new entrants join the labor force, yet formal job creation averages only 400,000–600,000 positions annually (PBS, 2025; Ministry of Planning, 2025). Structural constraints including limited technical and vocational training coverage (7 percent enrollment among youth), predominance of informal employment (72–75 percent of non-agricultural employment), sectoral concentration in low-productivity agriculture (37.2 percent of employment), and constrained SME financing restrict employment absorption (NAVTTTC, 2025; ILO, 2025; SMEDA, 2024).

Crucially, Pakistan exhibits weak employment elasticity of growth: a one percent increase in GDP yields only 0.3–0.4 percent employment growth (ADB, 2024). This decoupling undermines the conventional Phillips Curve trade-off, suggesting that without structural transformation, macroeconomic stabilization alone cannot reconcile inflation control with employment expansion.

### **Monetary and Fiscal Policy Dynamics in Pakistan's Inflation–Unemployment Context**

The State Bank of Pakistan (SBP), operating under enhanced autonomy following the SBP Act 2021, conducts monetary policy primarily through adjustments in the policy rate with price stability as its statutory objective. In response to the post-2022 inflation surge, the SBP increased the policy rate cumulatively by 1,225 basis points from 7 percent in September 2021 to 22 percent by June 2024 before gradually easing to 17.5 percent by early 2026 (SBP, 2025; 2026). While interest rate transmission to lending rates and aggregate demand typically materializes with a 6–8-month lag, several structural constraints dilute effectiveness. Pakistan's inflation is predominantly cost-push, driven by energy tariffs, exchange rate depreciation,

and indirect taxation, factors largely insensitive to domestic interest rate tightening. Moreover, historical fiscal dominance weakened policy credibility, though reforms have improved institutional discipline. Government borrowing absorbs nearly two-thirds of banking sector credit, crowding out private investment; private sector credit growth fell to 2.1 percent in FY2025, constraining output and employment (SBP, 2026). The sizeable informal economy further weakens monetary transmission. Consequently, disinflation via tight monetary policy imposes real sector costs, reinforcing short-run unemployment pressures.

Fiscal policy remains equally pivotal. Persistent budget deficits averaging above 7 percent of GDP and public debt near 74 percent of GDP (FY2025) perpetuate macroeconomic fragility (Ministry of Finance, 2025; IMF, 2025). Historically, deficit monetization expanded money supply, while contemporary tax-based consolidation has transmitted inflation through higher production costs. Debt servicing now consumes over half of federal revenues, compressing development expenditure from 4.5 percent of GDP in FY2018 to 2.8 percent in FY2025, limiting employment-generating public investment. The resulting policy dilemma is acute: fiscal consolidation restrains demand and employment, yet expansion risks inflation, currency pressure, and renewed instability.

### **Strategic Policy Implications for Stabilization and Employment**

The preceding analysis underscores that demand-side stabilization alone whether through monetary tightening or fiscal consolidation cannot resolve Pakistan's entrenched inflation–unemployment dilemma. While macroeconomic stabilization is indispensable for anchoring expectations, restoring investor confidence, and safeguarding external balances, contractionary policies impose significant short-run employment costs without correcting the structural drivers of cost-push inflation. A dual-track strategy is therefore essential: disciplined

macroeconomic management combined with comprehensive structural transformation.

Competitiveness-enhancing reforms constitute the only durable pathway toward reconciling price stability with employment expansion. Energy sector restructuring remains foundational. Eliminating circular debt, rationalizing tariffs while protecting low-income households, improving distribution efficiency, and accelerating renewable energy deployment would reduce import dependence and production costs. Export diversification is equally critical. Moving beyond textile concentration toward engineering goods, pharmaceuticals, information technology services, and processed agro-products would mitigate external vulnerability and create higher-productivity employment. Special economic zones must prioritize genuine value addition rather than enclave-style assembly operations.

Improving the investment climate is central to employment generation. Regulatory simplification, credible contract enforcement, predictable taxation, and expanded SME credit access can unlock private investment. Equally vital is human capital transformation. Curricular reform, alignment of university output with industry demand, large-scale expansion of technical and vocational education, and remediation of foundational learning deficits are prerequisites for raising labor productivity and reducing educated unemployment.

Labor market interventions require greater emphasis. Active labor market programs, job matching services, wage subsidies, apprenticeship schemes, and targeted retraining, remain severely underfunded relative to peer economies. Expanding such programs can directly mitigate unemployment rather than relying solely on aggregate growth effects.

Monetary–fiscal coordination under central bank autonomy remains necessary but insufficient. Fiscal consolidation must prioritize progressive revenue mobilization and documentation rather

than compressing development spending. Finally, strengthened social protection, through indexed cash transfers and graduation pathways, can cushion vulnerable households during structural transition, ensuring reform sustainability and social cohesion.

### Conclusion

The analysis of Pakistan's inflation-unemployment nexus reveals a complex interplay between structural constraints, policy dynamics, and external vulnerabilities. Unlike advanced economies where demand-driven inflation dominates, Pakistan's inflation is largely cost-push, stemming from energy shortages, exchange rate volatility, imported inputs, and fiscal measures. Simultaneously, unemployment remains structurally elevated due to skill mismatches, limited industrial diversification, low labor productivity, rapid demographic expansion, and a dominant informal sector. This combination has repeatedly produced stagflationary episodes, illustrating the inadequacy of conventional Phillips Curve expectations and highlighting the

limitations of standard monetary and fiscal interventions when applied in isolation.

Monetary tightening, while essential for anchoring inflation expectations, exerts short-run costs on output and employment. Fiscal consolidation, though critical for macroeconomic sustainability, is constrained by high debt servicing and the need to maintain development expenditure. The structural nature of Pakistan's unemployment and cost-push inflation underscores that stabilization alone cannot achieve inclusive growth. Durable solutions require integrated structural reforms: energy sector restructuring, export diversification, investment climate improvement, and human capital development. Complementary labor market programs and strengthened social protection mechanisms are necessary to buffer vulnerable populations and facilitate equitable adjustment.

In essence, Pakistan's macroeconomic challenges call for a dual-track strategy: disciplined macroeconomic management coupled with deep structural

transformation. Only through this coordinated approach can price stability, sustainable employment growth, and social resilience be reconciled, breaking the cyclical constraints that have historically limited the economy's potential.

**References:** Ahmed & Mustafa; Ahmed et al; Asian Development Bank; BISP; Dornbusch & Fischer; Federal Board of Revenue; FAO; Friedman; Haque & Qayyum; Haque et al; HEC; Hussain & Malik; ILO; IMF; Jafri et al; Javed et al; Khan & Ahmed; PIDE; SBP; UNESCO; World Bank.

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## Pakistan's Freshwater Crisis: A National Threat

An in-depth analysis of industrial water pollution in Pakistan's freshwater crisis, examining its impact on rivers and lakes, public health, agricultural productivity, regulatory failures, and the urgent policy reforms needed to protect freshwater resources and economic sustainability.

M Amjed Iqbal, Burhan Ahmad, and Asma Farooq

2/17/2026

Pakistan's industrial sector, contributing approximately 20–24% to Gross Domestic Product (GDP) and employing a substantial share of the labor force (Pakistan Economic Survey 2022-23), remains central to national economic growth and export earnings. Yet this structural importance has been accompanied by escalating environmental externalities, particularly acute freshwater contamination. Rivers such as the Indus River and its tributaries increasingly function as de facto effluent channels for industrial discharge. An estimated 9,000 million gallons of wastewater are generated daily across sectors, of which roughly 96% enters freshwater bodies untreated or inadequately treated (PCRWR, 2022).

Export-oriented industries, most notably textiles, which account for nearly 60% of total exports, are major contributors. Textile processing units discharge high-biochemical-oxygen-demand (BOD) effluents laden with azo dyes, heavy metals, and persistent organic pollutants. Leather tanneries release chromium and sulfides; chemical and pharmaceutical plants emit complex synthetic residues; and sugar mills contribute nutrient-rich effluents that intensify eutrophication. These cumulative discharges exceed the assimilative and regenerative capacity of aquatic ecosystems, degrading water quality parameters such as dissolved oxygen, turbidity, and total dissolved solids.

The crisis is structurally reinforced by rapid urban expansion, informal industrial clusters, and limited wastewater treatment infrastructure. Effluent Treatment Plants (ETPs), where installed, frequently operate below capacity due to energy shortages, maintenance deficits, or regulatory non-compliance. Although environmental statutes exist under the

Pakistan Environmental Protection Act, enforcement remains inconsistent, constrained by institutional fragmentation, limited monitoring capacity, and political-economic pressures.

The result is a compounding public health and ecological emergency: contaminated drinking water, declining fisheries, soil salinization in irrigated tracts, and rising healthcare costs. Without systemic reform, integrating industrial upgrading, regulatory enforcement, fiscal incentives for cleaner production, and investment in centralized treatment facilities, the environmental costs of industrialization will continue to undermine long-term economic sustainability and water security.

### **The Scale, Chemistry, and Socio-Economic Fallout of Industrial Water Pollution in Pakistan**

Industrial effluents discharged into Pakistan's waterways comprise a complex and hazardous mixture of contaminants that fundamentally alter aquatic chemistry and ecosystem viability. These discharges contain heavy metals, hexavalent chromium from tanneries, lead from battery manufacturing, mercury from chlor-alkali and other industrial processes, alongside toxic organic compounds, synthetic dyes, phenols, sulfides, and high biochemical oxygen demand (BOD) loads. Elevated BOD reduces dissolved oxygen concentrations, creating hypoxic conditions that are incompatible with aquatic life. Persistent organic pollutants and trace metals bioaccumulate through trophic chains, amplifying ecological and human health risks over time.

The Ravi River exemplifies the severity of contamination. Receiving more than 1,200 million gallons per day of untreated

municipal and industrial wastewater from Lahore alone (IRN, 2021), downstream water quality frequently falls below thresholds required for irrigation or aquatic survival. A 2023 study by the International Water Management Institute (IWMI) reported extreme coliform counts and heavy metal concentrations particularly chromium rendering sections of the river biologically "dead" for much of the year.

Similarly, Manchar Lake, historically Pakistan's largest freshwater lake, now functions as a receptacle for toxic inflows via the Main Nara Valley Drain. Elevated arsenic, cadmium, and lead concentrations have degraded potable water quality and precipitated dramatic declines in fisheries, undermining local livelihoods. In southern Sindh and Karachi's industrial corridors, effluent discharge into the Hub River and adjacent coastal waters further compound the crisis.

The socio-economic fallout is profound. Contaminated irrigation water reduces crop yields and introduces heavy metals into food chains, while polluted drinking sources increase the prevalence of waterborne diseases, dermatological conditions, and chronic toxic exposure. Healthcare burdens rise, fisheries collapse, and marginalized communities, often lacking alternative water supplies, bear disproportionate costs. Collectively, industrial water pollution constitutes not merely an environmental issue but a systemic development challenge with intergenerational consequences for public health, food security, and economic resilience.

### **Updated Health and Socio-Economic Fallout of Industrial Water Pollution in Pakistan**

The consequences of industrial water pollution in Pakistan extend far beyond ecological degradation, cascading through public health systems, household welfare, and macroeconomic performance. It is estimated that more than 30 million people are directly or indirectly exposed to contaminated water sources, with industrial effluents constituting a primary driver of chemical and microbial pollution. This exposure disproportionately affects peri-urban settlements and rural communities located downstream of major industrial clusters, where regulatory oversight and access to safe drinking water infrastructure remain limited.

Empirical evidence underscores the severity of the health burden. A 2022 systematic review of national water quality studies linked industrial contamination to elevated rates of childhood stunting, chronic gastrointestinal infections, and parasitic diseases in vulnerable populations (Azizullah et al., 2022). Persistent ingestion of heavy metals such as arsenic, cadmium, and chromium, commonly detected in contaminated surface and groundwater, poses long-term risks including renal dysfunction, neurological impairment, and carcinogenic outcomes. Around Manchar Lake, health assessments indicate a marked rise in dermatological conditions and waterborne illnesses. Despite visible pollution, 80-90% of surrounding households continue to rely on untreated lake water for domestic consumption (UNESCO, 2021), reflecting structural poverty and limited alternatives.

The macroeconomic implications are equally significant. The World Bank estimated in 2019 that environmental degradation imposes costs equivalent to roughly 6% of Pakistan's GDP annually. Updated assessments focusing specifically on water and sanitation indicate that poor water quality alone results in economic losses exceeding US\$1 billion per year, approximately PKR 250-300 billion, through healthcare expenditures, lost labor productivity, and premature mortality (World Bank, 2021).

Collectively, these figures illustrate that industrial water pollution is not merely an environmental externality but a systemic development constraint, eroding human capital formation, amplifying inequality, and undermining sustainable economic growth.

### **Regulatory Frameworks and Persistent Implementation Gaps in Industrial Water Governance**

Pakistan possesses a formal regulatory architecture intended to control industrial pollution, anchored in the Pakistan Environmental Protection Act (1997) and the National Environmental Quality Standards (NEQS). The NEQS were revised in 2021 to impose stricter discharge thresholds across 32 parameters, including heavy metals, total suspended solids, chemical oxygen demand (COD), and pH levels. On paper, the framework aligns with internationally recognized effluent standards. In practice, however, a pronounced implementation gap undermines regulatory efficacy.

The enforcement deficit is structural. Provincial Environmental Protection Agencies (EPAs), responsible for monitoring and compliance, face chronic fiscal and human resource constraints. For example, the Punjab EPA reportedly operates with fewer than 200 field officers to oversee thousands of industrial units dispersed across multiple districts (Punjab EPA, 2022). This imbalance severely limits inspection frequency, laboratory testing capacity, and prosecution of non-compliant entities. Political economic dynamics further complicate enforcement, particularly in export-oriented sectors with significant economic leverage.

Infrastructure shortcomings compound the problem. The prevailing policy emphasis on centralized Common Effluent Treatment Plants (CETPs) has yielded limited coverage; fewer than 5% of industrial estates operate fully functional systems. The Kasur Tanneries Pollution Control Project remains one of the few longstanding initiatives, yet it continues to encounter operational and maintenance challenges. Estimated capital requirements to modernize

wastewater management exceed US\$1.5 billion, far surpassing annual public allocations of under US\$50 million.

In the absence of robust state-led solutions, industries frequently resort to informal or superficial mitigation strategies, such as effluent dilution or rudimentary settling ponds. Affected communities adopt defensive coping mechanisms, boiling contaminated water or purchasing bottled alternatives, measures ineffective against dissolved heavy metals and economically unsustainable for low-income households. Public awareness remains limited; surveys indicate that fewer than 40% of residents in high-risk areas understand the specific health risks associated with industrial toxins (UNICEF, 2023). Collectively, these gaps reveal a governance system constrained not by legislative absence but by institutional fragility and resource inadequacy.

### **Comparative Global Lessons and a Strategic Path Forward for Pakistan**

A comparative perspective illustrates that industrial water pollution, while severe, is not intractable. Countries that once faced acute contamination crises have demonstrated that regulatory rigor, technological upgrading, and economic incentives can reverse environmental decline. In Japan, the public health catastrophe associated with Minamata disease catalyzed sweeping reforms grounded in the "Polluter Pays" principle. Strict liability laws, mandatory effluent treatment, and continuous environmental monitoring have transformed compliance behavior. Rivers such as the Yodo River have since been rehabilitated, supporting biodiversity and supplying potable water to major urban populations.

Similarly, Germany institutionalized prevention through closed-loop industrial systems and binding regulatory standards under the Industrial Emissions Directive. By mandating Best Available Techniques (BAT) and incentivizing resource efficiency, Germany reduced industrial freshwater withdrawals by over 30% since 1990 while expanding output. Pollution control became integrated into

industrial competitiveness rather than treated as an external constraint.

A closer regional parallel emerges in Bangladesh. Under international buyer pressure, its garment sector adopted the Zero Discharge of Hazardous Chemicals (ZDHC) framework, leading to the installation of advanced effluent treatment systems in over 200 factories. Compliance enhanced export credibility while reducing toxic discharge and enabling partial water reuse.

For Pakistan, these precedents underscore the need for a paradigm shift from dilution and disposal toward prevention, accountability, and circular resource management. Strengthening provincial Environmental Protection Agencies with digital monitoring tools, imposing deterrent financial penalties, and aligning national standards with global supply-chain benchmarks are critical first steps. Concurrently, targeted subsidies and concessional financing can accelerate the deployment of Common Effluent Treatment Plants and in-plant recycling technologies. Transparent public disclosure of discharge data and community-based monitoring would further enhance accountability.

### Conclusion

Pakistan's freshwater crisis is no longer a peripheral environmental concern; it is a structural threat to national development. The unchecked discharge of industrial effluents into rivers, lakes, and coastal waters has pushed critical ecosystems beyond their assimilative limits, while exposing over 30 million people to contaminated water. Evidence from the Ravi River, Manchar Lake, and the Hub River illustrates a pattern of ecological decline intertwined with public health deterioration, agricultural losses, and rising economic costs. What emerges is not merely an environmental management failure, but a systemic governance and development challenge.

Despite a formal regulatory framework under the Pakistan Environmental Protection Act and revised NEQS standards, enforcement deficits, infrastructure gaps, and limited institutional capacity have undermined progress. International experiences demonstrate that recovery is possible when regulatory accountability, technological modernization, and economic incentives are aligned. For Pakistan, incremental adjustments will be insufficient. A decisive transition toward

prevention-based regulation, circular water use, real-time monitoring, and market-linked compliance is imperative.

Industrial growth and environmental stewardship must no longer be treated as competing objectives. Long-term economic resilience, export competitiveness, and human capital formation depend on restoring freshwater integrity. Without urgent reform, the costs, ecological, social, and fiscal, will continue to compound across generations.

**References:** Azizullah et al; German Environment Agency; IRN; PCRWR; Pakistan Economic Survey; Punjab Environmental Protection Agency; Soomro et al; UNESCO; UNICEF; World Bank; ZDHC.

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## Understanding Water Scarcity in Türkiye

Water is a strategic asset vital for public health, food security, and economic productivity. Türkiye faces challenges of water scarcity including groundwater depletion and climate change, threatening agricultural sustainability and regional stability.

Mithat Direk

2/27/2026

Water is the essence of life. The human body is composed of approximately 60% water (USGS, 2019), underscoring its fundamental role in our survival and biological functions. While the adage that a person can survive for weeks without food but only days without water holds true, modern science refines this: the exact duration without water is influenced by environmental conditions, but the critical point of severe dehydration is typically reached within 2 to 3 days (Popkin, D'Anci, & Rosenberg, 2010). The value of this indispensable resource must be universally understood and respected.

Beyond personal health, water is the lifeblood of our agricultural systems. Global food security is inextricably linked to water availability. Rain-fed agriculture has its limits, but strategic irrigation can dramatically increase crop yields and stabilize production against climatic variability. According to the Food and Agriculture Organization (FAO), irrigated agriculture represents only 20% of the total cultivated land but contributes to 40% of the total global food production (FAO, 2021). This highlights the critical role of water in feeding a growing global population.

Türkiye is often perceived as relatively water-rich compared to its neighbors; however, this wealth is not limitless, nor is it evenly distributed. Currently, Türkiye is classified as a "water-stressed" country. With a population of approximately 85 million, the annual renewable water potential per capita has dropped to around 1,346 m<sup>3</sup> (TurkStat, 2020; DSI, 2021). This places Türkiye well below the previous estimate of 4,500 m<sup>3</sup> per capita and dangerously close to the absolute water scarcity threshold of 1,000 m<sup>3</sup> per capita per year. This dramatic decrease is due to population growth and the impacts

of climate change, which have reduced water availability (DSI, 2021). This new reality means Türkiye must urgently transition from a mindset of abundance to one of efficient management.

Globally, water scarcity is already a source of tension and innovation. Many nations in the Middle East and North Africa, for instance, rely heavily on expensive and energy-intensive desalination to meet their domestic and industrial water needs (Jones, Qadir, van Vliet, Smakhtin, & Kang, 2019). Water scarcity can also exacerbate transboundary water conflicts, making cooperative management of rivers like the Euphrates and Tigris a matter of strategic importance for regional stability.

### Enhancing Water Use Efficiency through Technological and Institutional Innovation

Improving water use efficiency represents one of the most strategic and cost-effective pathways for addressing growing water scarcity in arid and semi-arid regions such as Pakistan. Rapid population growth, urbanization, and climate-induced hydrological variability are intensifying pressure on already limited freshwater resources. In this context, technological modernization combined with institutional reform can generate substantial water savings across agriculture, industry, and urban systems without constraining economic productivity.

In agriculture, the largest water-consuming sector, modern irrigation technologies offer considerable efficiency gains. Transitioning from conventional flood irrigation to drip and sprinkler systems can reduce water application losses by 15-35 percent while maintaining, or even improving, crop yields. Precision agriculture tools,

including soil moisture sensors, satellite-based monitoring, and climate-informed irrigation scheduling, further optimize water allocation. These measures not only conserve water but also reduce energy use, fertilizer runoff, and soil salinity risks, thereby strengthening long-term sustainability.

Industrial water management presents even greater conservation potential. Through wastewater recycling, process re-engineering, and closed-loop cooling systems, industries can reduce freshwater withdrawals by 40-90 percent. Cleaner production technologies and water auditing frameworks enable firms to identify inefficiencies and internalize resource conservation within operational strategy. Such measures enhance both environmental compliance and cost competitiveness.

Urban systems also offer meaningful savings. Aging distribution networks in many municipalities lose significant volumes through leakage and illegal connections. Infrastructure rehabilitation, smart metering, and demand-side interventions such as low-flow fixtures and public awareness campaigns can reduce urban water consumption by 25-30 percent.

Collectively, these cross-sectoral efficiency gains illustrate that water scarcity is not solely a supply problem but also a management challenge. Strategic investment in technology, governance, and behavioral change can substantially narrow the gap between water demand and sustainable availability.

### Regional Water Imbalances and Strategic Imperatives in the Konya Plain

Although national water indicators suggest mounting stress, regional disparities across Türkiye reveal far more acute vulnerabilities. The Konya Plain, regarded as the country's agricultural heartland, has emerged as one of the most critical hotspots of groundwater depletion. Unlike coastal regions that benefit from relatively higher precipitation, the Konya basin relies heavily on aquifers to sustain irrigated agriculture. Decades of over-extraction, combined with recurrent droughts linked to climate variability, have resulted in falling water tables, land subsidence, and the proliferation of sinkholes. This trajectory poses systemic risks not only to farm income but also to national food security.

Within this context, the Konya Plain Project (KOP) assumes strategic significance. Conceived as an integrated regional development master plan, KOP encompasses 11 major irrigation schemes designed to serve approximately 1.8 million hectares, an irrigable area exceeding that of the Southeastern Anatolia Project (GAP), which covers roughly 1.2 million hectares. A central component involves inter-basin water transfers, including conveyance from the Göksu River, to stabilize agricultural production in the semi-arid interior. However, financial constraints, environmental externalities, and implementation delays have slowed progress, while escalating infrastructure costs intensify fiscal pressures.

Yet macro-level infrastructure alone cannot resolve structural water stress.

Efficiency gains at the farm level are equally decisive. The guiding paradigm must shift from output maximization toward water productivity, "more crop per drop." From a microeconomic standpoint, irrigation decisions should be governed by marginal analysis. If the marginal revenue generated by an additional irrigation does not exceed its marginal cost, including pumping energy, labor, and capital depreciation, the practice is economically irrational and environmentally unsustainable. For instance, if groundwater pumping for an additional wheat irrigation costs 500 TL per hectare but yields only 400 TL in added output, the producer incurs a net loss while accelerating aquifer depletion. Sustainable regional resilience therefore requires synchronizing large-scale public investment with farm-level behavioral and technological adaptation.

### Conclusion

Water is not merely a natural resource; it is a strategic asset that underpins public health, food security, economic productivity, and regional stability. As evidence shows, Türkiye has transitioned from perceived water abundance to structural water stress, with per capita availability steadily approaching scarcity thresholds. Population growth, climate change, and uneven regional distribution have intensified pressure on already constrained supplies, particularly in vulnerable zones such as the Konya Plain. Groundwater depletion, inefficient irrigation practices, and delayed infrastructure investments now pose

systemic risks to agricultural sustainability and national food security.

Large-scale initiatives such as the Konya Plain Project and the Southeastern Anatolia Project remain critical for long-term water stabilization. However, infrastructure alone cannot resolve the crisis. Sustainable water governance requires a paradigm shift toward efficiency, accountability, and economic rationality at every level from national planning institutions to individual farms. The principle of maximizing water productivity rather than output at any cost must guide policy and practice.

Ultimately, Türkiye's water future depends on integrating technological innovation, institutional reform, and behavioral change. Conscious management, grounded in data and economic logic, is essential to secure resilient agricultural systems, protect aquifers, and ensure intergenerational water security.

**References:** Aydın; Berkoff; Çakmak; FAO; DSI; Jones et al; OECD; Popkin et al; TurkStat; UNIDO; USGS.

Please note that the views expressed in this article are of the author and do not necessarily reflect the views or policies of any organization.

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# RURAL INNOVATION



## Conservation Agriculture: A Solution for Pakistan's Climate Challenges

Explore how conservation agriculture offers a sustainable solution to the challenges posed by climate change in Pakistan. With rising temperatures and extreme weather, this approach enhances soil health, conserves water, and boosts farm resilience while improving economic stability.

Muhammad Ismail Kumbhar & Aslam Memon

2/4/2026

Pakistan's agricultural sector is confronting an existential threat as climate change accelerates in both intensity and unpredictability. Average temperatures are rising by roughly 0.3°C per decade, while the frequency of drought events has increased by nearly 60 percent since 1990, disrupting crop calendars and straining already scarce water resources (World Bank, 2023; PMD, 2023). At the same time, extreme rainfall events have become more destructive, most visibly during the catastrophic floods of 2022 that submerged nearly one-third of the country, devastated cropland, and displaced millions. These shocks are no longer isolated events but recurring features of Pakistan's climate reality.

The consequences are profound because agriculture remains central to the national economy and social fabric. Contributing approximately 22.9 percent to GDP and employing 37.4 percent of the labor force, the sector underpins food security, rural livelihoods, and macroeconomic stability (Pakistan Economic Survey, 2022–23). Climate-induced yield losses, livestock mortality, and infrastructure damage therefore translate directly into higher food prices, income instability, and increased poverty. Pakistan's consistent ranking among the world's ten most climate-vulnerable countries reflect this exposure, with annual climate-related losses estimated at 3.8 billion US dollars, a burden that constrains development spending and fiscal resilience (Global Climate Risk Index, 2021).

In this increasingly volatile environment, conventional farming practices based on intensive tillage, monocropping, and heavy input use are proving inadequate and, in many cases, counterproductive. They accelerate soil degradation, reduce water retention, and amplify vulnerability to heat and drought. Conservation Agriculture

(CA) has therefore emerged as a necessary climate-smart paradigm rather than an optional innovation. By emphasizing minimal soil disturbance, permanent soil cover, and diversified crop rotations, CA improves soil structure, enhances moisture retention, and stabilizes yields under climatic stress. For Pakistan, scaling up Conservation Agriculture offers a practical pathway to build systemic resilience, protect farmer livelihoods, and safeguard national food security in a rapidly changing climate.

### Conservation Agriculture: Principles and Global Relevance

Conservation Agriculture is a resource-efficient and climate-responsive farming system designed to sustain productivity while restoring the ecological functions of soil. At its core, it rests on three closely connected principles that work as an integrated whole rather than isolated practices. The first is minimal soil disturbance, which reduces or eliminates conventional tillage. By limiting mechanical disruption, soil structure is preserved, organic matter is protected, and biological activity is allowed to recover, leading to better nutrient cycling and water infiltration. The second principle is maintaining permanent soil organic cover through crop residues or cover crops. This protective layer shields the soil from erosion, moderates temperature extremes, reduces evaporation losses, and gradually builds soil organic carbon. The third principle is cropping diversity, achieved through rotations, intercropping, or crop sequencing. Diversification interrupts pest and disease cycles, improves nutrient balance, and spreads production risk across different crops and seasons.

Together, these principles shift agriculture from extractive input-dependent systems toward regenerative processes that rely on

natural soil functions. The global expansion of Conservation Agriculture underscores its practical value. With adoption now exceeding 205 million hectares worldwide, CA has demonstrated its ability to improve yield stability, reduce production costs, and enhance resilience to climate stress across a wide range of agro-ecological conditions (Kassam et al., 2022). This global experience shows that Conservation Agriculture is not a niche approach but a scalable, proven framework for sustainable food production.

### Conservation Agriculture as a Pillar of Climate Mitigation and Farm Resilience

Conservation Agriculture offers Pakistan a rare opportunity to address climate mitigation, resource scarcity, and farm profitability through a single, integrated production system. Conventional tillage accelerates the breakdown of soil organic matter, releasing large volumes of carbon dioxide into the atmosphere and weakening soil structure over time. Conservation Agriculture reverses this trajectory by minimizing soil disturbance and maintaining organic cover, allowing carbon to remain stored in the soil profile. Empirical evidence shows that CA systems can reduce carbon dioxide emissions by 40 to 60 percent compared with conventional tillage practices (Paustian et al., 2019). More importantly, CA converts agricultural soils from net carbon emitters into active carbon sinks. Under sustained CA management, soils can sequester between 0.2 and 1.0 metric tons of carbon per hectare each year, directly contributing to national mitigation targets (Lal, 2020). For Pakistan, where agriculture accounts for a substantial share of methane emissions, scaling CA represents a practical and immediate pathway for reducing the sector's climate footprint (FAOSTAT, 2022).

Water security is another domain where Conservation Agriculture delivers measurable gains. With per capita water availability now around 860 cubic meters, well below internationally recognized scarcity thresholds, improving water use efficiency has become unavoidable (PCRWR, 2023). Crop residue retention under CA reduces surface evaporation by up to 35 percent and improves infiltration by 30 to 45 percent, allowing rainfall and irrigation to be captured rather than lost as runoff (Jat et al., 2020). Field trials in Punjab's rice-wheat systems show that CA practices can raise water productivity by 15 to 35 percent, offering farmers a critical buffer against erratic monsoons and extended dry spells (CIMMYT, 2021).

At the soil level, CA directly addresses widespread degradation affecting nearly 70 percent of Pakistan's farmland. Permanent soil cover and diversified rotations reduce erosion by more than 90 percent while steadily rebuilding soil organic carbon, with increases of 15 to 25 percent recorded within five to seven years (Gonzalez-Sanchez et al., 2019). These healthier soils translate into resilience, with crop survival rates during heatwaves and floods rising by 20 to 40 percent due to improved structure and moisture retention (Thierfelder et al., 2018).

Economic outcomes further strengthen the case for CA. Reduced tillage cuts fuel use by 50 to 70 percent, easing pressure from rising energy prices (Friedrich et al., 2020). Improved nutrient cycling lowers fertilizer requirements by 20 to 30 percent, while long-term studies from South Asia show net farm incomes increasing by at least 25 percent as costs fall and yields stabilize (Aryal et al., 2020). In a climate-volatile future, this combination of mitigation, efficiency, and yield stability positions Conservation Agriculture as a cornerstone of Pakistan's agricultural adaptation strategy.

### **Overcoming Barriers and Scaling Conservation Agriculture in Pakistan**

Despite strong empirical evidence supporting Conservation Agriculture, its adoption in Pakistan remains below three percent of the total cropped area, reflecting

structural and institutional barriers rather than technical failure. A major constraint is the limited availability and high upfront cost of zero-till seed drills and residue management equipment, particularly for smallholders who dominate the farming landscape. Even where machinery exists, access is uneven, and service provision models remain underdeveloped. Competition for crop residues presents another challenge. Residues are often diverted for livestock fodder or fuel, making it difficult for farmers to maintain adequate soil cover despite understanding its agronomic value. Policy signals further compound these constraints. Existing subsidies and procurement frameworks continue to favor conventional, input-intensive practices, inadvertently discouraging farmers from experimenting with alternative systems such as CA. At the field level, knowledge gaps persist among both farmers and extension staff, limiting confidence in CA practices and slowing diffusion.

Addressing these barriers requires a coordinated, system-level response. Conservation Agriculture must be formally embedded within national frameworks such as the National Climate Change Policy and the Agriculture Transformation Plan, clearly positioning it as a climate-smart pathway aligned with food security and climate action goals. Incentive structures should shift from blanket input subsidies toward targeted support for CA machinery, residue management solutions, and risk-sharing instruments such as insurance premium reductions for adopters. Parallel investments in research and extension are critical. Public and private institutions need to jointly develop locally adapted CA models for dominant systems such as rice-wheat and cotton-wheat, supported by a nationwide network of on-farm demonstration sites that translate theory into visible results. Finally, sustained capacity building is essential. National training programs for farmers, extension workers, and machinery service providers can build practical skills, normalize CA practices, and transform conservation agriculture from a pilot innovation into a mainstream production system.

### **Conclusion**

Pakistan's climate reality has fundamentally altered the terms under which agriculture can survive and prosper. Rising temperatures,

recurring droughts, and increasingly destructive floods have exposed the limits of conventional, input-intensive farming systems that degrade soils, waste water, and amplify vulnerability. This article demonstrates that Conservation Agriculture is not a peripheral technique but a strategic response to these intersecting crises. By restoring soil structure, conserving moisture, reducing emissions, and stabilizing yields, CA directly addresses the biophysical roots of climate risk while improving farm-level economics. Its capacity to turn soils into carbon sinks, cut fuel and fertilizer dependence, and enhance resilience during climatic shocks makes it uniquely suited to Pakistan's resource-constrained and climate-exposed context.

The persistence of low adoption reflects policy misalignment, institutional inertia, and gaps in access and knowledge rather than a lack of evidence. Scaling Conservation Agriculture therefore requires more than farmer-level change; it demands a deliberate shift in national priorities, incentive structures, research investment, and extension practice. When embedded within climate, food security, and agricultural transformation strategies, CA offers a realistic pathway to safeguard rural livelihoods, reduce fiscal and environmental costs, and strengthen national food security. In a future defined by uncertainty, Conservation Agriculture provides Pakistan with a practical, science-backed foundation for building a more resilient, efficient, and sustainable agricultural system.

**References:** Aryal et al; CIMMYT; FAOSTAT; Friedrich et al; Gonzalez-Sanchez et al; Jat et al; Kassam et al; Lal; Pakistan Economic Survey; Paustian et al; PCRWR; Thierfelder et al; World Bank.

*Please note that the views expressed in this article are of the author and do not necessarily reflect the views or policies of any organization.*

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## Agri-Based Entrepreneurship in Rural Pakistan

Explore how agri-based entrepreneurship can transform rural Pakistan by addressing low farm incomes and unemployment. Discover the importance of supportive policies, financial access, and market connections in fostering sustainable livelihoods and food security.

Ayesha Noreen

2/6/2026

Rural Pakistan is in the heart of economic, social, and food security situation in the country. The agricultural sector of the economy is an important factor in the national GDP, and it employs almost 38 percent of the labor force, most of whom live in the countryside (Government of Pakistan, 2023). Although this is important, the rural livelihoods are still limited by poor incomes on farms, under employment, incomplete land tenures and growing vulnerability to climate variability. Pakistan has traditional agricultural activities, which are mostly geared towards production and sale of raw materials like wheat, rice, cotton, sugarcane, fruits and livestock products, with little prospects of value addition and growth of income. Agri-based entrepreneurship has in this regard become a very important issue in the lives of rural economies whereby it has been observed to be a critical means of revitalizing the rural economies, increasing productivity and ensuring inclusive and sustainable development.

Agri-based entrepreneurship can be defined as the creation and development of businesses associated with the agricultural value chain, such as the input supply, production, processing, storage, transportation, and marketing (FAO, 2021). Contrary to subsistence agriculture, agri-entrepreneurship focuses on market orientation, innovation and risk-taking. Agri-based entrepreneurship allows rural families to reap more economic benefits, create jobs and enhance resilience to economic and environmental shocks by combining agriculture with business values and principles.

### **The Pakistan Agri-Based Entrepreneurship Requirement.**

The agricultural system in Pakistan is characterized by small and medium sized

farmers most of whom have small landholdings which do not give them a chance to enjoy economies of scale. These market limitations are aggravated by poor market connections and massive losses that occur after harvests, especially in horticulture and animal products. According to research, it is estimated that at least 25 and up to 40 percent of fruits and vegetables like mango, citrus, and tomatoes are spoiled during their storage, processing, and transportation, which result in post-harvest losses (FAO, 2021).

Agri-based entrepreneurship provides a proactive solution to these problems by providing an agricultural activity outside main production. The model of value addition to improving the rural incomes significantly is demonstrated by small-scale agro-processing units that produce rice flour, edible oil, dairy products, and packaged food items in Punjab and Sindh. On the same note, the growth of milk collection and processing businesses in areas like Sahiwal, Okara, and Kasur has helped small milk farmers to enter formal markets, stabilizing the prices and decreasing the fluctuation of incomes (IFAD, 2022).

In addition to the revenue-generating activity, agri-based entrepreneurship is associated with livelihood diversification and alleviation of poverty. Agribusiness enterprises can absorb the surplus rural labor (especially youth) by creating off-farm employment opportunities that cut off the distress migration to urban centers (World Bank, 2022).

### **Major types of Agricultural-based entrepreneurship in Pakistan.**

Agri-based entrepreneurship in Pakistan occurs in various forms in the agricultural value chains. One of the most notable is the Agro-processing enterprises which include the processing of rice milling, flour, and

fruit pulling, meat processing, and dairy product processing. A good illustration of how agro-processing increases the potential of exports and decreases post-harvest wastes is the mango processing units in Multan and Rahim Yar Khan which produce pulp, juices, and dried products (Tripoli & Schmidhuber, 2014).

The other dimension that is crucial is input and service-based entrepreneurship. The production of certified seeds, the distribution of fertilizers and pesticides, veterinary services, and the rental of farming machinery have been rural enterprises which have occupied key gaps in the agricultural support systems. Tractors, harvesters, and laser land-leveling services have been extensively adopted in Punjab by facilities known as custom hiring centers where smallholders can access modern machinery without necessarily having to invest high capital (Government of Pakistan, 2023).

The livestock-based entrepreneurship is one of the pillars of rural livelihoods in Pakistan. Dairy farming, poultry production and meat processing businesses present consistent sources of income and job opportunities especially to land-poor households. Women are the core of livestock business, and women are involved in milk production and backyard poultry systems, which they use to earn incomes and supply food to the household (UNDP, 2021).

Over the last few years, agri-tech and digital agribusinesses have started to transform the rural entrepreneurship. Startups run by the youth that provide mobile-based advisory services, weather forecasting, digital input markets, and farm to market logistics applications are making the market more accessible and informative. These innovations can explain that technology also can close traditional

discontinuities in the agricultural value chains in Pakistan (OECD, 2020).

### **Economic and Social Effects of Agri-Based Entrepreneurship.**

Agri-based entrepreneurship brings great economic and social impacts in rural Pakistan. Among the most direct effects is that it impacts a higher profitability of farms through value addition and better market access. The farmers who process, brand, and sell the products directly are considered to receive much better margins than raw produce sold in the traditional channels (FAO, 2021).

The other important result is employment generation. The agro-processing facilities, cold storage units, transport services, and rural retail outlets provide employment opportunities at a variety of value chain activities. These jobs are specifically valuable to the rural young people, as they will ease the unemployment and demand of rural-urban migration (Lowder et al., 2021).

Socially, agri-based entrepreneurship has helped women to be empowered in the economy. Dairy processing, food preservation, seedling nurseries and kitchen gardening which are operated by women have increased in most rural regions. The rise in income control leads to greater participation of women in decision-making in the household and increases the results in terms of nutrition, education and health (IFAD, 2022).

At the community level, agribusiness enterprises that thrive well trigger economic linkages in the locality. Due to high demands in packaging materials, transport services, veterinary services and activities at the retail level, multiplier effects are being created which are boosting the economic standing of the rural economies.

### **Limitations to Agri-Based Entrepreneurs in Pakistan.**

Although it has potential, agri-based entrepreneurship in Pakistan has several structural and institutional constraints. There is still a lack of access to finance. Agribusiness ventures are usually viewed as risky by formal financial institutions

since they lack collateral and uncertain incomes. Despite the growth of microfinance institutions in reach, loan amounts are often too small to make capital-intensive investments in agro-processing (World Bank, 2022).

Lack of infrastructure is also another limiting factor in the growth of enterprises. The lack of good rural roads systems, unreliable electricity, lack of good cold storage systems, and poor infrastructure in the market make transactions more expensive, and less competitive, especially when it comes to perishable goods. Those difficulties are particularly acute in remote parts of Balochistan and inner Sindh (Government of Pakistan, 2023).

The other significant limitation is the capacity and skills gap. Agricultural entrepreneurship is a business that needs business management skills, quality standards skills, marketing skills, and regulatory compliance skills besides technical expertise in agriculture. The lack of access to combined training and extension services inhibits enterprise performance and scalability (OECD, 2020).

The entrepreneurial environment is also complicated by policy and institutional fragmentation. The uncoordinated interaction between agricultural, industrial, and trade institutions and the intricate licensing system poses uncertainty to the rural entrepreneurs (Ellis, 2000).

### **Institutional, Educational, and Policy Support Role.**

The agri-based entrepreneurship in Pakistan is to be supported by institutes. The role of agricultural universities, research institutes and extension systems in technology transfer, innovation and human capital development is extremely important. Market-focused attitudes in future farmers and agripreneurs could be developed through introducing agribusiness and entrepreneurship education in the agricultural curriculum (UNDP, 2021).

Smallholders are especially interested in collective institutions like producer organizations and farmer cooperatives. Coupled with production and coordination

of marketing, these organizations enhance economies of scale, bargaining power, and access to finance (IFAD, 2022).

On policy front, a combined agribusiness development policy is very important. There can be credit schemes that are specifically designed to help reduce the barriers to entry through subsidized loans in agro-processing, crop and business insurance and incentives on value-added exports. Rural infrastructure, cold chains and digital connectivity investments are also needed to facilitate agri-entrepreneurship (World Bank, 2022).

### **The Future of Agricultural-based entrepreneurship in Pakistan.**

Technological innovation, the need to be sustainable, and evolving consumer preference will determine the future trend of agri-based entrepreneurship in Pakistan. Under the conditions of climate change, climate-smart agribusiness models which are instrumental to encourage efficient water consumption, renewable energy, and sustainable production practices will become more significant (FAO, 2021).

The digital platforms will increase market accessibility, price transparency, and financial inclusion. The increase in safe and traceable and value-added food products opens a new opportunity to certification, brand, and export-oriented agribusinesses (Tripoli & Schmidhuber, 2014). The solutions to lasting rural change and innovation will be the involvement of the youth in agri-tech startups.

### **Conclusion**

Agri-based entrepreneurship is a strong solution to change the rural Pakistan and resolve the endemic issues of low farm incomes, unemployment, and economic vulnerability. Agri-entrepreneurship facilitates the rural communities to quit subsistence-based agriculture by enhancing the value addition, market connection, and innovation.

Nevertheless, to achieve this potential, a concerted action is needed to overcome financial limitations, infrastructural limitations, institutional limitations, and capacity limitations. The right environment to agri-entrepreneurs requires

supportive policies, good extension services, availability of finance and facilitating market institutions.

Agri-based entrepreneurship, in a climate of uncertainty, population increase, and growing food demand, has the potential to make agriculture a dynamic source of rural prosperity. It has the potential to guarantee food security, economic and sustainable

livelihoods among rural population in Pakistan when properly enabled.

**References:** Ellis; FAO; Government of Pakistan Economic Survey; IFAD; Lowder et al.; OECD; Tripoli & Schmidhuber; UNDP; World Bank.

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## Unlocking Sweet Corn's Potential in Pakistan

Explore the untapped opportunity of sweet corn in Pakistan's agricultural landscape. Despite strong maize production, sweet corn faces challenges due to structural gaps in seed systems, extension services, post-harvest infrastructure, and market integrations.

Hajan Ambreen, Umara Sahar Rana & Muhammad Kashif

2/10/2026

In Pakistan, sweet corn (*Zea mays L. saccharata*) remains a niche crop, largely confined to health-conscious urban consumers, supermarkets, and the hospitality industry. Its limited footprint is striking given Pakistan's long history with maize cultivation and the availability of agro-climatic conditions that are well suited to sweet corn production. This paradox raises important questions about the underlying constraints to wider adoption. Is the marginal status of sweet corn primarily driven by consumer taste and entrenched food preferences, or does it reflect deeper shortcomings in varietal development, extension services, post-harvest handling, and market integration?

Pakistan is a major maize-producing country, with production overwhelmingly oriented toward grain and feed uses for poultry and livestock. According to the Pakistan Bureau of Statistics, maize cultivation covered approximately 1.74 million hectares during 2022–23, yielding about 10.99 million tons of output (PBS, 2023). Despite this scale, sweet corn accounts for a negligible share of total maize production and is not reported separately in national agricultural statistics. This absence from official data itself signals the crop's peripheral status in policy, research, and investment priorities.

International comparisons underscore the missed opportunity. In countries such as the United States, Canada, and Hungary, sweet corn is a mainstream vegetable crop, supported by well-developed seed systems, contract farming, cold chains, and processing industries producing frozen and canned products for both domestic and export markets (FAOSTAT, 2023). Within Asia, Thailand and China have successfully integrated sweet corn into agro-processing and export-oriented value chains. By contrast, in Pakistan, like

India and Bangladesh, sweet corn remains largely experimental, cultivated on small plots with weak market linkages. This suggests that the constraint is less agronomic feasibility and more the absence of coordinated value chain development, consumer awareness, and supportive institutional frameworks.

### Agronomic Specificities and Structural Market Constraints

Botanically, sweet corn originates from a natural recessive mutation, most associated with the *sugary1 (su1)* gene, that limits the conversion of sugars into starch within the endosperm. This genetic characteristic produces kernels with elevated sugar content, softer texture, and a distinctly sweet flavor profile that differentiates it from conventional field maize (Revilla et al., 2021). Although both crops belong to the same species, their agronomic management, harvest timing, and post-harvest handling requirements diverge significantly. Sweet corn must be harvested at the milk stage and rapidly cooled to preserve sweetness and quality, making it far more sensitive to delays and infrastructure gaps. In Pakistan, the absence of a specialized value chain including structured procurement systems, processing facilities, and targeted policy incentives renders sweet corn cultivation a comparatively high-risk enterprise for farmers. Limited cold storage capacity and inadequate rural logistics amplify post-harvest losses, discouraging even commercially oriented producers from diversifying into this crop (Rana et al., 2022).

The agronomic challenges are closely intertwined with supply chain deficiencies. Sweet corn requires precise sowing windows aligned with optimal temperature ranges, yet many farmers

apply traditional field corn calendars, leading to suboptimal yields and inconsistent kernel sweetness. Empirical trials in agro-ecological zones such as Multan, Peshawar, and Nowshera have demonstrated that planting dates directly influence cob development, pest resistance, and marketable quality, with even minor deviations reducing profitability (Khan et al., 2021). Furthermore, the genetic base of sweet corn in Pakistan remains narrow, heavily dependent on costly imported hybrid seeds. Limited domestic research and development restrict the availability of climate-resilient and region-specific cultivars suited to local production conditions (Iqbal et al., 2020). On the market side, weak cold-chain infrastructure leads to rapid quality deterioration after harvest. As a result, sweet corn is primarily marketed as a seasonal premium product in major urban centers like Lahore and Karachi, creating a persistent disconnect between rural production potential and consistent consumer demand. This highlights that, unlike traditional subsidized crops, the success of sweet corn hinges not merely on financial incentives but on the development of an integrated and responsive market ecosystem (Agricultural Policy Institute, 2022).

### A Strategic Pathway for Integrating Sweet Corn into Pakistan's Agri-Food System

Unlocking the commercial potential of sweet corn in Pakistan requires a coordinated, multi-stakeholder strategy that aligns production, research, infrastructure, and market development. Global experience demonstrates that successful sweet corn industries rarely emerge spontaneously; instead, they are deliberately built through public-private partnerships that link seed innovation,

farmer capacity building, and downstream processing and marketing (Tracy, 2021). Countries that have transformed sweet corn into a mainstream vegetable crop have invested simultaneously in genetics, logistics, and demand creation, ensuring that risks and returns are more evenly distributed along the value chain.

A logical starting point for Pakistan is varietal development. Collaboration with international research institutions such as CIMMYT, alongside domestic seed companies, can accelerate the breeding of high-yielding, disease-resistant sweet corn hybrids tailored to major agro-ecological zones. Locally adapted varieties would reduce dependence on expensive imported seed and improve yield stability under heat and water stress conditions. Parallel to this, capacity building must be strengthened. Extension services need to move beyond generic maize recommendations and provide crop-specific guidance on optimal planting windows, irrigation scheduling, nutrient management, and harvest timing to preserve kernel sweetness and market quality.

Equally critical is investment in value-chain infrastructure. Establishing localized pre-cooling and cold storage facilities near production clusters, combined with contract farming arrangements linked to processors, supermarkets, and the food service industry, can reduce post-harvest losses and provide farmers with assured markets and predictable prices. Such arrangements lower production risk and

encourage adoption by small and medium-scale growers. Finally, demand creation is essential for sustained growth. Consumer awareness campaigns emphasizing the nutritional value and culinary versatility of sweet corn, coupled with the development of processed products such as frozen kernels, vacuum-packed cobs, and ready-to-eat options, can expand domestic consumption beyond elite urban niches. Together, these measures can integrate sweet corn into Pakistan's agri-food system as a viable, income-generating diversification crop.

### Conclusion

Sweet corn represents a largely untapped opportunity within Pakistan's agricultural landscape one that contrasts sharply with the country's strong maize production base and favorable agro-climatic conditions. As this assessment shows, the marginal status of sweet corn is not rooted in agronomic infeasibility but in structural and institutional gaps that span seed systems, extension services, post-harvest infrastructure, and market integration. The absence of dedicated value chains, reliable cold storage, and assured procurement has positioned sweet corn as a high-risk crop, discouraging farmer adoption despite its strong income and diversification potential.

International experience demonstrates that sweet corn can evolve from a niche product into a mainstream vegetable when supported by coordinated public-private action. For Pakistan, progress hinges on shifting from isolated pilot efforts toward a systemic approach that

simultaneously addresses varietal development, farmer capacity, logistics, and consumer demand. Developing locally adapted hybrids, strengthening crop-specific advisory services, and investing in pre-cooling, processing, and contract farming arrangements can significantly reduce production and marketing risks. Equally important is stimulating demand through awareness of sweet corn's nutritional value and expanding processed product options that ensure year-round consumption.

If these elements are aligned, sweet corn can contribute to farm income diversification, rural employment, and dietary improvement, while reducing overreliance on traditional crops. The "golden grain" need not remain silent in Pakistan; with strategic vision and institutional commitment, it can rise as a viable component of a more resilient and market-responsive agri-food system.

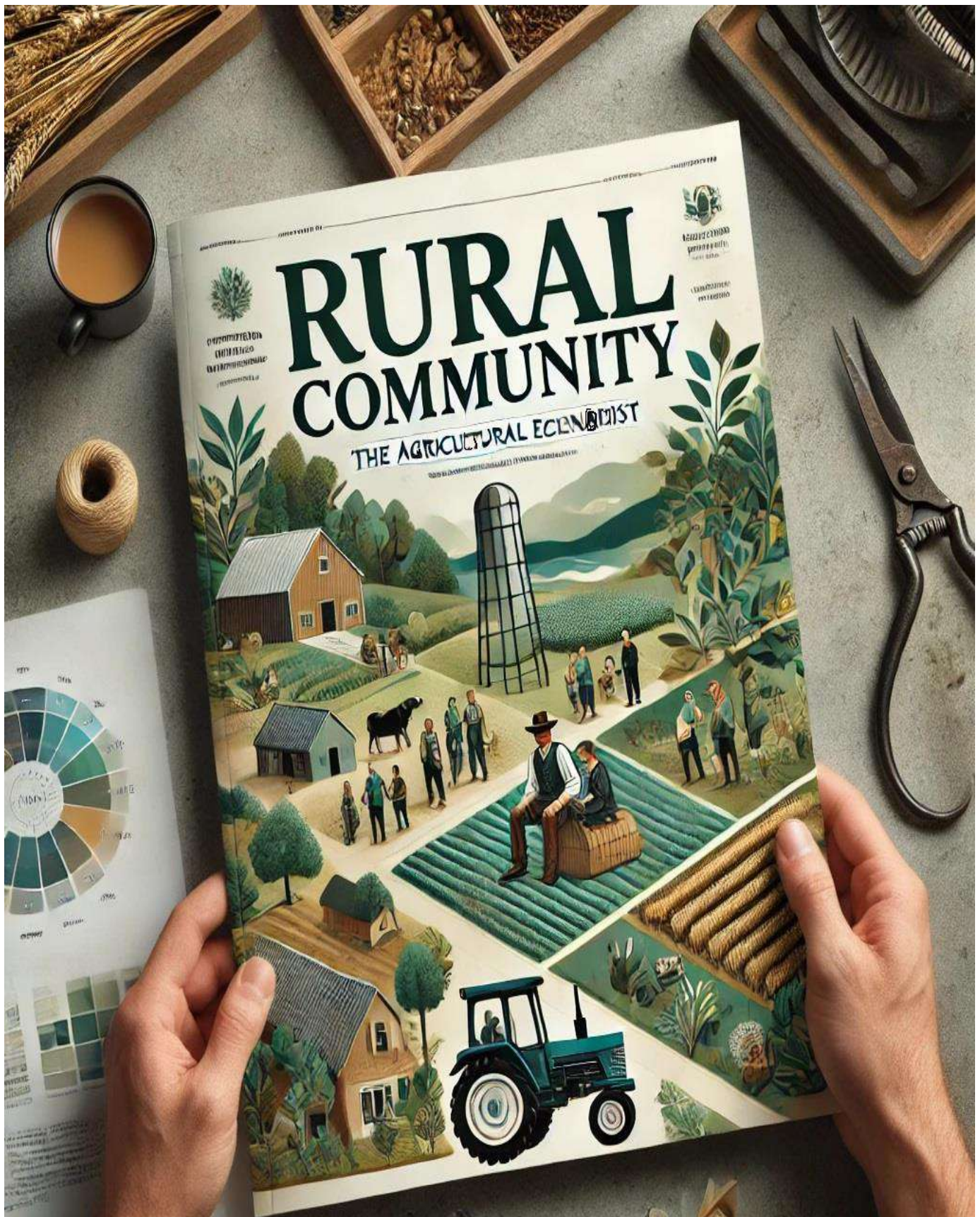
**References:** FAOSTAT; Iqbal et al; Khan et al; Pakistan Bureau of Statistics; Rana et al; Revilla et al; Tracy.

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**Figure:** Corn breeding by maize research group in University of Agriculture Faisalabad (Photo by PicKash)





## Tharparkar: A Living Desert of Resilience

Explore Tharparkar, a vibrant landscape shaped by history and environmental change. Discover the rich ecological knowledge and resilience of its people, who adapt to the challenges of a living desert. Learn how this region thrives despite historical neglect.

Nazar Gul & Hafiz Abdul Salam

2/5/2026

Pakistan's five major deserts cover nearly 11 million hectares and include the Thar, Cholistan, Thal, Kharan, and Katpana deserts, forming a vast arid belt that shapes livelihoods, settlement patterns, and ecological processes across the country (Khan, 2022). Among these, the Thar Desert is the most expansive and socially significant, occupying approximately 4.46 million hectares, or about 5.6 percent of Pakistan's total land area (Sindh Bureau of Statistics, 2023). Situated in southeastern Sindh, the Thar forms part of the larger transboundary Thar ecoregion that extends into India's Rajasthan, Gujarat, and Haryana. This shared ecological system is defined by extreme temperature variability, low and erratic rainfall, sandy soils, and a fragile vegetation cover that supports pastoralism, rainfed agriculture, and a unique biodiversity adapted to arid conditions.

Within Pakistan, the Thar stretches from the fringes of Cholistan in southern Punjab to the rocky hills of Nagarparkar near the Indian border. Tharparkar District occupies the core of this landscape and represents both the cultural and ecological heart of the desert. Its population has historically adapted to scarcity through mobile livelihoods, communal resource sharing, and strong social cohesion. Seasonal migration, livestock herding, and reliance on monsoon-dependent cropping systems reflect centuries of adjustment to climatic uncertainty.

The historical trajectory of Tharparkar reveals long-standing administrative marginalization. After the decline of the Indus Valley Civilization around 1900 BCE, the region passed through successive dynasties including the Soomras, Sammas, Arghuns, Kalhoras, and Talpurs, all of whom governed primarily from western Sindh, leaving the eastern desert relatively peripheral (Ahmed, 2021). British colonial

rule after the annexation of Sindh in 1843 further reshaped governance. The area was initially absorbed into the Kutch agency, later placed under Hyderabad, and labeled the Eastern Sindh Frontier, reinforcing its frontier status rather than integrating it into development planning (Ansari, 2020). Although formally declared a district in the late nineteenth century and later subdivided after Partition, Tharparkar continues to reflect the legacy of historical neglect. Today, it remains one of Pakistan's most distinctive arid regions, marked by rich cultural traditions, ecological fragility, and persistent development challenges.

### What Does "Tharparkar" Mean?

The name "Tharparkar" carries a layered meaning that reflects the region's physical landscape, historical mobility, and long-standing relationship with environmental uncertainty. Linguistically, the term combines two elements that are deeply rooted in the geography of southeastern Sindh. "Thar" is derived from words such as *thal* or *t'hul*, commonly interpreted as "sandy plain," "sand ridge," or "dune-filled terrain," a direct reference to the expansive desert environment that defines the region (Memon, 2019). This component emphasizes the arid ecology of shifting sands, sparse vegetation, and reliance on monsoon rains that have shaped livelihoods for centuries. The second element, "Parkar," translates as "to cross over" or "to pass through," capturing a dynamic rather than static understanding of place.

Historically, this notion of crossing was closely linked to seasonal movement. During the monsoon, the Rann of Kutch, a low-lying salt marsh to the southeast, would flood extensively, cutting off routes and submerging grazing lands. In response, local communities, traders, and travelers

were compelled to move toward higher sandy ground within the Thar, crossing natural boundaries in search of safety, water, and pasture. This seasonal migration was not an exception but a routine adaptation to the region's hydrological rhythms. The term "Parkar" thus came to symbolize both physical movement across flooded terrain and the broader culture of mobility that sustained life in an unpredictable desert environment.

Over time, the phrase "Thar and Parkar" evolved into the unified name "Tharparkar," reflecting the inseparability of landscape and movement in the region's identity. The name itself encapsulates a lived history of resilience, environmental awareness, and adaptation. Rather than merely denoting a place, "Tharparkar" describes a way of inhabiting a challenging ecology, where survival has long depended on reading the land, anticipating seasonal change, and crossing boundaries in response to nature's cycles.

### From Flowing Rivers to an Arid Landscape: The Geological Birth of the Thar Desert

The origin of the Thar Desert is the outcome of long-term geological, hydrological, and climatic transformations rather than a sudden or recent shift. Interdisciplinary research increasingly points to the desiccation of the Ghaggar-Hakra river system as a central process in the region's transition from a river-fed landscape to an arid desert (Clift et al., 2022). Geological surveys, satellite imagery, and sediment analysis reveal a dense network of palaeochannels beneath the sands, indicating that a large perennial river once flowed across what is now the Thar. This river is often associated with the Sarasvati described in ancient texts and is believed to have supported early agricultural societies until approximately

4,000–3,500 years ago (Giosan et al., 2020).

The decline of this river system is closely linked to tectonic reconfigurations in the Himalayan foreland. Gradual shifts redirected key tributaries, most notably the Sutlej toward the Indus system and the Yamuna toward the Ganges basin, depriving the Ghaggar-Hakra of sustained flow (Singh et al., 2022). These hydrological changes unfolded alongside a weakening of the Indian Summer Monsoon, reducing rainfall across northwest South Asia. The convergence of river diversion and climatic drying coincided with the decline of the Indus Valley Civilization between 1900 and 1700 BCE, suggesting a strong relationship between environmental change and social transformation (Dixit et al., 2021).

Importantly, the Thar Desert did not emerge solely from the collapse of river systems. Geological evidence shows that arid processes were active much earlier. Luminescence dating of sand dunes indicates that large-scale wind-driven sand accumulation began between 15,000 and 10,000 years ago, intensifying during the mid-Holocene as dry conditions became more persistent (Singhvi & Kar, 2021). Archaeological findings from sites such as Kalibangan and Jhukar confirm that the region experienced alternating wet and dry phases, allowing periodic human

settlement and cultivation (Pokharia et al., 2023).

Crucially, the formation of the Thar was driven by natural climatic and tectonic forces rather than human degradation. Over centuries, communities adapted through mobile pastoralism, rain-fed cultivation systems such as kair, and sophisticated water-harvesting practices. These adaptive strategies remain central to Tharparkar's socio-ecological resilience today, underscoring a long history of living with, rather than against, environmental change (Mustafa, 2022).

### Conclusion

Tharparkar emerges from this discussion not as a barren margin of the nation, but as a living desert shaped by deep history, environmental change, and human adaptation. Its landscape reflects millennia of climatic shifts, from river-fed plains to wind-sculpted dunes, while its people embody a long tradition of resilience rooted in mobility, cooperation, and ecological knowledge. The meaning of Tharparkar itself captures this relationship between land and life, where survival has always depended on reading seasonal signals, crossing boundaries, and adjusting livelihoods to uncertainty. Historical patterns of administrative neglect have reinforced the region's vulnerability, yet they have not erased its cultural vitality or adaptive capacity.

Understanding Tharparkar through geological, historical, and socio-ecological lenses challenges simplistic narratives that frame deserts as empty or unproductive spaces. Instead, it highlights them as dynamic systems that demand context-sensitive development approaches. As climate variability intensifies across Pakistan, the lessons embedded in Tharparkar's history, from water harvesting to pastoral flexibility, are increasingly relevant beyond the desert itself. Recognizing Tharparkar as a living landscape rather than a peripheral problem is essential for designing inclusive policies that respect local knowledge, address structural neglect, and strengthen resilience in one of the country's most distinctive regions.

**References:** Ahmed; Ansari; Clift et al; Dixit et al; Giosan et al; Khan; Memon; Mustafa; Pokharia et al; Sindh Bureau of Statistics; Singh et al; Singhvi & Kar.

*Please note that the views expressed in this article are of the author and do not necessarily reflect the views or policies of any organization.*

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## Forests in Pakistan: Vital for Climate Stability

Forests in Pakistan are crucial for climate stability, water security, and agricultural productivity. With forest cover below 6%, the country faces severe challenges due to deforestation, including increased flood risks and soil erosion, highlighting the urgent need for ecological regeneration.

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Pakistan remains classified as a developing economy, characterized by constrained industrial growth, fiscal instability, variable human development indicators, and governance deficits (UNDP, 2024). Alongside regional counterparts including India, Bangladesh, Sri Lanka, and Afghanistan, Pakistan continues to pursue structural reforms through bilateral and multilateral cooperation. Nevertheless, persistent challenges such as rapid demographic expansion, environmental deterioration, and suboptimal natural resource governance continue to impede progress toward sustainable development (World Bank, 2024a).

Among the most pressing environmental threats facing contemporary Pakistan is deforestation, which critically undermines ecological integrity, economic resilience, and public health outcomes. Forests serve as carbon sinks, hydrological regulators, biodiversity repositories, and livelihood foundations for millions. Their rapid depletion therefore constitutes not merely an environmental concern but a multisectoral crisis with intergenerational consequences (WWF-Pakistan, 2024).

### Structural Challenges and Ecological Implications

Developing countries face interrelated structural constraints, including multidimensional poverty, underemployment, income inequality, and mounting environmental stress. In Pakistan, these pressures are intensified by rapid population growth, prolonged political instability, persistent fiscal and trade deficits, deep-rooted regional disparities, and accelerating climate-induced degradation. Together, these dynamics create a complex development environment in which economic

vulnerability and ecological decline reinforce one another.

Pakistan's demographic trajectory is particularly consequential. With an estimated population of approximately 241.5 million in 2023–2024 (PBS, 2024), the country records one of the highest fertility rates in South Asia. Projections suggest that by 2050 the population could reach nearly 403 million, positioning Pakistan as the world's fourth most populous nation (UNDESA, 2024). This expansion imposes substantial pressure on finite natural resources, especially forests, freshwater systems, and cultivable land. Rising demand for housing, fuelwood, and agricultural expansion has accelerated deforestation, frequently through informal or illegal land conversion (GoP, MoCC, 2023).

Forest resources in Pakistan remain critically limited. Current satellite-based and national inventory estimates indicate that forest cover constitutes only 4.8–5.7 percent of total land area approximately 3.12 million hectares (FAO, 2024; MoCC, 2024). This figure falls well below the internationally recommended benchmark of 25 percent considered necessary to maintain ecological balance and climate resilience (IUCN, 2023). Net annual forest loss is estimated at 42,000–47,000 hectares, driven by illegal logging, agricultural encroachment, infrastructure development, and weak enforcement mechanisms (WWF-Pakistan, 2024).

Although forest governance was devolved to provinces following the Eighteenth Constitutional Amendment, institutional capacity varies significantly across regions, and coordination remains fragmented (Khan et al., 2024). Forest types range from coniferous stands in northern highlands to irrigated plantations, scrub forests, riverain forests

along major floodplains, and extensive rangelands in arid zones. However, without strengthened governance, demographic management, and sustainable land-use planning, continued degradation threatens biodiversity, water security, and long-term climate resilience.

### Environmental, Economic, and Societal Consequences of Deforestation in Pakistan

Deforestation in Pakistan imposes substantial and quantifiable economic and environmental costs, undermining ecological stability and long-term development prospects. Hydrological assessments demonstrate that forest degradation has significantly weakened watershed regulation functions, intensifying flood frequency and severity. The catastrophic floods of 2022, which submerged nearly one-third of the country, affected approximately 33 million people, caused damages estimated at US\$14.9 billion, and required US\$16.3 billion for recovery and reconstruction, illustrating the scale of vulnerability (GoP & World Bank, 2022; UNDP, 2023). While extreme rainfall was the immediate trigger, degraded catchments and reduced vegetative cover amplified runoff, sedimentation, and downstream destruction.

Beyond floods, deforestation accelerates soil erosion, with agricultural productivity estimated to decline by 0.5–1.2 percent annually due to nutrient depletion and land degradation (Majeed & Mumtaz, 2023). The erosion of fertile topsoil alone is valued at approximately PKR 70 billion each year (Pakistan Economic Survey, 2023–24). Sediment loads transported into major reservoirs including Tarbela, Mangla, and Chashma reduce water storage capacity and hydropower generation efficiency,

compounding energy insecurity (WAPDA, 2024). Simultaneously, an estimated 30 million acre-feet of freshwater flows unused into the Arabian Sea annually, partly reflecting impaired upstream retention and groundwater recharge in degraded watersheds (PCRWR, 2024). Forest ecosystems play indispensable hydrological roles through canopy interception, enhanced infiltration, and aquifer replenishment; their removal heightens flash flooding, sedimentation, and agricultural risk, directly threatening food security (Zafar et al., 2024).

Forests also sustain human livelihoods and public health. Approximately 62 percent of rural households depend partially on fuelwood for domestic energy, while non-timber forest products provide subsistence and income particularly for women and marginalized communities (UNDP, 2024). Medicinal plants sourced from forest ecosystems contribute to traditional healthcare systems and emerging pharmaceutical industries (Sher et al., 2024). Globally, forests sequester around 2.6 billion tonnes of carbon dioxide annually, underscoring their central role in climate mitigation (IPCC, 2023).

Urban evidence further highlights forests' regulatory functions. Studies in Lahore and Karachi show that mature trees reduce ambient temperatures by 2–5°C through evapotranspiration and shading (Shahid et al., 2023). A single mature broadleaf tree can deliver cooling effects comparable to multiple air-conditioning units operating for extended periods (Nowak et al., 2023). Trees also filter airborne pollutants, capturing particulate matter and absorbing harmful gases. In cities such as Lahore, where PM<sub>2.5</sub> concentrations exceed WHO guidelines by several multiples, expanding greenbelts could reduce particulate pollution by 8–25 percent (Khokhar et al., 2024; Anjum et al., 2023).

Finally, forest conservation aligns with Islamic environmental ethics, which emphasize stewardship (*khilafah*) and continuous charity (*sadaqah jariyah*) through tree planting. Integrating

ecological restoration with socioeconomic planning and ethical frameworks is therefore not merely an environmental imperative but a developmental necessity for Pakistan's resilience and sustainability.

### Urban Forestry, Indigenous Species, and Community-Centered Environmental Governance

Pakistan's rapid urbanization, projected at approximately 3.2 percent annually, demands the systematic incorporation of green infrastructure into urban planning frameworks (PBS, 2024). Major metropolitan centers such as Lahore, Karachi, Faisalabad, Rawalpindi, and Peshawar face acute shortages of accessible green space, frequently falling below the World Health Organization's recommended minimum of 9 square meters per capita. This deficit exacerbates urban heat island effects, air pollution exposure, and declining public health outcomes. To address these vulnerabilities, provincial and municipal authorities must embed urban forestry within statutory master plans and zoning regulations. Priority measures include establishing urban forests and vertical gardens, mandating minimum green space allocations in housing developments, incentivizing green building certification, legally protecting heritage trees, and setting measurable tree cover targets (Ahmed et al., 2024).

Unlike pollution control technologies that rely on capital-intensive and energy-consuming systems such as electrostatic precipitators or fabric filters, urban forestry provides a cost-complementary and multifunctional mitigation strategy (Ali et al., 2024). Trees moderate temperatures, enhance aesthetic value, reduce stormwater runoff, and improve psychological well-being, while simultaneously filtering airborne pollutants.

Afforestation initiatives should prioritize indigenous, broad-canopied, evergreen or semi-evergreen species with high pollution tolerance and climate adaptability. Species such as Peepal (*Ficus religiosa*), Banyan (*Ficus benghalensis*), Neem (*Azadirachta*

*indica*), Arjun (*Terminalia arjuna*), Sukh Chain (*Pongamia pinnata*), and Jaman (*Syzygium cumini*) demonstrate strong particulate capture capacity and require relatively low maintenance (Amin et al., 2024; Shah et al., 2023). Native species also support biodiversity and avoid the ecological risks associated with invasive exotics.

Sustainable urban forestry ultimately depends on civic engagement. Environmental education, community-based forest management models, and participatory conservation committees such as those piloted in Khyber Pakhtunkhwa and Punjab illustrate that durable environmental governance requires active public stewardship. As local wisdom affirms, planting trees is an intergenerational investment in resilience and collective well-being.

### Strategic Policy and Institutional Recommendations for Sustainable Forest Governance

Strengthening Pakistan's forest governance framework requires coordinated institutional reform, technical upgrading, and regulatory modernization. A permanent Inter-Provincial Forest Commission should be constituted to harmonize forest policies across provinces, standardize forest inventory and data protocols, and align forestry governance with agriculture, water, wildlife, energy, and national climate adaptation strategies. Such vertical and horizontal coordination would reduce duplication and enhance policy coherence.

Provincial forestry training institutes must be modernized to deliver specialized curricula in biodiversity conservation, carbon forestry, climate-resilient silviculture, GIS-based monitoring, and ecosystem accounting to meet emerging environmental and reporting demands. Simultaneously, forest classification systems should transition from traditional use-based categories toward ecosystem-based typologies consistent with international standards, incorporating metrics such as carbon density, biodiversity significance, and watershed sensitivity.

Participatory governance mechanisms should be institutionalized through statutory district-level forest management committees involving local governments, forest-dependent communities, civil society organizations, and technical experts to enhance transparency and compliance. Legal consolidation is equally critical; fragmented legislation including the Forest Act 1927 and various provincial statutes should be rationalized into comprehensive, enforceable conservation laws with clear penalties and monitoring provisions.

At the federal level, coordination for international environmental commitments (UNFCCC, CBD, UNCCD, SDGs, and REDD+) must remain robust while respecting provincial jurisdiction. Provinces should allocate at least 1% of Annual Development Plans to forestry, establish research institutes, and maintain updated forest accounts. Circular economy measures, sustainable harvesting cycles, and mandatory 10:1 compensatory afforestation with geo-tagged verification should further reinforce ecological sustainability and long-term forest regeneration.

### Conclusion

Forests in Pakistan are not peripheral ecological assets; they constitute

foundational infrastructure for climate stability, water security, agricultural productivity, and public health. With forest cover remaining below six percent of total land area and demographic pressures intensifying, the country confronts a structural imbalance between resource demand and ecological regeneration. The evidence is unequivocal: deforestation amplifies flood risk, accelerates soil erosion, undermines hydropower efficiency, exacerbates urban heat stress, and erodes rural livelihoods. The economic costs, reflected in disaster losses, declining agricultural yields, sedimented reservoirs, and rising health expenditures, demonstrate that forest degradation is fundamentally a development crisis rather than a narrow environmental issue.

Yet the prospects for reversal remain tangible. Strengthened inter-provincial coordination, ecosystem-based classification, legal consolidation, enhanced budgetary allocations, and community-centered governance can reposition forestry within Pakistan's macroeconomic and climate resilience strategy. Urban forestry, indigenous species restoration, circular economy practices, and science-based monitoring further offer cost-effective pathways toward ecological recovery. Aligning

forest conservation with ethical stewardship, international commitments, and socioeconomic planning transforms afforestation from a symbolic exercise into a strategic national investment.

Sustainable forest governance, therefore, must be integrated into Pakistan's long-term growth paradigm. Without restoring ecological capital, economic stability and human survival will remain precarious; with it, resilience and inclusive development become achievable.

**References:** Ahmed et al; Ali et al; Amin et al; Anjum et al; FAO; Gade; GoP; MoCC; IPCC; IUCN; Khan & Ahmad; Khan et al; Khattak et al; Khokhar et al; Majeed & Mumtaz; Nowak et al; Ozdemir; PCRWR; Pakistan Forest Survey; Sahih al-Bukhari; Sahih Muslim; Shah et al; Shahid et al; UNESCO. WAPDA; World Bank.

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## Tharparkar Demographics: Population Growth Insights

Explore the demographic profile of Tharparkar, highlighting rapid population growth amidst ecological and socioeconomic challenges. Understand how religious plurality, caste hierarchies, and linguistic diversity impact education, health, and livelihoods in this unique district.

Nazar Gul & Hafiz Abdul Salam

2/13/2026

Tharparkar is widely recognized as one of the most densely populated desert regions in the world, reflecting a demographic trajectory that is both distinctive and developmentally consequential. According to the 2023 Pakistan Digital Census, the district's population has reached 1,872,912, rising from 1,647,036 in 2017 and 914,291 in 1998 (PBS, 2023; GoS, 2018). Although the inter-censal growth rate between 2017 and 2023, approximately 1.5 percent annually, has moderated relative to the 1998–2017 period, the absolute population increase continues to exert mounting pressure on fragile desert ecosystems characterized by water scarcity, erratic rainfall, and limited cultivable land.

Population density has more than doubled over the past quarter century, increasing from 50.2 persons per square kilometer in 1998 to 103.2 in 2023. Despite marginal urbanization, the district remains overwhelmingly rural, with 89.7 percent of residents living in villages. The slight rise in the urban share to 10.3 percent is largely attributable to administrative reclassification rather than structural economic transformation or industrial expansion (GoS, 2022). Consequently, livelihood patterns remain heavily dependent on rain-fed agriculture, livestock rearing, and informal trade, intensifying ecological vulnerability.

Significant intra-district disparities persist. Dahli Taluka exhibits the highest density at 158.4 persons per square kilometer, followed by Kaloi and Chachro, whereas Nagarparkar records the lowest density despite its expansive geography. Such uneven spatial distribution signals imbalances in infrastructure provision, service delivery, and economic opportunity. The sex ratio

of 1,132 males per 1,000 females reflects persistent demographic asymmetries influenced by migration patterns and reporting dynamics. Collectively, these demographic trends underscore the urgency of integrated population, environmental, and rural development planning to safeguard long-term sustainability in Tharparkar.

### Religious, Caste, and Linguistic Dynamics in Tharparkar

Tharparkar remains Pakistan's most religiously diverse district, exhibiting demographic patterns distinct from provincial and national trends. The 2023 Census indicates that Hindus now constitute 45.2 percent of the district's population, increasing from 43.39 percent in 2017 and 40.47 percent in 1998, while the Muslim share has declined to 54.6 percent (PBS, 2023). Differential fertility rates and comparatively lower out-migration among Hindu communities are cited as principal drivers of this shift (Ahmed & Rajar, 2022). Spatial concentration is pronounced: Mithi, Islamkot, and Nagarparkar maintain Hindu majorities, with Mithi recording 72.3 percent Hindu population, whereas Dahli remains overwhelmingly Muslim at 89.1 percent. The urban–rural divide has also widened, with Hindus constituting 67.4 percent of urban residents, while Muslims account for 61.3 percent of the rural population. This demographic duality carries implications for electoral alignments, public-sector representation, and inter-communal cohesion (Soomro et al., 2020).

Caste continues to structure social and economic life. Anthropological surveys identify roughly 14 Hindu and 8 Muslim caste groups, with growing recognition of sub-caste identities (Hasan & Shaikh,

2023). Scheduled castes comprise an estimated 31 percent of the population, though under-reporting remains a concern (PBS, 2023). Prominent Hindu communities include Meghwar, Kolhi, Bheel, Lohana, Thakur (Rajput), Suthar, and Soni. The Kolhi community remains among the most socioeconomically marginalized, exhibiting low literacy and limited occupational mobility (Ahmed, 2022). Among Muslims, Lohar, Kumbhar, Mangrio, Arbab, Khaskheli, Bajeer, and Jat groups are significant. Caste influences landholding, trade specialization, labor segmentation, and voting behavior.

Linguistically, Tharparkar occupies a transitional zone between Sindhi and Rajasthani traditions. While 98.4 percent report Sindhi as their primary language, Dhatki (Thari) functions as the dominant vernacular in many rural areas. Parkari Koli and related dialects remain vital within specific caste communities, underscoring the district's layered cultural identity.

### Education Deficits and Public Health Vulnerabilities in Tharparkar

Literacy remains the most persistent structural constraint on human development in Tharparkar. According to the 2023 Census, the literacy rate for the population aged 10 years and above stands at 32.1 percent, reflecting only a modest increase from 29.78 percent in 2017 (PBS, 2023). This implies that more than two-thirds of adults remain functionally illiterate, limiting workforce productivity, civic participation, and intergenerational mobility. Gender disparities, although slightly narrowing, remain acute. Male literacy has reached 24.3 percent, while female literacy lags at 9.7 percent, an incremental rise of just 1.72 percentage points over six years.

Structural barriers including early marriage, sociocultural mobility restrictions, limited availability of female teachers, and inadequate access to secondary schooling for girls continue to constrain progress (UNICEF, 2022).

The urban–rural divide further compounds educational inequality. Urban literacy has improved to 59.4 percent, whereas rural literacy remains critically low at 28.7 percent (PBS, 2023). Taluka-level disparities persist, with Mithi reporting the highest literacy rate at 41.2 percent and Nagarparkar the lowest at 23.9 percent. Infrastructure deficiencies exacerbate these outcomes: a significant proportion of primary schools lack boundary walls, potable water, and reliable electricity. Teacher shortages remain severe, with rural pupil–teacher ratios substantially exceeding national benchmarks (AEPAM, 2022). High dropout rates, particularly during the transition from primary to middle school, reflect both supply-side constraints and household economic pressures (ASER Pakistan, 2022).

Health and food security indicators reveal parallel vulnerabilities. Tharparkar records the highest maternal mortality ratio in Sindh at 298 deaths per 100,000 live births, alongside elevated infant mortality (PDHS, 2020). Chronic malnutrition is endemic, with high prevalence of stunting, underweight, and wasting among children under five (WFP, 2022). Seasonal food insecurity limited dietary diversity, inadequate sanitation, and constrained access to maternal healthcare collectively

perpetuate a cycle of poverty and underdevelopment. Sustainable improvement requires integrated investments in education, primary healthcare, nutrition, water access, and climate-resilient livelihoods.

### Conclusion

The demographic profile of Tharparkar reveals a district undergoing sustained population expansion amid severe ecological and socioeconomic constraints. Rapid growth, rising population density, and persistent rural predominance have intensified pressure on fragile desert ecosystems and limited public infrastructure. At the same time, Tharparkar’s unique religious plurality, entrenched caste hierarchies, and linguistic diversity shape patterns of political representation, economic participation, and social mobility. These demographic characteristics are not merely descriptive; they fundamentally influence development outcomes across education, health, and livelihoods.

Human capital indicators remain deeply concerned. Low literacy rates particularly among women combined with weak school infrastructure and high dropout rates constrain long-term productivity and perpetuate intergenerational poverty. Parallel deficiencies in maternal and child health, chronic malnutrition, and seasonal food insecurity underscore the multidimensional nature of deprivation in the district. The convergence of demographic pressure, environmental vulnerability, and institutional gaps creates a development trap that cannot be

addressed through isolated sectoral interventions.

Sustainable progress in Tharparkar requires an integrated strategy that aligns population planning, educational reform, primary healthcare strengthening, nutrition-sensitive agriculture, and climate-resilient rural livelihoods. Without coordinated policy action and targeted investment, demographic momentum will continue to outpace service delivery capacity. Conversely, with evidence-based planning and inclusive governance, Tharparkar’s diverse social fabric can become a foundation for resilient and equitable development in Pakistan’s desert frontier.

**References:** Academy of Educational Planning and Management; Ahmed; Ahmed & Rajar; ASER Pakistan; Government of Sindh; Hasan & Shaikh; Khan & Memon; Laghari et al; Memon et al; Pakistan Bureau of Statistics; Pakistan Demographic and Health Survey; Rahman; Ramesh & Kumar; Sindh Education Foundation; Soomro et al; UNICEF; UNDP; World Food Program.

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## Türkiye's Agricultural Consultancy Reform

Explore Türkiye's agricultural consultancy system, a vital reform enhancing knowledge transfer and market responsiveness. Discover the role of certified consultants and the challenges faced in farmer participation.

Mithat Direk

2/20/2026

The global agricultural sector is undergoing sustained structural transformation, driven by liberalized trade regimes, climate pressures, digitalization, and shifting consumer expectations regarding food safety and environmental stewardship. Multilateral negotiations under the World Trade Organization have progressively reshaped domestic support instruments, encouraging member states to transition from trade-distorting subsidies toward decoupled income support, rural development measures, and “green box” policies compatible with sustainability objectives. These reforms have compelled governments to recalibrate agricultural governance frameworks, placing greater emphasis on productivity, compliance, and innovation.

As a WTO member and an official candidate for accession to the European Union, Türkiye has actively aligned its agricultural policy architecture with international norms. Harmonization efforts have included restructuring support mechanisms, strengthened food safety standards, and enhanced institutional capacity in rural development programming. A particularly notable reform has been the formalization of an agricultural consultancy system designed to bridge the knowledge gap between research institutions and farm-level implementation.

This consultancy framework institutionalizes agricultural extension services, certifies professional advisors, and incentivizes farmers to adopt improved agronomic practices, precision input management, and compliance with environmental and quality standards. By facilitating knowledge transfer, the system aims to enhance productivity, resource-use efficiency, and market integration, particularly for small and

medium-sized producers facing competitive pressures.

Nevertheless, diffusion constraints remain. Regional disparities, limited farmer awareness, financial barriers, and uneven service quality hinder full system penetration. Strengthening monitoring mechanisms, expanding digital advisory platforms, and integrating consultancy services with rural finance instruments will be critical to scaling impact. Despite these challenges, Türkiye's institutionalization of agricultural consultancy represents a significant modernization milestone, demonstrating how policy reform, trade alignment, and knowledge-based support can collectively reposition national agriculture within an increasingly competitive global environment.

### **Institutional Development and Current Dynamics of Türkiye's Agricultural Consultancy System**

Türkiye's agricultural consultancy system emerged as a structural response to the growing need for knowledge-intensive, market-oriented farming. Designed to provide professional, science-based guidance to producers, the system seeks to bridge the persistent gap between agricultural research institutions and on-farm application. Operating on a voluntary basis, it positions knowledge transfer as a strategic production input, arguably the most critical factor in enhancing productivity and resilience in contemporary agriculture (Direk, 2015). Formalized through a 2006 regulation under the Ministry of Agriculture and Forestry, the framework authorizes certified agricultural engineers, technicians, and veterinarians to deliver up-to-date technical information, regulatory guidance, and farm management advice directly to producers. Its overarching objective extends beyond

incremental yield gains: it aims to strengthen competitiveness, reduce input inefficiencies, and secure long-term sectoral sustainability.

Implementation metrics reflect both progress and structural constraints. As of 2024, the number of licensed agricultural consultants has surpassed 5,500, compared to roughly 4,000 in the mid-2010s. However, active participation remains significantly lower than total certification figures. A 2021 assessment found that of more than 5,000 certified consultants, only about 1,500 were actively delivering advisory services, with many employed in public administration or agribusiness sectors (Özkan & Yılmaz, 2021).

To stimulate farmer demand, state financial support for consultancy services was introduced in 2009 and has been periodically adjusted. In 2024, annual support was increased to 15,000 TL per farmer, signaling strong fiscal commitment. Despite this substantial subsidy, adoption remains limited. Of approximately 2 million farmers nationwide, only around 12,000 were benefiting from state-supported consultancy services as of 2023. This disparity underscores significant untapped capacity and highlights the need for enhanced outreach, trust-building mechanisms, and integration with rural finance and digital extension platforms to scale system-wide impact.

### **Structural Constraints Undermining the Effectiveness of Agricultural Consultancy in Türkiye**

Despite its progressive intent, Türkiye's agricultural consultancy system continues to face deep-rooted structural and operational weaknesses that constrain its overall effectiveness and credibility. Foremost among these is the persistent knowledge transfer gap between

consultants and farmers. Many producers, particularly smallholders operating under tight financial constraints, remain reliant on inherited practices shaped by experience rather than formal science. This often generates skepticism toward external advice, especially when recommendations involve upfront costs, behavioral change, or delayed returns. As a result, technically sound guidance may be only partially adopted or ignored altogether, weakening farmers' perception of consultancy as a value-adding service rather than a discretionary expense.

A second major challenge lies in institutional ambiguity. Provincial and district agricultural directorates continue to provide advisory services alongside their regulatory and supervisory roles. While these public institutions are indispensable for disease control, subsidy administration, and compliance monitoring, their dual role as advisors creates overlap and competition with private consultants. This parallel structure blurs accountability and discourages the development of a truly market-oriented consultancy profession. The original rationale of the system was to enable individualized, demand-driven advice tailored to farm-specific conditions. Without a gradual and clearly communicated withdrawal of the state from routine extension functions, private consultants struggle to differentiate their services and build sustainable client relationships, as highlighted by Gülçubuk et al. (2020).

A further structural weakness is the enduring conflict of interest associated with agricultural input suppliers. Historically, advisory services were informally delivered by seed, fertilizer, and pesticide dealers, whose guidance was closely linked to product sales rather than holistic farm optimization. Although the formal consultancy system was designed to correct this distortion, the legacy persists. Farmers often continue to trust suppliers due to accessibility and familiarity, even when advice prioritizes input intensity over efficiency or environmental sustainability. For the consultancy system to gain legitimacy,

consultants must maintain strict impartiality, offering diagnostics-based recommendations independent of commercial incentives. Without resolving these structural tensions, the system risks underperforming relative to its transformative potential in modernizing Turkish agriculture.

### **The Path Forward: Embracing a Market-Oriented Agricultural Paradigm**

The long-term viability of Türkiye's agricultural consultancy system depends not solely on the technical competence of certified advisors, but equally on the strategic orientation of farmers. The traditional production logic "whatever I produce, I will sell" is increasingly incompatible with volatile commodity prices, input cost inflation, climate variability, and international quality standards. In a liberalized and competitive agri-food economy, production decisions must be guided by market intelligence, comparative advantage, and risk-adjusted profitability rather than habit or subsistence logic.

A market-oriented approach requires farmers to treat agriculture as an entrepreneurial activity grounded in data-driven planning. Decisions regarding crop selection, planting schedules, input intensity, contract farming opportunities, and post-harvest management must align with demand forecasts, value chain requirements, and certification standards. Agricultural consultants are uniquely positioned to facilitate this transition. By providing real-time information on domestic and export market trends, climate-smart production techniques, input optimization strategies, and regulatory compliance requirements, consultants can help farmers reduce uncertainty and improve margin efficiency.

However, this transformation necessitates a collaborative model rather than a top-down advisory dynamic. Farmers must actively engage in joint problem-solving, sharing farm-level data, articulating constraints, and participating in performance evaluation. Trust-building, transparency, and measurable outcomes are essential to strengthening this partnership. Over time, such cooperation can shift consultancy from a subsidized service to a strategic investment, enhancing competitiveness,

resilience, and long-term farm sustainability within Türkiye's evolving agricultural economy.

### **Conclusion**

Türkiye's agricultural consultancy system represents a strategically significant reform within a broader context of global agricultural restructuring shaped by the World Trade Organization disciplines and harmonization efforts linked to the European Union. By institutionalizing professional advisory services under the Ministry of Agriculture and Forestry, Türkiye has taken a decisive step toward embedding knowledge transfer, regulatory compliance, and market responsiveness into farm-level decision-making. The measurable expansion in certified consultants and increased fiscal support signal political commitment; however, limited active participation and low farmer uptake reveal persistent structural frictions.

The system's future effectiveness hinges on resolving three core constraints: closing the knowledge adoption gap among smallholders, clarifying institutional roles between public directorates and private consultants, and eliminating conflicts of interest associated with input-linked advisory practices. Equally critical is a cultural shift toward market-oriented farming, where consultancy is perceived not as a subsidized add-on but as a strategic investment in competitiveness and resilience.

If supported by digitalization, rural finance integration, and performance-based accountability, the consultancy framework can evolve into a cornerstone of Türkiye's agricultural modernization. Its success will ultimately depend on aligning policy design, institutional clarity, and farmer engagement within a coherent, market-driven development strategy.

**References:**TEPGE; Gülçubuk et al; Ministry of Agriculture and Forestry; Özkan & Yılmaz.

*Please note that the views expressed in this article are of the author and do not necessarily reflect the views or policies of any organization.*

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## Resilient Agriculture in Thar Desert, Pakistan

Explore the agriculture in Thar Desert of Pakistan, particularly in Tharparkar District. Discover how rain-fed farming and localized irrigation systems foster resilience and enhance livelihoods in arid environments.

Nazar Gul, Muhammad Ashraf & Hafiz Abdul Salam

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Since time immemorial, agricultural activity has formed the structural foundation of human settlement, food systems, and economic organization. In the Thar Desert of Pakistan, agriculture represents far more than a livelihood; it embodies a long-standing process of ecological adaptation under conditions of chronic water scarcity and climatic volatility. Covering roughly 19,000 square kilometers in the southeastern part of Sindh, Tharparkar District sustains a dense rural population that has historically survived through ingenuity, mobility, and diversified agro-pastoral strategies (Ahmed et al., 2021).

The region's farming systems are broadly divided into two distinct but interlinked models: rain-fed (*barani*) agriculture and irrigated agriculture. Rain-fed farming remains the dominant system, entirely dependent on the erratic monsoon. Farmers cultivate drought-tolerant crops such as millet, cluster bean, and pulses during favorable rainfall years. Production levels fluctuate sharply, reflecting high climatic risk, yet the system is characterized by low external input use, traditional seed varieties, and strong integration with livestock rearing. Herd mobility and communal grazing serve as built-in risk management mechanisms.

In contrast, irrigated agriculture, though limited in spatial coverage, relies on tube wells, dug wells, and localized water harvesting structures. This system allows for relatively stable production of wheat, vegetables, and fodder crops, but it faces growing constraints from groundwater depletion and rising pumping costs. While irrigated plots demonstrate higher productivity per hectare, they also entail higher financial and environmental costs.

Together, these dual systems provide valuable insights into climate-resilient agriculture. Tharparkar illustrates that

sustainability in arid environments depends not solely on technological intensification, but on balancing water efficiency, crop diversity, indigenous knowledge, and adaptive risk management in an era of accelerating climate change.

### Rain-Fed Agriculture: The Heart of the Thar

Rain-fed agriculture, locally known as *pahari* cultivation, constitutes the dominant farming system across the vast landscape of the Thar Desert in Pakistan. Except for the Karoonjhar Hills near Nagarparkar, where localized geological conditions slightly modify land use patterns, cultivation across Tharparkar District depends almost entirely on the erratic summer monsoon occurring between June and September (Hassan et al., 2022). In this hyper-arid ecology, rainfall variability is the single most decisive production factor, shaping cropping intensity, yield stability, and household food security.

The farming calendar reflects a highly refined system of ecological risk management. Prior to the anticipated monsoon, farmers clear herbaceous weeds and residual stubble to reduce evapotranspiration losses and competition for soil moisture. Fallow lands are plowed using a cultivator to uproot perennial grasses and create a rough soil surface that enhances in-situ rainwater harvesting. This micro-topographical roughness increases infiltration and reduces runoff, an essential adaptation in sandy soils with limited water-holding capacity.

Sowing is triggered only when rainfall sufficiently moistens the soil profile to a depth of approximately 6–9 inches. Timing is critical: seeds are planted within two to three days to capitalize on stored moisture. The traditional camel-drawn *ard* plough, a single-coulter seed drill, remains the

principal sowing implement (Rao & Marwah, 2020). Despite its simplicity, it offers notable agro-ecological advantages. It operates without fossil fuel, thereby producing negligible greenhouse gas emissions. Capital costs are minimal, eliminating dependence on diesel and machinery maintenance. A single camel can sow nearly one and a half acres per day, making it operationally efficient at small scales. Importantly, the *ard* opens narrow furrows without inverting the soil, preserving soil structure, reducing moisture loss, and maintaining microbial integrity. Chemical fertilizers and synthetic pesticides are virtually absent, rendering production systems organically aligned by default.

The socio-economic framework underpinning rain-fed cultivation is the traditional sharecropping arrangement known as *bhagai*. Under this system, landowners supply land, seeds, and limited cash inputs, while tenant farmers contribute labor for land preparation, weeding, harvesting, threshing, and post-harvest processing. Output is divided according to pre-agreed shares. This arrangement distributes production risk in a highly uncertain climatic regime and provides landless households with access to livelihood opportunities (Shah & Qureshi, 2021).

Crop selection prioritizes drought tolerance and multi-functionality. Cluster bean (*guar*) serves as the primary cash crop; pearl millet (*bajra*) functions as both staple grain and fodder; pulses such as mungbean and black-eyed pea supplement dietary protein; sesame provides oil; and cucurbits including watermelon and melon are frequently intercropped to maximize land productivity. Yield data reveal a differentiated performance profile. *Guar* yields in Tharparkar match or exceed provincial averages, reflecting its

physiological suitability to arid conditions and strong market demand linked to industrial gum extraction (Mudgal et al., 2021). In contrast, pearl millet, mungbean, and sesame yields remain below national averages due to rainfall volatility and reliance on unimproved seed varieties (Mari et al., 2020).

### **Irrigated Agriculture: The Nagarparkar Oasis**

Within the predominantly arid landscape of the Thar Desert in Pakistan, the taluka of Nagarparkar represents a distinctive agro-ecological enclave. Situated near the Karoonjhar Hills and close to the Indian border, this pocket benefits from localized hydrological advantages that enable irrigated agriculture to complement the broader rain-fed system of Tharparkar District. Farmers draw water primarily from shallow aquifers accessed through dug wells and from small surface storage structures such as the Malji Dam, which captures runoff from the surrounding granitic hills during episodic rainfall events.

Given the extremely sandy and porous soil profile, conventional flood irrigation would result in substantial deep percolation losses. To mitigate this, farmers have developed an adaptive micro-plot irrigation strategy. Cultivated fields are divided into compact plots of roughly 25 square feet ( $5 \times 5$  ft). Each plot receives an initial heavy soaking dose to saturate the root zone, followed by light but frequent irrigation at intervals of four to seven days. This method reduces uncontrolled seepage, improves root-zone moisture control, and enhances water-use efficiency under scarcity conditions. It effectively represents a localized, low-technology analogue to precision irrigation systems.

Cropping patterns in Nagarparkar are more diversified and market-oriented than in the rain-fed areas. Major crops include wheat, rapeseed and mustard, onion, chilli, tomato, berseem (fodder), and lemon orchards. This diversification supports year-round income flows, stabilizes household consumption, and reduces vulnerability to single-crop failure.

Yield comparisons reveal differentiated performance outcomes. Wheat productivity in Nagarparkar exceeds the national average and closely approaches the provincial benchmark, demonstrating that assured irrigation can substantially elevate staple grain output (Shaheen et al., 2020). Chilli cultivation stands out as a comparative advantage: yields surpass both provincial and national averages, suggesting favorable microclimatic conditions and effective crop management. In contrast, onion, tomato, berseem, and especially lemon yields lag broader benchmarks. The relatively poor performance of lemon orchards may reflect groundwater salinity, suboptimal varietal selection, or limitations in orchard management practices (Memon et al., 2021).

### **Strategic Recommendations for Sustainable Agriculture in Tharparkar**

Strengthening agricultural sustainability and productivity in Tharparkar District within the Thar Desert of Pakistan requires an integrated, evidence-based intervention framework that addresses water scarcity, low input use, and market constraints.

First, rainwater harvesting must be systematically expanded. Investment in low-cost, on-farm moisture conservation practices such as contour ploughing, micro-catchments, and vegetative bunding can significantly enhance in-situ water retention. Complementary construction of small check dams, recharge ponds, and percolation tanks would improve groundwater replenishment and provide supplemental irrigation during dry spells (Hassan et al., 2022).

Second, collaboration with national and provincial agricultural research institutions is essential to introduce certified, drought-tolerant, and higher-yielding varieties of pearl millet, mungbean, and sesame. Varietal improvement tailored to local soil and rainfall regimes can narrow yield gaps while preserving resilience.

Third, irrigation efficiency in localized irrigated zones such as Nagarparkar should be upgraded through the promotion of low-cost, solar-powered drip irrigation systems. Replacing traditional micro-plot flooding

with controlled drip applications would reduce conveyance losses, lower pumping costs, and potentially increase yields for high-value crops, particularly chillies and vegetables.

Fourth, institutional capacity building must be prioritized. Strengthened extension services through both government agencies and NGOs should deliver targeted training in improved agronomic practices, integrated pest management built upon the region's largely organic production base, and farm-level economic decision-making focused on water productivity.

Fifth, value chain development is critical. Establishing local facilities for grading, storage, and primary processing, especially for cluster bean (guar) and chillies, would reduce post-harvest losses and enable farmers to access premium and export markets (Mudgal et al., 2021).

Finally, targeted soil fertility mapping and groundwater quality assessments should guide crop planning in irrigated pockets. Integrating indigenous practices into provincial climate adaptation strategies, including community-based drought insurance mechanisms, will ensure that resilience-building efforts are both locally grounded and policy supported.

### **Conclusion**

Agriculture in the Thar Desert of Pakistan particularly within Tharparkar District demonstrates that resilience in arid environments is not accidental but systematically constructed through adaptive knowledge, resource efficiency, and socio-economic cooperation. The coexistence of rain-fed and localized irrigated systems illustrates a dynamic balance between ecological constraints and livelihood imperatives. Rain-fed farming, grounded in indigenous techniques and low external inputs, reflects a deeply embedded culture of risk management aligned with climatic uncertainty. Meanwhile, irrigated pockets such as Nagarparkar reveal how targeted water access, even at small scales, can significantly enhance productivity and diversify income sources.

However, escalating climate variability, groundwater stress, and market pressures

threaten this equilibrium. The sustainability of Tharparkar's agricultural systems will depend on integrating traditional knowledge with modern agronomic science, strengthening water governance, improving varietal resilience, and enhancing value chain participation. Policy support, institutional extension, and investment in decentralized water infrastructure are essential to prevent ecological degradation and economic marginalization.

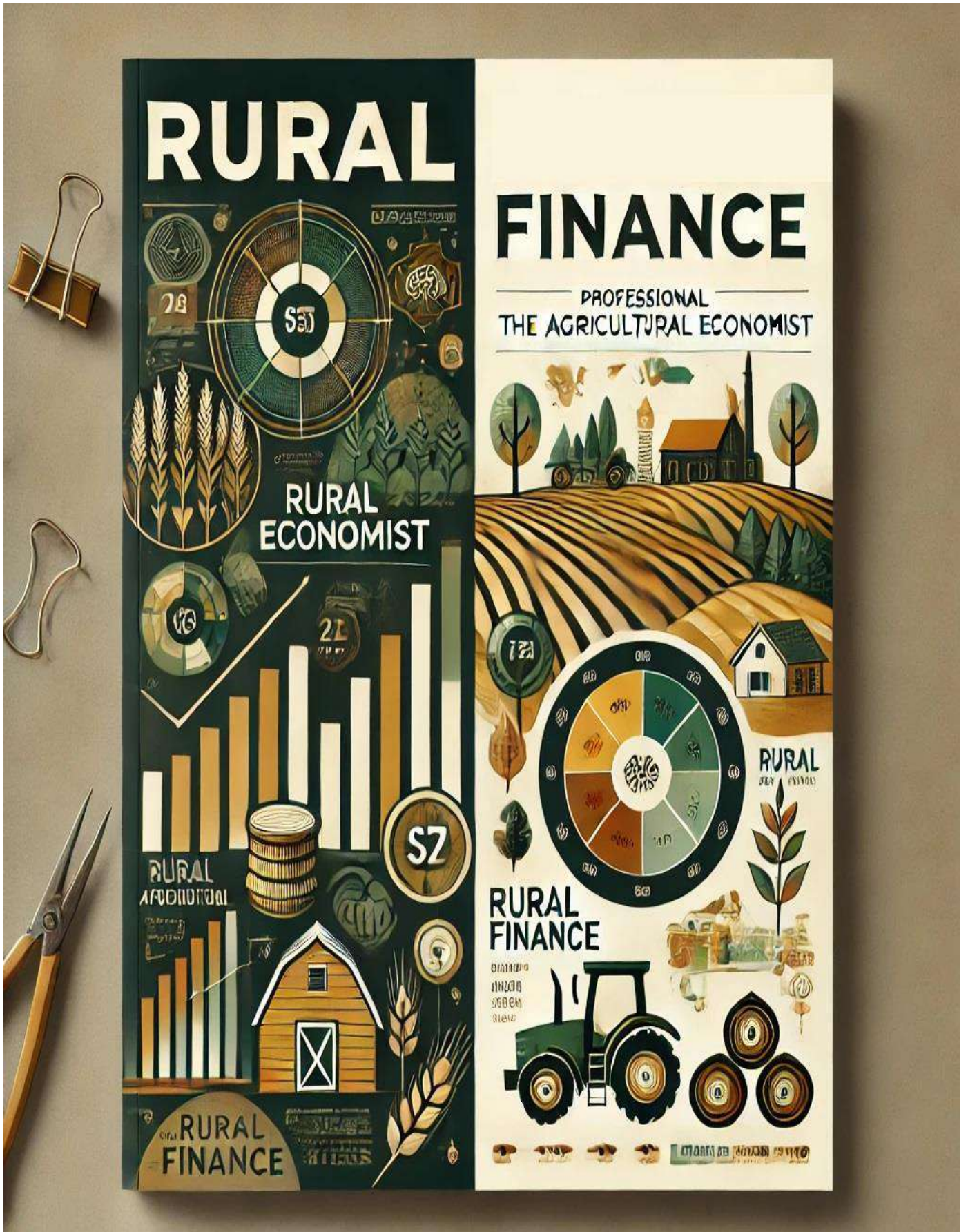
Ultimately, Tharparkar offers more than a case study of survival under scarcity; it provides a replicable framework for climate-resilient farming in drylands globally. Its experience underscores a central principle of sustainable development: productivity, equity, and environmental stewardship must advance together to secure long-term rural stability.

**References:** Ahmed et al; GoP; Hassan et al; Mari et al; Memon et al; Mudgal et al; Rao & Marwah; Shah & Qureshi; Shaheen et al; Toan et al.

*Please note that the views expressed in this article are of the author and do not necessarily reflect the views or policies of any organization.*

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## Pakistan's Budget Deficit: A Structural Challenge

Explore the complexities of Pakistan's budget deficit, highlighting its roots in fiscal imbalance and debt-driven financing. Understand the impacts on monetary policy, inflation, and social inequality.

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A budget deficit, defined as the excess of government expenditures over revenues within a fiscal year, is not inherently detrimental. In macroeconomic management, it can function as a counter-cyclical instrument, enabling public investment in infrastructure, human capital, and social protection, particularly during downturns or external shocks (IMF, 2023). When deployed within a credible medium-term fiscal framework, deficits can crowd in private investment and enhance long-run productive capacity. However, persistent and structurally embedded deficits, financed through excessive domestic borrowing or external debt accumulation, can generate inflationary pressures, currency depreciation, rising debt-servicing burdens, and diminished investor confidence. Pakistan exemplifies this fiscal paradox.

For several decades, Pakistan has faced a chronic structural imbalance rooted in a narrow tax base, low tax-to-GDP ratio, energy-sector subsidies, loss-making state-owned enterprises, and high defense and debt-servicing expenditures. Rather than being primarily cyclical, deficits have reflected entrenched revenue weaknesses and rigid expenditure commitments. During growth phases, fiscal expansion has often been pro-cyclical, amplifying macroeconomic overheating. Conversely, during downturns, revenue shortfalls and exchange rate pressures have widened deficits further, reinforcing vulnerability (Kemal, 2019).

Core economic institutions including the Ministry of Finance and the State Bank of Pakistan play pivotal roles in fiscal coordination and monetary stabilization. Repeated stabilization programs with the World Bank and the IMF have sought fiscal consolidation through tax reforms, subsidy rationalization, and structural

adjustments. Yet implementation has frequently been constrained by political economy dynamics, weak administrative capacity, and reform fatigue. The resulting “stop-go” cycle, periods of adjustment followed by slippages, has undermined policy credibility and perpetuated reliance on external financing, limiting Pakistan’s fiscal sovereignty and long-term development planning.

### Structural Determinants of Pakistan’s Persistent Budget Deficit

Pakistan’s chronic budget deficit is rooted in deep structural distortions rather than short-term cyclical imbalances. Foremost among these is persistently weak revenue mobilization. Pakistan’s tax-to-GDP ratio has hovered around 9–10 percent in FY2024, significantly below the Asia-Pacific developing economy average of approximately 15 percent (ADB, 2024). A narrow tax base, widespread informality, and heavy reliance on indirect taxation constrain revenue buoyancy. Only about 5.2 million individuals are active taxpayers in a population exceeding 240 million (FBR, 2024). The agricultural sector, contributing roughly one-fifth of GDP, remains lightly taxed due to constitutional divisions of power and entrenched political interests. Weak compliance enforcement, administrative inefficiencies, and pervasive tax evasion further erode fiscal capacity (Pasha, 2022).

On the expenditure side, fiscal rigidity compounds revenue weaknesses. Current expenditures dominate the budget, leaving limited room for development outlays. Large allocations to public sector wages and a structurally unsustainable pension regime impose recurring obligations. Untargeted subsidies particularly in energy and export sectors

continue to strain the exchequer (Ministry of Finance, 2024). Defense spending, shaped by regional security dynamics, claims a significant share of resources. Most critically, debt servicing has become the single largest expenditure component.

The debt overhang represents a self-reinforcing constraint. By FY2024, interest payments consumed over half of total federal revenues (Ministry of Finance, 2024). This creates a classic “snowball effect,” wherein borrowing to finance past deficits raises future interest obligations, perpetuating a cycle of fiscal stress (Khan, 2023). Pakistan’s exposure to domestic interest rate fluctuations and external financing conditions heightens vulnerability, as new borrowing increasingly finances debt rollover rather than productive capital formation.

The energy sector constitutes another structural fault line. High generation costs, transmission and distribution losses averaging 16–18 percent, and tariff distortions have generated persistent circular debt. By mid-2024, accumulated liabilities in the power sector exceeded Rs. 2.6 trillion (SBP, 2024). Government bailouts to stabilize state-owned energy enterprises directly inflate the fiscal deficit, crowding out social and infrastructure spending.

Political economy constraints further impede reform. Influential interest groups resist broadening the tax net or rationalizing subsidies (Ahmed & Mustafa, 2021). Short electoral cycles incentivize expansionary, populist fiscal measures while discouraging structural adjustments that yield benefits beyond a single term. Policy discontinuity and frequent government transitions undermine credibility and investor confidence.

Finally, structural external vulnerabilities exacerbate fiscal fragility. Pakistan’s

import-dependent economy is highly sensitive to commodity price shocks. Global energy and food price surges following the Russia-Ukraine conflict intensified subsidy burdens and widened the current account deficit (World Bank, 2023). Additionally, catastrophic climate events (most notably the 2022 floods causing over \$30 billion in damage) necessitated substantial unbudgeted expenditures (UNDP, 2022). Collectively, these structural weaknesses entrench fiscal imbalances, rendering deficit reduction contingent upon comprehensive and sustained institutional reform rather than temporary stabilization measures.

### **International Dimensions of Pakistan's Fiscal Imbalance**

Pakistan's persistent budget deficit carries substantial international implications, shaping its engagement with multilateral lenders, global capital markets, and currency dynamics. Foremost is its recurrent reliance on stabilization programs with the International Monetary Fund. In July 2023, Pakistan entered its 24th IMF-supported arrangement, underscoring a long-standing dependence on external balance-of-payments support. These programs typically require fiscal consolidation through enhanced revenue mobilization, rationalization of expenditures, energy tariff adjustments, and a market-determined exchange rate regime (IMF, 2024). While IMF financing provides critical liquidity and serves as a policy credibility anchor, often unlocking additional funding from bilateral and multilateral partners, it also entails austerity measures that can suppress short-term growth and provoke domestic political resistance. The cyclical pattern of program entry, partial compliance, and renewed distress has reinforced perceptions of structural fragility.

Chronic fiscal deficits and rising public debt also directly affect sovereign creditworthiness. International rating agencies such as Moody's, Fitch Ratings, and S&P Global Ratings evaluate Pakistan's repayment capacity based on fiscal sustainability metrics, external

buffers, and political risk. Pakistan's ratings have frequently remained near speculative or "junk" status, elevating sovereign risk premiums. Consequently, access to international bond markets becomes constrained and borrowing costs escalate. This creates an adverse feedback loop: deficits necessitate external borrowing, yet deteriorating credit metrics make such borrowing increasingly expensive and limited, discouraging foreign direct investment and portfolio inflows (Fitch Ratings, 2024).

Large fiscal imbalances further contribute to exchange rate vulnerability. Heavy reliance on external financing increases foreign currency liabilities and heightens rollover risk. When investor confidence weakens due to concerns over debt sustainability, capital outflows intensify, placing downward pressure on the Pakistani rupee (SBP, 2024). Currency depreciation inflates the domestic cost of servicing external debt and raises import prices, particularly for energy and essential commodities, thereby exacerbating inflationary pressures and widening subsidy burdens. Thus, Pakistan's fiscal deficit is not merely a domestic accounting imbalance but a structural determinant of its international economic standing.

### **Macroeconomic and Social Consequences of Persistent Fiscal Deficits**

Pakistan's sustained fiscal imbalances have generated profound macroeconomic distortions and adverse social outcomes. One of the most immediate macroeconomic consequences is inflationary pressure. When fiscal deficits are monetized, effectively financed through central bank liquidity creation, they expand the monetary base and intensify demand-side inflation. Although the State Bank of Pakistan has strengthened its institutional autonomy and adopted inflation-targeting frameworks, historical episodes of fiscal dominance have constrained its capacity to maintain price stability (SBP, 2023). Inflation averaged above 29 percent in FY2023, severely eroding purchasing

power, compressing real wages, and disproportionately harming fixed-income households. High inflation volatility also heightens uncertainty, raises risk premiums, and discourages long-term private investment.

A second critical channel is the crowding-out effect. Heavy government borrowing from domestic commercial banks absorbs a significant share of available loanable funds. In FY2024, public sector borrowing remained elevated, limiting credit allocation to private enterprises (SBP, 2024). This distortion reduces capital formation in productive sectors, suppresses entrepreneurship, and weakens employment generation. Over time, diminished private investment undermines total factor productivity and constrains potential GDP growth.

Persistent deficits also compress development expenditure. As debt servicing and recurrent expenditures consume a growing share of revenues, allocations to the Public Sector Development Program decline. In FY2024, development spending constituted less than 15 percent of total expenditure (Ministry of Finance, 2024). Chronic underinvestment in infrastructure, education, and healthcare impairs human capital accumulation and long-run competitiveness. In essence, current consumption is financed at the expense of future prosperity.

The social ramifications are equally severe. Regressive taxation structures and inflation disproportionately burden lower-income households, widening inequality. Underfunded public services weaken social mobility and perpetuate intergenerational poverty. Moreover, constrained investment in labor-intensive and high-growth sectors contributes to elevated youth unemployment in a demographically young society. Prolonged economic stress can exacerbate social tensions and erode institutional trust, reinforcing a cycle of fiscal fragility and governance challenges.

### **Pathways Toward Sustainable Fiscal Consolidation**

Achieving fiscal sustainability in Pakistan necessitates a coherent medium-term adjustment strategy anchored in structural reform rather than episodic stabilization. Central to this effort is broadening the tax base. Comprehensive reforms must prioritize documentation of the informal economy, integration of retail and agricultural income into the tax net, rationalization of exemptions, and simplification of compliance procedures. Leveraging digitalization such as data integration, e-invoicing, and risk-based audits can strengthen enforcement and reduce evasion (FBR, 2024). A shift toward progressive direct taxation would enhance equity while improving revenue buoyancy.

Expenditure rationalization is equally critical. Untargeted subsidies, particularly in energy and commodity markets, should transition toward targeted, means-tested cash transfers. Programs such as the Benazir Income Support Program demonstrate how social protection can be preserved while reducing fiscal leakages. Simultaneously, reforming and restructuring loss-making state-owned enterprises is essential to halt recurrent quasi-fiscal losses (Ministry of Finance, 2024). Transparent governance frameworks, professional management, and selective privatization can alleviate long-term fiscal pressures.

Institutional strengthening underpins all reforms. Enhancing public financial management systems, digitizing

expenditure tracking, and reinforcing anti-corruption oversight mechanisms would improve allocative efficiency and restore investor confidence. Finally, durable fiscal consolidation depends on sustained growth. A strategy focused on export diversification, productivity enhancement, and foreign direct investment, supported by structural reforms and regional trade integration, can expand the revenue base and foreign exchange earnings (ADB, 2024). Fiscal sustainability, therefore, requires synchronized reforms across revenue mobilization, expenditure discipline, governance, and growth strategy.

### Conclusion

Pakistan's budget deficit is not merely a recurring fiscal imbalance but a manifestation of deep structural weaknesses embedded in the country's political economy and institutional architecture. While deficits can serve as legitimate macroeconomic tools when strategically deployed, Pakistan's experience demonstrates the risks of persistent, debt-driven financing unsupported by adequate revenue mobilization and expenditure discipline. A narrow tax base, rigid current expenditures, mounting debt-servicing obligations, energy-sector inefficiencies, and vulnerability to external shocks have collectively entrenched fiscal fragility. The consequences extend beyond accounting metrics, distorting monetary policy, fueling inflation, crowding out

private investment, compressing development spending, and exacerbating inequality and social vulnerability.

Repeated stabilization efforts have provided temporary relief but have not fundamentally altered the structural drivers of the deficit. Sustainable fiscal consolidation will require political commitment to broaden the tax net, rationalize subsidies, reform state-owned enterprises, strengthen governance, and foster export-led growth. Without such coordinated reforms, Pakistan risks remaining trapped in a cycle of borrowing, adjustment, and renewed crisis. Conversely, decisive structural transformation can convert fiscal policy from a source of instability into a foundation for inclusive growth and long-term economic resilience.

**References:** Ahmed, & Mustafa; ADB; FBR; Fitch Ratings; Husain; IMF; Kemal; Khan; Ministry of Finance; Pasha; SBP; UNDP; World Bank.

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## Bridging the Preparedness Financing Gap

Explore the critical systemic vulnerabilities in global economic priorities highlighted by the COVID-19 crisis. Learn how inadequate preparedness financing affects frontline readiness in vulnerable nations and the need for integrated funding solutions.

Maleeha Imran

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In an era of unprecedented mobility and accelerating climate change, the distance between a remote outbreak and a global crisis has collapsed. A pathogen can move from an isolated village to a densely populated international hub within hours. Yet the decisive battleground is rarely in the advanced laboratories of high-income countries; it lies within the overstretched primary health facilities, laboratories, and disease surveillance units of low-resource settings. Financing epidemic preparedness and response in these environments remains one of the most urgent and persistently underfunded global health priorities of the 21st century. From recurrent Ebola outbreaks in Central Africa to the slow-burning pandemic of antimicrobial resistance, national capacity to prevent, detect, and respond to infectious threats is fundamentally shaped by the reliability and adequacy of domestic and external health financing.

Epidemics are opportunistic. They exploit weak governance, fragmented surveillance systems, inadequate laboratory networks, and shortages of trained personnel. Where reporting systems are paper-based, diagnostic turnaround times are slow, and supply chains are unreliable, outbreaks gain critical momentum before containment measures can be deployed. Climate change compounds these vulnerabilities by expanding vector habitats, altering rainfall patterns, and intensifying zoonotic spillover risks. In such contexts, epidemic control is not merely a biomedical challenge; it is a financing and systems challenge.

Investment in preparedness functions as a global firewall. Strengthened surveillance, community health worker networks, laboratory capacity, emergency stockpiles, and rapid response teams

generate collective security benefits that extend far beyond national borders. However, preparedness suffers from a political economy dilemma: its returns are largely invisible when successful. Governments often prioritize immediate service delivery over contingent threats, while international donors shift attention once crises fade. The central question remains unresolved: who finances prevention for outbreaks that may never materialize? Sustainable, pooled, and predictable funding mechanisms are indispensable if global health security is to move from reactive crisis management to proactive risk mitigation.

### The Economic Imperative for Financing Epidemic Preparedness

The economic rationale for investing in epidemic preparedness is unequivocal: prevention yields exponentially higher returns than crisis response. A 2022 joint assessment by the World Bank and the World Health Organization's Global Preparedness Monitoring Board estimated that strengthening global health systems to pandemic-ready levels would require approximately \$10–15 billion annually. While substantial, this investment is negligible compared to the estimated \$13.6 trillion in global output losses attributed to COVID-19 through 2024, according to the International Monetary Fund. The cost-benefit calculus is stark: modest, sustained spending today averts catastrophic fiscal and human losses tomorrow.

Targeted investments in routine immunization, laboratory networks, genomic surveillance, and community health worker programs significantly reduce outbreak amplification. Evidence from countries such as Bangladesh and Ethiopia shows that integrated cholera vaccination campaigns combined with

water, sanitation, and hygiene (WASH) interventions, supported by Gavi, the Vaccine Alliance, can cut case incidence by more than 60% in high-risk districts. These are not abstract gains; they translate into preserved productivity, reduced healthcare expenditure, and macroeconomic stability.

Yet financing remains fragmented and politically fragile. Domestic health budgets in low-income countries average just \$39 per capita annually, according to the WHO's Global Health Expenditure Database, severely constraining long-term preparedness investments. Although commitments such as the African Union's Abuja Declaration set a 15% budget allocation target for health, compliance remains limited due to fiscal pressures and competing development priorities.

International funding, meanwhile, follows a recurrent "panic-then-neglect" cycle. During the 2014–2016 Ebola crisis, emergency financing surged, only to contract sharply afterward. Major institutions including The Global Fund to Fight AIDS, Tuberculosis and Malaria and the World Bank play essential roles, but funding is often vertically structured around specific diseases. While effective for targeted control, such models may underinvest in broad surveillance and workforce systems required to detect emerging pathogens.

The creation of the Pandemic Fund in 2022 marks a strategic shift toward sustained preparedness financing. However, its long-term viability depends on predictable replenishment commitments from donor economies. Without durable financing architecture, global health security will remain reactive rather than preventive.

### **Persistent Barriers to Effective Epidemic Financing**

Despite the proliferation of global financing instruments, substantial structural barriers continue to undermine the effectiveness of epidemic preparedness funding. A central challenge remains the predominance of reactive expenditure. Financial mobilization often accelerates only after a crisis escalates to the level of a Public Health Emergency of International Concern (PHEIC), as declared by the World Health Organization. By that stage, transmission chains are already established, response costs have multiplied, and economic disruption is underway. Delayed disbursement transforms what could have been a contained outbreak into a high-cost humanitarian and fiscal emergency.

Governance and absorption capacity constraints further complicate financing effectiveness. In several low-resource settings, weak public financial management systems, procurement bottlenecks, and limited administrative expertise delay the translation of pledged funds into operational capacity. Even when allocations are secured from institutions such as the World Bank or other multilateral donors, ministries of health may struggle to comply with complex reporting requirements, safeguard standards, and grant management procedures. As a result, funds remain underutilized or are reprogrammed, weakening frontline preparedness.

A third structural barrier is the incomplete integration of climate adaptation and epidemic preparedness financing. Climate change is amplifying zoonotic spillover risks, expanding vector habitats, and intensifying internal displacement. The World Bank projects that by 2050, climate impacts could displace 216 million people within their own countries, increasing population density and sanitation stress in vulnerable regions. Yet financing frameworks often treat climate resilience and health security as parallel agendas rather than interconnected priorities. Without integrated investment strategies, funding gaps will persist precisely where

epidemiological risk is accelerating most rapidly.

### **A Path Forward: From Panic to Prevention**

The COVID-19 pandemic exposed the structural fragility of global health security and reinforced a central truth: preparedness cannot be improvised during crisis. As emphasized by Tedros Adhanom Ghebreyesus of the World Health Organization, the next pandemic is inevitable; vulnerability is not. Transitioning from reactive panic to preventive investment requires a systemic recalibration of financing priorities.

First, domestic resource mobilization must expand. Governments in low- and middle-income countries can strengthen fiscal space through targeted excise taxes on tobacco, alcohol, and sugar-sweetened beverages. Countries such as the Philippines and Thailand have demonstrated that well-designed “sin taxes” simultaneously reduce non-communicable disease burdens and generate predictable revenue streams earmarked for health system strengthening. Such mechanisms create sustainable funding bases less dependent on volatile donor cycles.

Second, international partners must prioritize flexible, multi-year financing over short-term, disease-specific grants. Instruments such as the Pandemic Fund represent a structural improvement yet require consistent replenishment and political commitment. Funding architecture should increasingly center on strengthening Primary Health Care (PHC) systems such as surveillance networks, laboratory platforms, workforce training, and community engagement rather than narrow vertical interventions. Robust PHC systems serve as early warning mechanisms capable of detecting both known and novel pathogens.

Third, multilateral development banks must embed health risk assessments into infrastructure, water, sanitation, urban planning, and climate adaptation investments. Epidemic resilience is inseparable from resilient infrastructure and environmental management.

Ultimately, epidemic financing constitutes global public good. Investment in vulnerable health systems is not charity; it is collective risk mitigation. Paying for prevention today remains the most economically rational and ethically responsible strategy to avert the far greater cost of crisis tomorrow.

### **Conclusion**

The widening epidemic financing gap is not a technical oversight; it is a systemic vulnerability embedded within global economic and political priorities. As the COVID-19 crisis demonstrated, pathogens exploit fiscal hesitation as effectively as biological susceptibility. While institutions such as the World Health Organization, the World Bank, and the Pandemic Fund have advanced the architecture of preparedness financing, the scale, predictability, and integration of funding remain insufficient. The economic case is unequivocal: annual preparedness investments measured in billions prevent losses measured in trillions. Yet fragmented governance, reactive disbursement patterns, climate-blind financing structures, and limited domestic fiscal space continue to constrain frontline readiness in the world’s most vulnerable nations.

Closing this gap requires a paradigm shift from crisis-driven mobilization to institutionalized prevention. Sustainable domestic revenue strategies, flexible multi-year donor commitments, and integrated development financing that embeds health resilience into infrastructure, water, and climate adaptation planning are essential. Epidemic preparedness must be treated not as discretionary health spending, but as macroeconomic risk insurance and a global public good. The cost of prevention is visible and budgeted; the cost of panic is exponential and destabilizing. The policy choice is therefore not whether to invest, but whether to invest proactively or pay reactively. History suggests the next outbreak is inevitable. Financial foresight will determine whether it becomes a contained event or another global catastrophe.

**References:** Gavi; Moon et al; Pandemic Fund; World Bank; WHO.

*Please note that the views expressed in this article are of the author and do not*

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## Agricultural Import Dependence: A Macro Vulnerability

Explore how agricultural import dependence creates macroeconomic vulnerabilities and affects external debt sustainability. Discover the impact of food import shocks on low- and middle-income economies, including inflationary pressures and fiscal stress.

Hafiza Minahil Imran

2/24/2026

The relationship between agricultural imports and external debt sustainability has emerged as a structural macroeconomic concern for developing economies. As global food systems confront intensifying pressures from climate variability, supply chain disruptions, and geopolitical conflict, countries with high food import dependence face amplified balance-of-payments risks. For many low- and middle-income countries (LMICs), food imports constitute a large share of total merchandise imports, making them particularly vulnerable to commodity price spikes and currency depreciation. This review synthesizes theoretical and empirical literature to examine how agricultural import dependence affects debt accumulation, foreign exchange adequacy, and broader macroeconomic stability.

The analytical foundation rests on the two-gap model developed by Chenery and Strout (1966), which posits that developing economies face binding savings and foreign exchange constraints. When domestic savings are insufficient to finance investment (the savings gap), or when export revenues cannot cover required imports (the foreign exchange gap), external borrowing becomes the adjustment mechanism. In food-import-dependent economies, sudden increases in global grain or edible oil prices widen the foreign exchange gap, forcing governments to draw down reserves or accumulate external debt to maintain food security and political stability.

The debt overhang hypothesis (Krugman, 1988; Sachs, 1989) further explains how excessive external borrowing can suppress long-term growth. When debt stocks exceed sustainable thresholds, anticipated servicing obligations deter private investment and constrain fiscal

policy. Empirical evidence from Checherita-Westphal and Rother (2012) suggests that debt-to-GDP ratios above 70–90% impair growth in advanced economies, while emerging markets often face lower tolerance thresholds due to weaker institutions and higher risk premiums.

Recent scholarship applies Dynamic Stochastic General Equilibrium (DSGE) models and panel econometric approaches including Autoregressive Distributed Lag (ARDL) and cointegration techniques to quantify how food price shocks transmit through exchange rates, inflation, fiscal balances, and sovereign risk indicators. The evidence increasingly indicates that chronic agricultural import dependence can transform temporary trade shocks into persistent debt vulnerabilities, particularly where export diversification and reserve buffers are limited.

### Global Trends and Empirical Evidence

The acceleration of agricultural import dependence has become a defining structural feature of many low- and middle-income economies. According to the Food and Agriculture Organization (FAO), food import bills for low-income food-deficit countries reached approximately \$58 billion in 2024 representing a 28% increase compared to 2020 levels. Countries such as Eritrea and Haiti now allocate more than 40% of their merchandise export earnings to food imports. This structural imbalance is driven by stagnant agricultural productivity, climate-induced production volatility, rapid urbanization, and dietary transitions toward import-intensive staples such as wheat and edible oils.

Empirical literature reinforces the macroeconomic implications of this dependence. Mwangi et al. (2020)

demonstrate that in Sub-Saharan Africa, a 10% increase in agricultural import volumes is associated with a 3.2% rise in external debt-to-GDP ratios over a five-year horizon. Similarly, Bakari and Tiba (2022) identify a parallel dynamic in China, where agricultural imports contribute to domestic consumption smoothing and growth but increase external liabilities when not offset by export expansion.

The foreign exchange dimension intensifies these vulnerabilities. Between 2021 and 2023, the US dollar appreciated roughly 18%, amplifying import costs for countries with depreciating currencies. Egypt, the world's largest wheat importer, experienced an estimated \$3 billion surge in its wheat import bill in 2022 due to elevated global prices and exchange rate depreciation (CAPMAS, 2023). This "double burden" of high international prices and currency weakness has significantly eroded reserve buffers.

Macroeconomic spillovers are substantial. Research by Falana et al. (2024) in Nigeria indicates that a 10% currency depreciation translates into a 4.2% increase in domestic food prices within three months. Elevated food inflation often compels central banks to tighten monetary policy, raising interest rates and debt servicing costs thereby reinforcing a cycle of fiscal stress and rising sovereign risk.

### Regional Case Studies

Country-level evidence illustrates how agricultural import dependence interacts with debt structures, exchange rate regimes, and fiscal capacity to shape macroeconomic vulnerability.

In Pakistan, the food import bill reached \$8.3 billion in FY2024, dominated by edible oils (\$4.5 billion) and wheat (\$1.2

billion), according to the Pakistan Bureau of Statistics. By 2025, external debt had climbed to approximately \$130 billion, about 33.8% of GDP, with 58% denominated in US dollars. This currency composition exposes the country to significant exchange rate risk. The International Monetary Fund's 2025 Debt Sustainability Analysis highlights acute sensitivity to depreciation shocks, estimating that exchange rate movements could raise the debt-to-GDP ratio by 5–7 percentage points, particularly during food price surges.

In Ghana, external debt reached 59.3% of GDP in 2022, while debt servicing absorbed over half of government revenues, as reported by the Bank of Ghana. Although earlier borrowing supported agricultural modernization, rising servicing costs have increasingly crowded out capital expenditure in the sector. Empirical work by Sogah et al. (2024) and Appiah Agyei Sylvester (2019) confirms a positive association between imports, inflation, GDP growth, and external debt accumulation.

In Nigeria, exchange rate liberalization in 2023 triggered sharp depreciation, pushing food inflation above 40% in 2024 according to the National Bureau of Statistics. Imported food items exhibit markedly higher exchange rate pass-through than domestically produced goods, intensifying inflationary pressures.

Similarly, Egypt saw its debt-to-GDP ratio rise from 32% in 2020 to 37.5% in 2023 amid global food price shocks. In Argentina, a severe 2022–2023 drought cut agricultural exports by an estimated \$20 billion, eroding reserves and deepening debt stress in an economy heavily exposed to foreign currency liabilities.

### **The Role of Agricultural Finance and Policy**

Agricultural finance and policy architecture play a decisive role in shaping a country's capacity to reduce structural food import dependence and enhance macroeconomic resilience. Access to affordable agricultural credit remains a foundational constraint. Khan

et al. (2024) identify high interest rates, stringent collateral requirements, limited financial literacy, and complex application procedures as persistent barriers to smallholder farmers across 31 developing economies. These constraints suppress on-farm investment in productivity-enhancing inputs such as certified seeds, mechanization, and irrigation technologies. The Asian Development Bank (2025) underscores the transformative potential of digital financial services, noting that mobile-based credit platforms in pilot districts in India increased crop yields by 15–20%. By lowering transaction costs and improving credit scoring through alternative data, fintech solutions can expand inclusion while mitigating default risk.

Public investment is equally pivotal. The African Union's Maputo Declaration sets a benchmark of allocating 10% of national budgets to agriculture; however, most member states remain below this threshold (AU, 2023). Chronic underinvestment in irrigation infrastructure, agricultural research and development, rural roads, and storage facilities perpetuates low productivity and post-harvest losses, thereby reinforcing import reliance. Empirical evidence consistently links sustained public capital formation in agriculture to long-term gains in food self-sufficiency and export competitiveness.

Trade policy interventions alone are insufficient. Nugroho et al. (2021) finds that import duties exert limited influence on agricultural value added in developing countries, largely because staple foods are frequently exempt to protect consumers. Strategic import substitution such as oilseed development initiatives in Pakistan can reduce external vulnerability, but success depends on coherent policy sequencing, private sector incentives, and stable macroeconomic conditions.

### **Conclusion**

Agricultural import dependence is not merely a trade phenomenon but a structural macroeconomic vulnerability with direct implications for external debt sustainability.

Drawing on the two-gap framework and debt overhang theory, the evidence shows how food import shocks widen foreign exchange gaps, accelerate external borrowing, and elevate sovereign risk particularly in low- and middle-income economies with limited export diversification and shallow reserve buffers. Empirical findings from Africa, South Asia, and Latin America consistently confirm that exchange rate depreciation, global food price spikes, and high import intensity interact to amplify inflationary pressures and fiscal stress.

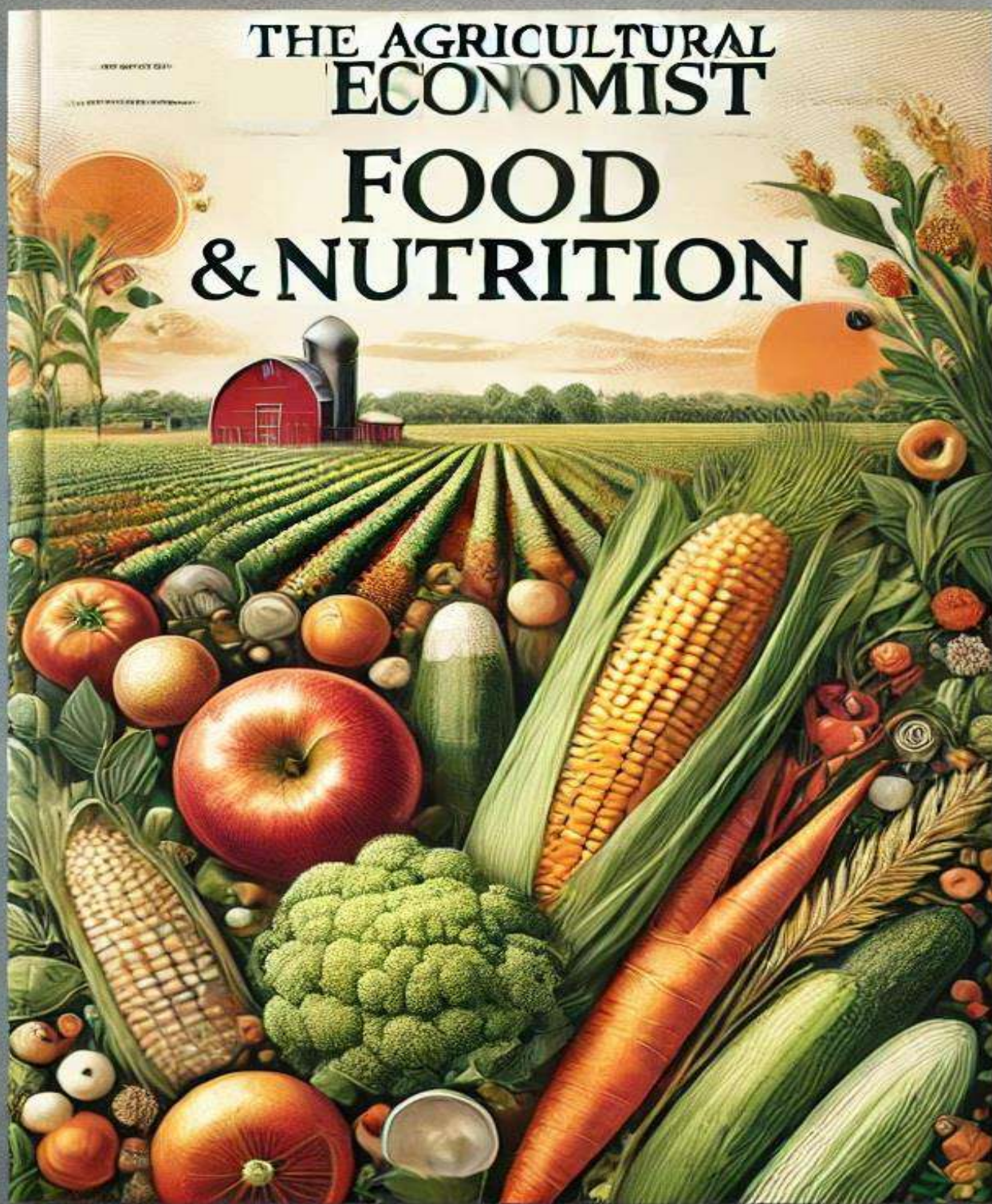
Country experiences including Pakistan, Ghana, Nigeria, Egypt, and Argentina illustrate how currency composition of debt, weak agricultural productivity, and constrained fiscal space convert temporary commodity shocks into persistent debt overhang risks. The transmission mechanisms are clear: higher import bills deplete reserves, depreciation fuels food inflation, monetary tightening raises debt servicing costs, and public investment is crowded out thereby reinforcing structural dependence.

Policy responses must therefore extend beyond short-term trade management. Expanding agricultural credit access, strengthening digital finance, meeting public investment benchmarks, and promoting productivity-enhancing innovation are central to reducing import reliance. Sustainable debt trajectories ultimately require coordinated macroeconomic stabilization, agricultural transformation, and export diversification. Without such structural reforms, food import dependence will remain a recurrent driver of external debt fragility.

**References:** Sylvester; Asian Development Bank; Bakari & Tiba; Checherita-Westphal & Rother; Chenery & Strout; Falana et al; FAO; IMF; Khan et al; Mwangi et al; Nugroho et al; Sogah et al; World Bank.

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## Thar Desert Climate Change: Evidence of Extremes

A data-driven synthesis of long-term meteorological evidence (2004–2020) from the Thar Desert, Pakistan, highlighting rising temperatures, extreme rainfall variability, high evapotranspiration, and their implications for climate resilience, food security, and rural livelihoods.

Nazar Gul, Muhammad Ashraf & Hafiz Abdul Salam

2/20/2026

The Thar Desert, extending into Pakistan's Sindh province, represents one of the most densely populated arid zones in South Asia. Unlike many desert ecosystems characterized by sparse human settlement, Thar supports a substantial rural population reliant on rain-fed agriculture and livestock rearing. This demographic pressure intensifies competition over already limited water, pasture, and arable land resources (Meghwar et al., 2020). Climatically, the region is defined by high interannually variability, erratic monsoon rainfall, prolonged dry spells, and extreme temperature regimes.

Historical assessments indicate that during the twentieth century, mean temperatures in the region increased by approximately 1.0 to 2.5 °C, accompanied by a decline in average precipitation of 5–12 mm and humidity fluctuations ranging from 5–25 percent (Meghwar et al., 2020). These climatic shifts have heightened the frequency and severity of drought episodes, accelerated evapotranspiration rates, and reduced soil moisture retention, thereby undermining agricultural productivity and groundwater recharge. The combined effects exacerbate food insecurity, malnutrition, and forced seasonal migration.

This article draws upon a 17-year meteorological dataset (2004–2020) obtained from the Pakistan Meteorological Department Mithi station to provide an updated empirical analysis of local climatic trends. By examining temperature patterns, rainfall variability, and humidity dynamics, the dataset offers granular insight into evolving microclimatic conditions within Thar. Establishing this evidence-based baseline is critical for informing adaptive water management strategies, climate-resilient agricultural planning,

and policy interventions aimed at mitigating environmental stress in one of Pakistan's most climate-sensitive regions. All statistical observations and trend analyses referenced herein are derived directly from this PMD dataset unless otherwise noted.

### Integrated Analysis of Climatic Extremes and Hydro-Meteorological Stress

This section presents a comprehensive assessment of key climatic variables derived from the 2004–2020 dataset recorded at the Mithi station in the Thar Desert, located in Sindh, Pakistan. The analysis reveals a climate system characterized by extreme thermal variability, erratic rainfall, fluctuating humidity, strong seasonal winds, and exceptionally high atmospheric water demand collectively reinforcing the region's structural vulnerability.

Maximum temperature dynamics confirm intense and persistent heat stress. Average annual maximum temperatures ranged between 34.6 °C and 36.9 °C, over the study period. The seasonal cycle is sharply defined: mean monthly maxima increase from 27.3 °C in January to a peak of 41.7 °C in May before gradually declining toward 29.1 °C in December. However, beyond seasonal regularity, recent years show amplification of extremes. Notably, May 2018 recorded 44.1 °C, June 2019 reached 43.0 °C, and May 2020 again touched 43.0 °C. These elevated peaks align with broader warming patterns documented by the Intergovernmental Panel on Climate Change (2021), which highlight increasing frequency and intensity of heatwaves globally. For Tharparkar's agro-pastoral systems, such extremes intensify evapotranspiration, accelerate soil moisture depletion, reduce crop

viability, and increase heat-related morbidity.

Minimum temperature patterns reveal equally significant variability. Annually minimum temperatures range from 17.5 °C to 19.9 °C. Winter months can be particularly cold, with January and December averages of 6.2 °C and 7.3 °C respectively. Extreme cold anomalies occurred in January 2007 and January 2014, with monthly averages dropping to between 2.9 °C and 4.5 °C. Conversely, summer nights provide limited thermal relief; June averages reach 27.1 °C. The coexistence of scorching daytime temperatures and warm nocturnal conditions during summer compounds cumulative heat stress, while cold winter nights affect livestock survival and crop germination. This broad diurnal and seasonal thermal amplitude test the adaptive thresholds of both ecosystems and human communities.

Relative humidity exhibits pronounced seasonal oscillation. Mean annual humidity ranged between 51% and 58%. The driest pre-monsoon months (March–April) recorded averages near 44%, intensifying aridity and dust generation. With monsoon onset, humidity rises sharply, peaking at 71% in August and 67% in September. Exceptional values were observed in August 2006 (78%) and September 2011 (81%). These rapid transitions from extreme dryness to high humidity alter perceived heat stress, influence vector ecology, and increase crop disease susceptibility.

Rainfall remains the most critical determinant of livelihood security. The 17-year mean annual rainfall was 376.1 mm, with nearly 90% concentrated in June–September. August is typically the wettest month (146.2 mm average). However, interannual variability is

extreme: totals ranged from only 61 mm in 2018 to 1361.3 mm in 2011. Severe drought years, 2013 (191 mm), 2014 (208 mm), and especially 2018 (61 mm), demonstrate the volatility of monsoon dependence. Conversely, excessive rainfall generates flooding and infrastructure stress. This high variability, repeatedly highlighted by the Pakistan Meteorological Department, translates directly into food insecurity, livestock mortality, and groundwater instability.

Wind speed patterns further intensify environmental stress. Mean annual wind speed ranged between 4.8 and 7.3 knots, with the pre-monsoon and early monsoon period (May–July) being the windiest (9.5–10.3 knots). Extreme monthly values such as 16.7 knots in May 2008 reflect strong dust-raising winds that exacerbate soil erosion and increase evapotranspiration losses.

Finally, reference evapotranspiration (ET<sub>o</sub>), estimated via the MODIS MOD16 Penman–Monteith framework, ranged from 2336 mm to 2665 mm annually (2015–2020). This is approximately six to seven times the mean annual rainfall, underscoring a chronic hydrological deficit. Atmospheric water demand vastly exceeds precipitation supply, particularly in Dahli Taluka where ET<sub>o</sub> is highest. Even minor rainfall variability thus produces outsized ecological and economic impacts.

Collectively, the data confirm that Tharparkar's climate system is defined not merely by aridity, but by volatility, thermal intensification, and a structural imbalance between water supply and atmospheric demand, conditions that necessitate urgent climate-resilient planning and adaptive resource management.

### Escalating Climate Extremes and Socioeconomic Vulnerability

The long-term climatic record (2004–2020) for the Thar Desert in Pakistan presents compelling empirical evidence of a progressively harsher and more volatile environment. The data confirms a regime defined by four interlinked

stressors. First, intensifying heat is evident in rising maximum temperatures and recurrent severe heatwaves, consistent with projections of the Intergovernmental Panel on Climate Change (2021). Summer peaks exceeding historical norms are no longer anomalies but recurring features, increasing thermal stress on crops, livestock, and human health.

Second, rainfall variability remains extreme. Although the mean annual rainfall appears moderate, the distribution is highly erratic. The catastrophic floods of 2011 contrast sharply with severe drought years such as 2013, 2014, and particularly 2018, when rainfall collapsed to critically low levels. Such oscillations validate findings by Usman and Nichol (2020) that drought frequency and intensity are increasing across arid Pakistan. For a region dependent on a short monsoon window, even minor rainfall deviations translate into disproportionate livelihood shocks.

Third, reference evapotranspiration (ET<sub>o</sub>) consistently exceeds rainfall by several multiples, generating a structural hydrological deficit. High pre-monsoon winds further accelerate soil moisture loss, intensifying water scarcity during critical cropping stages.

Finally, these stressors interact synergistically. Heat amplifies evaporation; drought reduces vegetative cover; wind accelerates land degradation. The cumulative outcome is declining soil fertility, reduced fodder availability, livestock mortality, and chronic food insecurity. In densely populated Tharparkar, climatic volatility directly converts into economic fragility and humanitarian risk.

Robust adaptation therefore demands evidence-based planning: drought-tolerant crop varieties, decentralized rainwater harvesting, strengthened early warning systems, and targeted social protection. As climate change accelerates, integrating long-term, ground-truthed climatic analysis into regional policy is not optional, it is indispensable for safeguarding livelihoods and ensuring ecological resilience.

### Conclusion

The synthesis of long-term meteorological evidence from the Thar Desert, based on 2004–2020 data from the Pakistan

Meteorological Department Mithi station, confirms that Tharparkar's climate is undergoing measurable intensification in extremes rather than gradual linear change. Rising maximum temperatures, pronounced diurnal variability, erratic monsoon rainfall, high wind speeds, and exceptionally elevated reference evapotranspiration collectively define a system under structural hydrological stress. With atmospheric water demand exceeding annual rainfall by multiple folds, the region remains in a chronic water deficit, where even minor rainfall shocks translate into disproportionate socioeconomic consequences.

The evidence demonstrates that climatic volatility is directly linked to declining agricultural productivity, livestock vulnerability, soil degradation, and groundwater instability. For a densely populated arid zone heavily dependent on rain-fed agriculture, these dynamics magnify food insecurity, poverty risk, and climate-induced migration. The findings are consistent with broader warming projections highlighted by the Intergovernmental Panel on Climate Change, reinforcing that Tharparkar represents a frontline climate-sensitive region within Pakistan.

Moving forward, adaptation must be data-driven and region-specific. Climate-resilient crop planning, decentralized water harvesting, drought preparedness systems, and targeted social protection measures are not optional interventions but strategic necessities. Integrating long-term climatic diagnostics into provincial planning frameworks is essential to safeguard livelihoods, enhance ecological resilience, and secure sustainable development pathways in Thar.

**References:** IPCC; Meghwar et al.

*Please note that the views expressed in this article are of the author and do not necessarily reflect the views or policies of any organization.*

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## Climate Change: A Macro Risk to Food Security

Climate change is now a pressing macroeconomic risk that exacerbates global food insecurity. It affects agricultural productivity, supply chains, and household incomes, threatening the four pillars of food security: availability, access, utilization, and stability.

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2/25/2026

Food security exists when "all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food" (FAO et al., 2022). Climate change fundamentally threatens this ideal. Extreme weather events such as droughts, floods, and storms have increasingly disrupted agricultural production, triggering food crises and price spikes across vulnerable regions. In 2022, the number of people facing acute food insecurity reached 258 million across 58 countries, the highest on record, driven in large part by climate shocks compounded by the war in Ukraine and post-pandemic economic disruptions (FSIN & Global Network Against Food Crises, 2023).

In a globalized market, local climate shocks propagate through international trade and economic pathways, exposing systemic vulnerabilities. Climate change alters pest prevalence and increases the frequency of shock pest events, further endangering agricultural systems (Deutsch et al., 2018). Key processes linking climate to food insecurity include reduced agricultural output, increased volatility in food and commodity prices, higher financing costs for inputs, disruptions to distribution networks, and depressed rural household incomes. The Food and Agriculture Organization estimates that extreme weather events are a direct contributor to a significant portion of observed food insecurity (FAO et al., 2021).

The risk intensifies when these physical and market disruptions intersect with economic vulnerabilities, rising prices, trade shocks, fiscal pressures, and elevated poverty rates. This convergence limits household purchasing power and constrains government response capacity. This review synthesizes existing literature on the interplay between climate,

nutrition, and macroeconomic conditions, aiming to guide future research and policy initiatives toward adaptive food systems.

### Pathways from Climate Change to Food Insecurity

Climate change affects food security through interconnected biophysical, economic, and social transmission mechanisms that operate at local, national, and global scales. One of the most direct pathways is declining agricultural productivity. Rising mean temperatures, shifting precipitation regimes, and intensified pest and disease pressures reduce crop yields, particularly in tropical and semi-arid regions. Challinor et al. (2014) estimate that, in the absence of adaptation, yields of major staples could decline by 10–30% by 2050 in many low-latitude areas. Reduced output constrains domestic food availability and increases reliance on imports, heightening exposure to global price volatility. Warmer temperatures also elevate food safety risks by accelerating microbial growth and contamination, compounding food insecurity through health-related productivity losses (Hammond et al., 2015).

Extreme weather events constitute a second major pathway. Droughts, floods, and heatwaves generate acute supply shocks that reverberate through markets. Attribution research, including Verschuur et al. (2021) on the 2007 Lesotho drought, demonstrates that anthropogenic climate change intensified drought severity, triggering food shortages and price spikes. Between 2020 and 2022, climate-related disruptions combined with geopolitical conflict to drive a global food price surge that pushed an estimated 30–40 million additional people into acute food insecurity, according to the World

Bank. Such shocks often produce prolonged inflationary effects, especially when synchronized across major producing regions.

Household-level impacts operate through income and access channels. Yield losses and livestock mortality directly depress farm incomes, limiting households' capacity to purchase food or reinvest in production. Evidence from South Asia and Sub-Saharan Africa indicates that climate variability significantly increases the probability of household food insecurity (Mekonnen et al., 2021). Recurrent shocks erode asset bases, deepen poverty traps, and undermine resilience where social protection systems are underdeveloped.

Climate change also exposes structural weaknesses in food supply chains. Damage to rural roads, storage facilities, ports, and cold chain infrastructure disrupts distribution networks and inflates post-harvest losses. Tchonkouang et al. (2024) document systemic logistical vulnerabilities that amplify localized production shortfalls into wider regional shortages and higher consumer prices.

Macroeconomic channels further mediate these effects. Rising food prices contribute to inflationary pressures; the International Monetary Fund estimated global food inflation averaged 14% in 2022. For food-importing countries, higher import bills deteriorate trade balances and strain foreign exchange reserves. Nelson et al. (2014) project sustained food price increases under multiple climate scenarios, while quantitative models suggest that severe yield shocks can reduce GDP growth in agriculture-dependent economies by 1–3 percentage points during stress periods.

Finally, climate change undermines nutritional outcomes. The

Intergovernmental Panel on Climate Change emphasizes that climate risks affect all four pillars of food security: availability, access, utilization, and stability. Reduced dietary diversity, heightened disease prevalence, and declining micronutrient availability intensify malnutrition particularly among children, thereby entrenching intergenerational vulnerability.

### **Evidence, Gaps, and Policy Implications**

South Asia represents one of the world's most climate-vulnerable regions, where dense populations, agrarian livelihoods, and hydrological dependence intersect with rising temperatures and monsoon instability. Pakistan illustrates these systemic risks. The 2022 floods inundated roughly one-third of the country, affected 33 million people, and destroyed an estimated 40% of cotton and rice crops, according to the National Disaster Management Authority. The production shock translated into severe macroeconomic stress: food inflation exceeded 40% in 2023, as reported by the Pakistan Bureau of Statistics, sharply constraining household purchasing power and deepening poverty.

Across the Indus Basin, rising temperatures have depressed wheat and rice yields, slowing agricultural GDP growth and tightening domestic availability. Irregular monsoons generate crop failures and water stress, fueling food price inflation and eroding access. Floods impose large fiscal burdens through reconstruction spending and emergency imports, undermining stability. In Sindh and Balochistan, recurrent droughts reduce livestock herds, increase rural unemployment, and entrench chronic food insecurity. Climate-driven pest outbreaks raise input costs and widen trade imbalances by increasing reliance on imported food and agrochemicals.

Empirical and modeling studies reinforce these linkages. Mirzabaev et al. (2023) show that severe warming scenarios could lock vulnerable economies into persistent food insecurity and weak economic resilience absent institutional adaptation.

Campbell et al. (2016) highlight deficiencies in integrated system-level models, noting that macroeconomic feedback particularly inflation, fiscal stress, and trade deterioration remain underrepresented. Abeysekera et al. (2023) find that climate-induced food shortages and price surges depress GDP growth and employment in developing economies. Bezner Kerr et al. (2022) project that food security risks intensify sharply after 2050, especially under high-emissions trajectories. Complementing this, Tchonkouang et al. (2024) document how supply-chain weaknesses magnify localized climate shocks into broader macroeconomic disturbances.

Several research gaps persist. First, integrated modeling frameworks linking agricultural systems with computable general equilibrium (CGE) and dynamic stochastic general equilibrium (DSGE) structures are limited, constraining robust policy simulation. Second, vulnerability is highly context-specific; comparative regional analyses accounting for fiscal capacity, financial market depth, and import dependence are needed. Third, non-crop systems such as fisheries, livestock, and micronutrient composition remain underexamined despite their nutritional importance. Fourth, systematic evaluation of policy instruments such as tariffs, subsidies, and social protection in stabilizing macroeconomic outcomes is sparse. Finally, interdisciplinary research is required to understand how macroeconomic policy influences adaptation investments in irrigation, seed technology, and post-harvest systems.

Policy implications are complex. South Asian economies face "double vulnerability": structural socioeconomic constraints compounded by climate-sensitive agriculture. Climate shocks elevate inflation, widen trade deficits, and restrict fiscal maneuverability, disproportionately affecting low-income households that allocate larger income shares to food. The 2022 global price spike exposed the fragility of just-in-time supply chains, underscoring the need for domestic resilience alongside strategic engagement with global markets. Effective governance, infrastructure

investment, social protection, and calibrated macroeconomic policy are essential. Integrated policy packages combining buffer stocks, targeted subsidies, adaptive infrastructure, and long-term climate resilience are more effective than isolated interventions, though optimal design remains an open empirical question.

### **Conclusion**

Climate change is no longer a distant environmental concern but an immediate macroeconomic risk multiplier for global food insecurity. Through interconnected pathways declining agricultural productivity, extreme weather shocks, supply-chain disruptions, inflationary pressures, and weakened household incomes climate change undermines all four pillars of food security: availability, access, utilization, and stability. Evidence from global modeling and regional case studies, particularly in South Asia, confirms that physical climate shocks translate rapidly into macroeconomic instability, especially in agriculture-dependent and import-reliant economies.

The literature consistently shows that rising temperatures and precipitation variability reduce yields, elevate food prices, and widen trade deficits. These pressures constrain fiscal space, heighten inflation, and reduce growth, disproportionately affecting low-income households. Without adaptation, projected warming particularly beyond mid-century threatens to entrench persistent food insecurity and economic fragility. At the same time, gaps in integrated modeling, policy evaluation, and interdisciplinary analysis limit the precision of policy design.

Addressing climate-induced food insecurity therefore requires systemic transformation rather than incremental adjustment. Investments in climate-resilient agriculture, diversified supply chains, adaptive infrastructure, and strengthened social protection systems must be complemented by macroeconomic stabilization and effective governance. Building resilient food systems is not solely an agricultural priority; it is a macroeconomic and

developmental imperative central to sustainable growth and human well-being.

**References:** Abeysekara et al; Bezner et al; Campbell et al; Challinor et al; Deutsch et al; FAO; IFAD; UNICEF; WFP; WHO; FSIN; GRFC; Hammond et

al; IMF; IPCC; Mekonnen et al; Mirzabaev et al; Nelson et al; Pakistan Bureau of Statistics; Tchoukouang et al; Verschuur et al; World Bank.

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## Health Risks of Agricultural Pesticides

Explore the impacts of agricultural pesticides on crop productivity and public health. Understand the dangers of pesticide poisoning, chronic exposure effects, and the economic burden on communities, especially in low- and middle-income countries.

Malaika Ihsan

2/19/2026

Across the globe, agricultural pesticides have become an indispensable input in modern, high-intensity farming systems. Herbicides, insecticides, fungicides, and rodenticides are widely deployed to mitigate biotic stressors, stabilize crop output, and reduce post-harvest losses. As the global population surpassed 8 billion in 2023, the imperative to enhance food security has intensified, contributing to annual pesticide use exceeding 4 million metric tons (FAOSTAT, 2024; Sharma et al., 2020). In the short run, these agrochemicals increase yields, improve crop uniformity, and lower per-unit production costs. However, mounting scientific evidence suggests that their extensive and frequently underregulated application generates significant long-term health and environmental externalities.

A growing body of epidemiological and toxicological research links pesticide exposure to acute poisoning, endocrine disruption, neurotoxicity, reproductive disorders, and elevated risks of certain cancers, effects that are particularly pronounced in rural communities across low- and middle-income countries (LMICs). The associated economic burden, including direct healthcare expenditures, productivity losses due to morbidity, and environmental remediation costs, remains largely uninternalized in agricultural pricing and policy frameworks, constituting a substantial hidden subsidy to chemical-intensive agriculture (Bourguet & Guillemaud, 2016).

Human exposure pathways are multifaceted. Occupational exposure is the most immediate, affecting farmers, pesticide applicators, and field laborers involved in mixing, loading, and spraying operations. In many LMICs, inadequate access to personal protective equipment,

limited regulatory oversight, and insufficient training exacerbate risk (Lekei et al., 2023). Non-occupational exposure affects the broader population through dietary intake of pesticide residues, contaminated groundwater, and airborne drift from treated fields (Kim et al., 2017). Chronic, low-dose dietary exposure particularly via fruits and vegetables underscores that pesticide-related health risks are not confined to agricultural workers but represent a systemic public health challenge.

### Acute and Chronic Health Impacts of Pesticide Exposure

The most immediate and clinically visible consequence of pesticide exposure is acute poisoning, a condition that continues to impose a substantial global health burden. Clinical manifestations range from mild, self-limiting symptoms such as nausea, vomiting, headaches, dizziness, dermal irritation, and conjunctival inflammation to life-threatening complications including respiratory depression, bronchospasm, muscle fasciculations, seizures, cardiac arrhythmias, and coma. Organophosphate and carbamate insecticides are particularly hazardous due to their mechanism of action: inhibition of acetylcholinesterase, a critical enzyme responsible for regulating neurotransmission in the central and peripheral nervous systems (Mostafalou & Abdollahi, 2018). According to a landmark global assessment, an estimated 385 million cases of unintentional acute pesticide poisoning occur annually, resulting in approximately 11,000 deaths worldwide (Boedeker et al., 2020). The overwhelming majority of cases occur among agricultural workers in low- and middle-income countries, where inadequate protective equipment, weak regulatory enforcement, and limited

access to emergency medical care amplify vulnerability. Underreporting and weak surveillance systems suggest that the true magnitude of morbidity and mortality is likely higher.

Beyond acute toxicity, chronic, low-dose exposure presents more insidious and long-term risks. The International Agency for Research on Cancer has classified several widely used pesticides as carcinogenic or probably carcinogenic to humans, linking exposure to elevated risks of non-Hodgkin lymphoma, leukemia, prostate cancer, and multiple myeloma (IARC, 2017; Kim et al., 2017). Prolonged exposure is also associated with neurodegenerative disorders, including Parkinson's disease and progressive cognitive decline (Paul et al., 2023). Many pesticides function as endocrine-disrupting chemicals, interfering with hormonal regulation and contributing to infertility, congenital anomalies, miscarriage, and low birth weight (Kahn et al., 2020). Children are particularly susceptible; early-life exposure has been correlated with developmental delays, behavioral disorders, and diminished cognitive performance (Sass & Colosio, 2021). Collectively, these outcomes underscore the profound public health implications of sustained pesticide reliance.

### Economic Burden of Pesticide-Related Morbidity and Mortality

The adverse health outcomes associated with pesticide exposure generate substantial direct economic costs, particularly for rural households in developing economies. Direct costs include expenditures on outpatient consultations, emergency treatment, inpatient hospitalization, pharmaceuticals, laboratory diagnostics, and prolonged clinical management of

chronic conditions such as cancer, neurodegenerative disorders, and endocrine dysfunction. In contexts where health insurance coverage is limited or nonexistent, these out-of-pocket expenses can be financially catastrophic. For low-income agricultural households, a single episode of acute poisoning or the diagnosis of a chronic illness may consume a significant share of annual income. Coping mechanisms frequently involve distress asset sales such as livestock or land high-interest borrowing from informal lenders, or reductions in essential expenditures, including food consumption and children's education (Ajayi & Akinnifesi, 2022). Such strategies erode long-term economic resilience and deepen vulnerability.

Indirect costs often exceed direct medical expenditures and exert broader macroeconomic effects. Lost productivity arises when farmers or agricultural laborers are unable to work due to illness, particularly during peak planting or harvesting seasons when labor demand is inelastic. Premature mortality eliminates productive labor permanently, reducing household income streams and local agricultural output. Additionally, caregiving responsibilities, commonly assumed by women and older children, impose opportunity costs in the form of forgone wages or interrupted schooling, reinforcing intergenerational poverty traps.

Beyond measurable financial losses, intangible costs including pain, psychological distress, reduced functional capacity, and diminished quality of life constitute significant welfare losses that are rarely captured in conventional cost-benefit analyses (Wilson & Tisdell, 2021). Collectively, these economic burdens reveal that pesticide-related health impacts represent not merely a public health concern but a substantial impediment to sustainable rural development.

### **Inequities, Market Failures, and Policy Pathways in Pesticide Governance**

The health and economic burdens of pesticide use fall disproportionately on low- and middle-income countries

(LMICs), reflecting structural inequalities in regulation, market governance, and healthcare capacity. Regulatory frameworks governing pesticide importation, distribution, and application are frequently fragmented or weakly enforced (Schreinemachers & Tipraqsa, 2022). As a result, highly hazardous pesticides (HHPs), many of which are banned or severely restricted in high-income countries, remain widely accessible across Asia, Africa, and Latin America (PAN International, 2023). Limited monitoring of residue levels, inadequate labeling standards, and informal sales channels further exacerbate unsafe usage. Compounding these risks is constrained healthcare infrastructure in rural regions, where diagnostic capacity, toxicological expertise, and emergency response systems are often insufficient (United Nations Environment Program, 2023). Consequently, both morbidity and long-term disability rates are elevated, and economic losses intensify.

From a welfare economics perspective, pesticide overuse constitutes a classic negative externality and thus market failure. Market prices reflect private production and purchase costs but exclude broader social costs such as healthcare expenditures, productivity losses, biodiversity decline, and water contamination (Bourguet & Guillemaud, 2016). This divergence between private and social cost leads to allocative inefficiency and over-application. Estimates suggest that global health-related external costs of pesticide exposure range between \$4.5 billion and \$24 billion annually (Pretty & Bharucha, 2023).

Addressing these distortions requires coordinated policy intervention. Strengthening regulatory regimes and phasing out HHPs, consistent with guidance from the Food and Agriculture Organization and the World Health Organization, is essential. Promoting Integrated Pest Management (IPM) can reduce chemical dependence through biological control, crop diversification, and resistant varieties. Complementary investments in farmer education, protective equipment, toxicovigilance

systems, and rural healthcare infrastructure are critical to internalizing externalities and advancing sustainable agricultural development.

### **Conclusion**

The extensive use of agricultural pesticides, while enhancing crop productivity and supporting global food security, carries profound and often underappreciated health and economic consequences. Acute pesticide poisoning continues to afflict millions of agricultural workers, particularly in low- and middle-income countries, with symptoms ranging from nausea and dizziness to seizures and death. Beyond immediate toxicity, chronic, low-dose exposure contributes to long-term health conditions, including cancers, neurodegenerative disorders, endocrine disruption, and developmental impairments in children. These health impacts not only compromise individual well-being but also impose substantial economic burdens on households and communities, through direct medical expenses, lost labor productivity, premature mortality, and caregiving costs.

The distribution of these costs is highly inequitable, with LMICs disproportionately affected due to weak regulatory oversight, widespread availability of highly hazardous pesticides, and limited healthcare infrastructure. Economically, pesticide overuse exemplifies market failure: private costs are internalized, but the broader social and environmental damage remain unaccounted for, leading to inefficient resource allocation and persistent over-application.

Addressing these challenges requires coordinated policy and practical interventions. Strengthening regulatory frameworks, banning or restricting hazardous chemicals, promoting Integrated Pest Management (IPM), and investing in farmer education and healthcare systems are critical. By internalizing the social costs of pesticide use and enhancing capacity for safe management, these measures can mitigate health risks, reduce economic losses, and promote sustainable agricultural

development. Ultimately, balancing productivity goals with human and environmental health is essential to ensure that modern agriculture supports both food security and long-term well-being.

**References:** Ajayi & Akinnifesi; Boedeker et al; Bourguet & Guillemaud;

FAOSTAT; FAO; WHO; IARC; Kahn et al; Kim et al; Lekei et al; Mostafalou & Abdollahi; PAN International; Paul et al; Pretty & Bharucha; Sass & Colosio; Schreinemachers & Tipraqsa; Sharma et al; UNEP; Wilson & Tisdell.

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