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ROOTED IN RESILIENCE

INDIGENOUS WISDOM, YOUTH ENERGY AND CLIMATE ACTION

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August Focus: Rooted in Resilience- Equity in Agriculture

Explore the urgent theme of equity, inclusion, and ecological stewardship in agriculture as we confront climate change and biodiversity loss. Join the conversation on how indigenous traditions and youth innovation can shape a resilient future in farming.

Muhammad Khalid Bashir

8/1/2025

As the world confronts accelerating climate change, biodiversity loss, and growing inequality, the path forward for agriculture must be one that is grounded in equity, inclusion, and ecological stewardship. This August, *The Agricultural Economist* turns its focus to a timely and urgent theme: *Rooted in Resilience*- a call to recognize the strength embedded in indigenous traditions, youth innovation, and climate-conscious transformation.

Three global observances guide our reflections this month: **World Biofuel Day** (August 10), **International Day of the World's Indigenous Peoples** (August 9), and **International Youth Day** (August 12). Together, they highlight the intersections of ancestral knowledge, modern innovation, and the pressing need for sustainable energy and food systems.

Across the globe, indigenous communities have practiced regenerative agriculture for centuries—intercropping, seed saving, water harvesting, and managing forests in harmony with ecosystems. Their knowledge systems are not relics of the past, but blueprints for the future. Yet, they remain underrepresented in agricultural policy and investment. Celebrating their contributions means more than cultural recognition; it demands legal land rights, participatory governance, and the integration of traditional knowledge into national climate strategies.

At the same time, youth are reshaping agriculture with energy, creativity, and digital tools. From launching agri-tech startups to promoting agroecology and sustainable finance, rural youth are redefining what farming looks like. But barriers persist—limited land access, poor infrastructure, and lack of finance keep many young people out of agriculture altogether. If we are serious about rural transformation, we must invest in youth, through skills training, innovation hubs, and inclusive policy platforms that recognize them as central actors, not just beneficiaries.

Climate action binds these narratives together. Agriculture, both victim and driver of climate change, holds transformative potential. Renewable energy, including biofuels and solar irrigation, offers paths to decarbonize rural economies. Yet climate-smart solutions must be accessible and context-specific. Biofuel initiatives, for example, must balance energy goals with food security, land rights, and biodiversity protection.

This edition of *The Agricultural Economist* features powerful stories and analyses that illustrate these interconnections. We explore how breadfruit, a climate-resilient crop, could transform food systems in arid zones. We examine Turkey's post-conflict food strategy as a case in adaptive resilience. We delve into the role of women and youth in sustainable farming, spotlighting policies and practices that can foster equity across generations.

What emerges is a hopeful yet sobering picture. The tools for change exist, cooperatives, digital platforms, community forestry, inclusive finance. But what is required now is political will and a shift in priorities. Resilience is not just about bouncing back; it's about transforming unjust systems and building futures that are rooted in knowledge, justice, and sustainability.

As we move forward, let us listen more closely to indigenous communities, invest more boldly in young people, and act more urgently on climate. Let agriculture not just survive but lead the way toward a more equitable and resilient planet.

Regards,
Muhammad Khalid Bashir

Managing Editor

The Agricultural Economist

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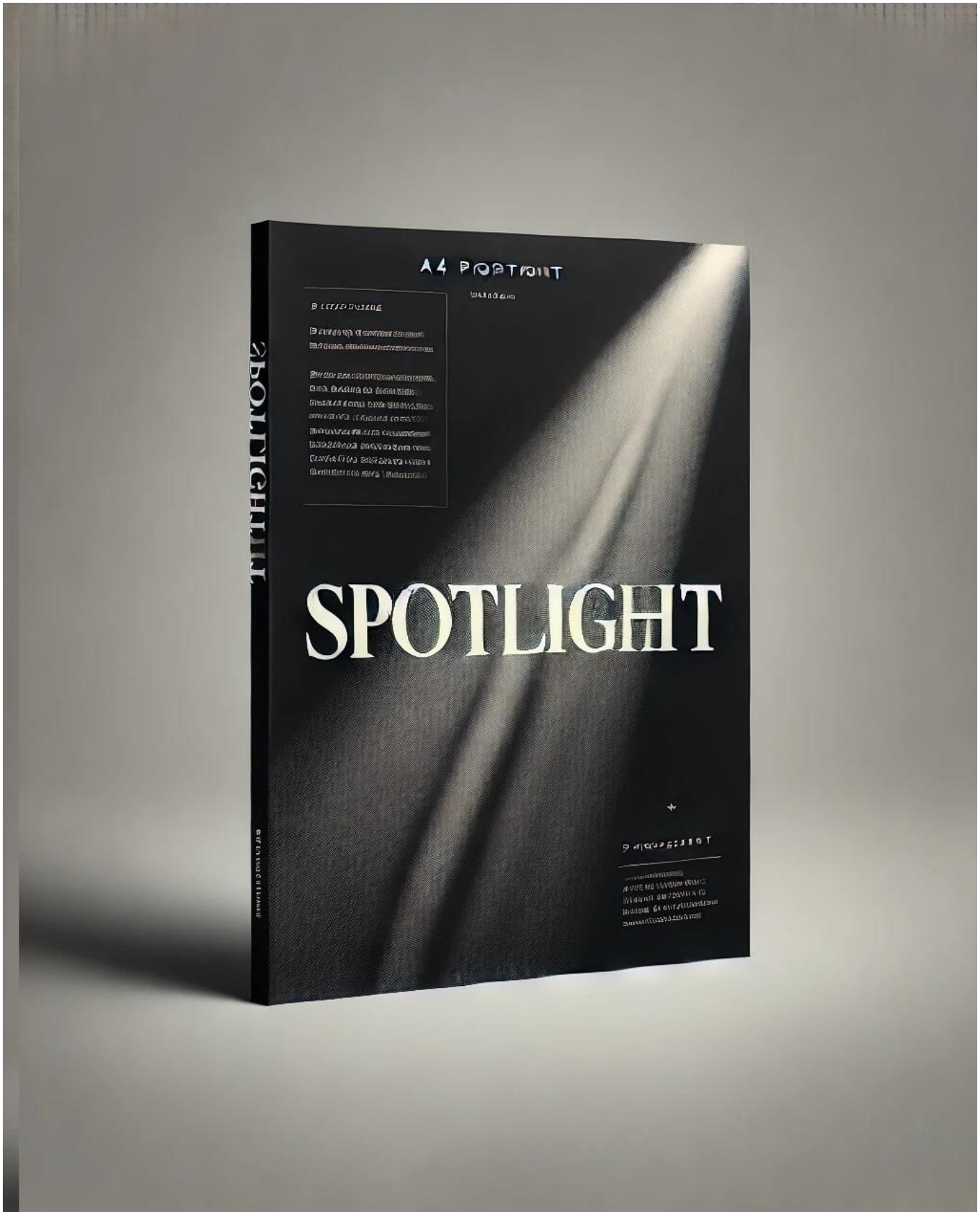

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Türkiye's Agricultural Sector: Challenges & Opportunities

Explore the pivotal challenges and opportunities in Türkiye's agricultural sector. Discover how alternative agriculture, crop diversification, and modern innovations can enhance food security and rural incomes while leveraging the country's agro-ecological potential.

Mithat Direk

8/8/2025

Agriculture remains one of humanity's most vital sectors, yet it faces unprecedented challenges due to population growth, climate change, and shifting dietary demands. The global population is projected to reach 9.7 billion by 2050, requiring a 70% increase in food production (FAO, 2022). Meanwhile, agricultural land shrinking 12 million hectares are lost annually to degradation (UNCCD, 2023). These pressures necessitate alternative agricultural approaches that enhance productivity, sustainability, and market efficiency.

In Türkiye, a country with a rich agricultural heritage and significant agro-ecological diversity, these global challenges intersect with local vulnerabilities. Although agriculture employs around 17% of the workforce and contributes approximately 6.5% to GDP, it remains heavily exposed to climate variability, water scarcity, and outdated practices in some regions. Droughts and erratic rainfall in the Anatolian plateau have increasingly disrupted crop yields, while urban sprawl threatens fertile coastal and valley farmlands. Furthermore, rising input costs, especially fertilizers and energy, have squeezed profit margins for smallholder farmers.

Despite its fundamental importance, agriculture in Türkiye often struggles to translate high yields into economic gains. Post-harvest losses in perishable products like fruits and vegetables remain significant, due to limited cold storage infrastructure and inefficiencies in supply chains. Regional disparities in farm productivity also persist, reflecting uneven access to extension services and modern technologies.

To remain competitive and food secure, Türkiye must prioritize systemic reforms across the agricultural value chain. This includes investing in smart irrigation, digitized logistics, and climate-resilient crops. Equally important is strengthening farmer cooperatives, export competitiveness, and rural finance mechanisms. With strategic innovation and inclusive policy frameworks, Türkiye can position its agriculture sector not just as a source of food, but as a driver of rural prosperity and sustainable economic growth in the face of 21st-century pressures.

The Productivity Paradox in Türkiye: High Output, Low Profitability

Türkiye's agricultural sector showcases nature's extraordinary productivity, where even a single corn plant can yield hundreds of kernels. Despite this biological abundance, many Türkiye's farmers are caught in a cycle of low profitability, primarily driven by market inefficiencies, perishability of goods, and lack of support systems. For perishable commodities like strawberries, milk, and leafy greens, the window between harvest and spoilage is incredibly narrow—often just a few hours. Without a functioning cold chain infrastructure, an estimated 20–30% of fruits and vegetables are lost before ever reaching consumers. In Türkiye, this is particularly evident in cherry farming: studies indicate that unrefrigerated cherries lose half their market value within just six hours (TÜİK, 2023).

The Türkiye's proverb, "Can you sell what you grow?" reflects a core issue: production is not the bottleneck, marketing and selling are. An illustrative case involved a large-scale onion farmer who abandoned his crop due to low prices. A neighboring farmer attempted to salvage it but lacked proper storage; rain destroyed the crop, leading to total loss. Ironically, onion prices surged just weeks later, but the farmer, disillusioned by repeated market shocks, chose to exit onion production entirely. This volatility discourages investment and long-term planning across farming communities.

Türkiye's agro-climatic diversity holds untapped potential for alternative crops such as quinoa, chia, and organic herbs. However, the promise of diversification is hindered by uncertain market demand, inadequate local processing facilities, and cumbersome export procedures. These barriers discourage farmers from shifting to higher-value, climate-resilient crops. Without policy reforms that stabilize prices, strengthen market access, and invest in agri-infrastructure, Türkiye risks squandering its natural advantages. Bridging the gap between high output and economic sustainability is essential to empower its rural economy and ensure agricultural resilience in the decades to come.

Revitalizing Türkiye's Agriculture through Trade, Processing, and Innovation

In Türkiye, agricultural trade and food processing play an increasingly important role in ensuring food security and economic viability. While local production forms the backbone of food supply, it cannot always meet domestic demand or align with global market opportunities. Agricultural trade helps bridge these gaps, as seen in the European Union, which imports nearly half of its fresh produce from Africa and South America (Eurostat, 2023). Likewise, food processing significantly extends the utility and shelf life of

perishable crops; for example, surplus tomatoes can be turned into paste, preserving value for months or even years (IFT, 2023).

However, Türkiye's dependence on agricultural trade exposes farmers to global market volatility. Wheat, a staple crop in the country, experienced a 60% price surge after the Russia-Ukraine conflict disrupted supply chains (IMF, 2023). Export restrictions and trade barriers have similarly impacted the availability and affordability of inputs like fertilizers and seeds (WTO, 2023), directly affecting Türkiye's growers.

To build resilience, Türkiye must invest in cold chain infrastructure and modern storage systems. India's example, where solar-powered cold storage reduced post-harvest tomato losses by 25% (ICAR, 2023), offers a replicable model. Integrating digital solutions like blockchain can also enable traceability and faster, more transparent payments, benefiting smallholders and cooperatives alike (WEF, 2023).

Diversification into high-value crops like avocado, medicinal herbs, and nuts could tap into premium export markets. Countries like Kenya have seen a 200% rise in avocado exports in five years by aligning with EU standards (World Bank, 2023). Moreover, innovations like vertical farming offer significant yield gains with minimal land use, an important consideration for urban and peri-urban Türkiye's agriculture.

Conclusion

Türkiye's agricultural sector stands at a pivotal juncture where traditional practices, structural inefficiencies, and modern pressures converge. While the country possesses immense agro-ecological potential and biological productivity, the disconnect between high yields and low profitability continues to stifle progress. From post-harvest losses and weak market linkages to price volatility and underdeveloped infrastructure, the challenges facing Türkiye's farmers are systemic and multifaceted. Yet within these challenges lie tremendous opportunities. By embracing alternative agriculture, diversifying crops, improving value chains, modernizing storage and logistics, and leveraging digital innovations, Türkiye can not only safeguard food security but also enhance rural incomes and economic resilience.

Strategic policy reforms are essential. Cold chain investments, smart subsidies, cooperative development, and export facilitation must become national priorities. Equally, empowering farmers through access to finance, training, and market intelligence will be key to unlocking innovation and climate resilience. As global food systems become more complex and competitive, Türkiye's ability to adapt, innovate, and lead in sustainable agriculture will determine its future. With bold vision and inclusive action, the country can transform its agriculture sector from a story of paradox into one of prosperity, turning challenges into catalysts for lasting change and sustainable growth.

References: FAO; World Bank; IMF; WEF; EC; UNCCD; TÜİK; Eurostat; IFT; WTO; ICAR

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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Naseerabad's Climate Crisis: Water & Agriculture Challenges

Explore Naseerabad's struggle against the climate crisis, characterized by dwindling water resources and agricultural decline. Discover how rising temperatures and erratic rainfall threaten livelihoods and food security, while also presenting an opportunity for reimagining sustainable development.

Imam uddin Palal

8/11/2025

Naseerabad Division in Balochistan where I, Imamuddin Palal, reside is on the frontlines of climate change. Once known for its fertile plains and productive farmlands, the region now faces escalating temperatures, prolonged heatwaves, and increasingly erratic rainfall patterns. Agriculture, the backbone of the local economy, is under severe stress. With summer temperatures now exceeding 50°C (PMD, 2023) and annual rainfall declining by 20% over the past two decades (World Bank, 2022), crop yields are dwindling, irrigation canals are drying, and water tables are falling at an alarming rate. This environmental shift is not only threatening food security but also exacerbating poverty, migration, and public health crises.

The combination of heat stress, water scarcity, and poor waste management has left communities vulnerable to disease outbreaks, reduced labor productivity, and economic stagnation. Traditional farming systems heavily dependent on canal water and predictable weather are ill-equipped to withstand these new extremes. Without targeted adaptation measures, the region risks losing both its agricultural productivity and its population to climate-induced displacement.

Building resilience in Naseerabad requires a multi-pronged approach. Heat mitigation measures such as planting shelterbelts, expanding green cover, and using reflective roofing can reduce temperature stress for both people and crops. The adoption of the “3Rs” (Reduce, Reuse, Recycle) in waste management can lower pollution, prevent drainage blockages, and improve community health. Renewable energy solutions, particularly solar-powered irrigation and off-grid systems, can reduce reliance on fossil fuels, improve water access, and cut household energy costs.

Climate adaptation in Naseerabad is no longer optional; it is a lifeline. By combining local knowledge with innovative technologies, strengthening community participation, and ensuring government support, the division can transition from a climate-vulnerable zone to a model of rural resilience in Pakistan. The time for decisive action is now before the damage becomes irreversible.

The Climate Crisis in Naseerabad Division

Naseerabad’s arid to semi-arid climate is rapidly intensifying under the pressures of global warming, placing unprecedented strain on its people, land, and resources. Recent climate data paints a grim picture: average summer temperatures have risen by 1.5°C since 2000 (PMD, 2023), while monsoon variability has significantly reduced water availability, worsening drought conditions (IUCN, 2022). Over-extraction of groundwater has caused alarming declines in water tables, dropping by 2–3 meters each year (PCRWR, 2023).

Agriculture, which sustains more than 70% of the local population, is bearing the brunt of this crisis. Wheat and cotton yields have declined by 15–20% due to persistent heat stress and acute water shortages (FAO, 2023). Soil degradation now affects 40% of arable land, cutting productivity and undermining food security (Balochistan Agriculture Department, 2022). Shifting and unpredictable monsoon patterns have disrupted traditional planting cycles, pushing farmers into greater financial and production risks.

Water scarcity has become a looming catastrophe. Excessive irrigation is accelerating groundwater depletion, while outdated and inefficient canal systems lose 30–40% of water through seepage (IWMI, 2023). The division has experienced three major droughts in the last decade (NDMA, 2023), further depleting reserves and intensifying competition for limited resources.

The health implications of this climatic shift are equally severe. Heatstroke cases have surged by 35% in the past five years (WHO, 2023), with children, the elderly, and outdoor laborers at greatest risk of dehydration, heat exhaustion, and related illnesses. Limited access to healthcare facilities in rural areas compounds the danger, leaving vulnerable communities with few coping mechanisms. Naseerabad’s climate crisis is not a distant threat it is a present and escalating emergency. Without swift adaptation measures, both livelihoods and

lives will remain in jeopardy, eroding the resilience of the region.

Building Climate Resilience in Naseerabad

Naseerabad's escalating climate challenges demand integrated solutions that address both immediate heat stress and long-term sustainability. Urban greening and afforestation stand out as effective first steps. Planting native, drought-resistant species such as Kikar and Neem can lower local temperatures by 2–5°C (UNEP, 2022), while community-led afforestation inspired by the Billion Tree Tsunami can help restore degraded lands. In urban centers like Dera Murad Jamali, introducing green roofs and expanding park spaces can combat the urban heat island effect and improve air quality.

Adapting the built environment through climate-smart architecture can further protect communities. Combining traditional cooling designs such as thick mud walls and shaded courtyards with modern insulation and reflective roofing can cut indoor heat and reduce cooling energy needs by up to 30% (World Green Building Council, 2023). On the waterfront, sustainable management practices are essential. Rainwater harvesting through small dams and ponds can increase local water availability by 25%, while switching to drip irrigation can halve agricultural water consumption (FAO, 2022).

Resilience also depends on informed and prepared communities. Early warning systems for heatwaves, delivered via mobile networks, can save lives. Training farmers to cultivate drought-resistant crops like sorghum and millet strengthens food security in a changing climate.

Waste management forms another critical pillar of climate action. Applying the 3R's, Reduce, Reuse, Recycle, through local initiatives like banning single-use plastics, composting crop residues, and establishing rural recycling cooperatives can cut emissions, enhance soil health, and reduce landfill waste.

Renewable energy adoption offers a sustainable pathway forward. With over 300 sunny days annually, Naseerabad can harness solar power for tube wells, microgrids, and household needs, reducing reliance on diesel and wood. Wind speeds of 5–7 m/s in select areas open possibilities for small-scale turbines and hybrid solar-wind systems, ensuring reliable energy in off-grid communities. Promoting energy efficiency through LED lighting and solar water heaters further reduces environmental strain while lowering household costs.

By integrating green infrastructure, efficient resource use, and renewable energy, Naseerabad can not only reduce the impacts of extreme heat but also lay the foundation for a climate-resilient, energy-secure future.

Conclusion

Naseerabad's struggle against intensifying heat, dwindling water resources, and agricultural decline is emblematic of the climate crisis gripping arid regions worldwide. The evidence is clear rising temperatures, erratic rainfall, and worsening droughts are no longer abstract forecasts but lived realities threatening livelihoods, food security, and public health. Yet within these challenges lies an opportunity to reimagine the district's development path.

By embracing climate-smart strategies urban greening, sustainable water management, traditional-meets-modern architecture, and renewable energy adoption Naseerabad can pivot from vulnerability to resilience. Community-led initiatives such as afforestation drives, waste recycling cooperatives, and farmer training in drought-resistant crops will not only reduce environmental stress but also generate social and economic co-benefits. At the same time, policy alignment, infrastructure investment, and knowledge-sharing will be essential to scaling these solutions.

The transformation will require political will, community participation, and sustained investment, but the rewards are profound: cooler cities, productive farms, reliable water and energy supplies, and healthier, more secure communities. Climate change may be the defining challenge of our era, but with decisive, coordinated action, Naseerabad can become a model for rural adaptation in Pakistan demonstrating that resilience is not just possible, but within reach.

References: AEDB; FAO; IUCN; PMD; World Bank; PCRWR; Balochistan Agriculture Department; IWMI; NDMA; WHO; UNEP

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Revolutionizing Forest Monitoring with GIS Technologies

Explore the pivotal role of GIS and remote sensing technologies in the fight against deforestation. Discover how AI and cloud computing enable near-real-time forest monitoring, leading to successful interventions like those seen in Indonesia and Brazil.

Ahtisham Ul haq & Shahid Hafeez Khan

8/14/2025

Deforestation and forest degradation remain pressing global concerns, responsible for an estimated 12% of annual greenhouse gas emissions (Global Carbon Project, 2023) and accelerating biodiversity loss at a pace unparalleled in human history (WWF, 2023). These processes threaten not only climate stability but also the ecological integrity of landscapes that sustain millions of species and provide vital ecosystem services to humanity. Over the past decade, Geographic Information Systems (GIS) and remote sensing technologies have transformed the way forests are monitored, offering unprecedented capabilities for large-scale, cost-effective, and near real-time assessment of forest cover changes.

Between 2020 and 2024, global monitoring systems have documented alarming deforestation rates in tropical regions, alongside modest gains in forest restoration in some temperate zones. Technological innovations including artificial intelligence, cloud computing, and multi-sensor fusion have significantly enhanced the precision and timeliness of forest data, enabling more proactive interventions. Machine learning algorithms now analyze terabytes of satellite imagery to detect subtle signs of degradation, while big data platforms integrate diverse datasets to generate comprehensive deforestation risk maps.

However, challenges persist data gaps in remote regions, limited policy enforcement, and socio-economic pressures on forest communities undermine conservation gains. Policy frameworks such as REDD+, the UN Sustainable Development Goals, and emerging carbon credit markets offer promising avenues for aligning economic incentives with forest protection but require stronger governance and community engagement to be effective. Strengthening global forest governance will depend on integrating cutting-edge technology with robust legal frameworks, transparent data sharing, and inclusive decision-making that empowers local stakeholders. Ultimately, reversing deforestation trends will require a coordinated global effort that couples technological progress with political will and sustainable economic alternatives for communities dependent on forest resources.

Global Deforestation Trends (2020–2024)

Between 2020 and 2023, the world experienced an average annual forest loss of 4.1 million hectares, showing a modest improvement compared to the 4.7 million hectares lost annually from 2015 to 2020 (FAO, 2023). This decline reflects the growing impact of conservation policies, reforestation initiatives, and stricter environmental enforcement in certain countries. However, deforestation remains a critical challenge, particularly in tropical regions where forest ecosystems store vast amounts of carbon and support unparalleled biodiversity.

The Amazon in Brazil continues to be a focal point of global concern, losing approximately 1.5 million hectares in 2023 alone (INPE, 2024), largely due to agricultural expansion, cattle ranching, and infrastructure development. In contrast, Indonesia has demonstrated significant progress, achieving a 75% reduction in deforestation since 2016 by enforcing stricter palm oil regulations and expanding peatland restoration programs (GFW, 2024). Meanwhile, the Congo Basin, home to the world's second-largest tropical rainforest, continues to lose about 500,000 hectares annually, driven primarily by illegal logging, slash-and-burn agriculture, and mining activities (WRI, 2023).

Beyond outright forest loss, degradation poses an even greater but often overlooked threat. Forest degradation caused by selective logging, fires, and habitat fragmentation impacts nearly twice the land area of deforestation itself (Science Advances, 2023). These degraded forests store less carbon, are more vulnerable to disease and fire, and provide diminished habitats for wildlife.

While some regions show that deforestation can be slowed through strong governance and targeted policy measures, global trends indicate that sustained and coordinated action is essential. Protecting forests will require combining policy enforcement, technological monitoring, and community engagement to address both visible deforestation and the less apparent but equally damaging process of forest degradation.

GIS and Remote Sensing in Forest Monitoring

Geographic Information Systems (GIS) and remote sensing have become indispensable tools in tracking and combating deforestation, offering unprecedented spatial and temporal resolution for monitoring forest changes. Satellite-based monitoring forms the backbone of these systems, with platforms such as Landsat and Sentinel-2 providing 10–30-meter resolution imagery, enabling regular deforestation alerts and historical trend analysis. NASA's Global Ecosystem Dynamics Investigation (GEDI) uses LiDAR technology to capture precise measurements of canopy height and above-ground biomass, enhancing the accuracy of carbon stock assessments (Dubayah et al., 2023). PlanetScope, with

its daily 3-meter resolution imagery, offers high-frequency monitoring, making it especially effective for detecting illegal logging in near real-time.

Artificial intelligence (AI) and machine learning further amplify the capabilities of remote sensing. Deep learning models, including U-Net and Transformer-based architectures, have boosted land-cover classification accuracy to over 90% (Nature Remote Sensing, 2023). These models excel at distinguishing subtle differences between natural forest cover, plantations, and degraded areas. Platforms like Google Earth Engine integrate these AI capabilities with petabyte-scale datasets, enabling near-real-time deforestation alerts and comprehensive spatial analyses (Gorelick et al., 2023).

Sensor fusion, combining optical, radar, and LiDAR data, provides a more robust monitoring framework. Sentinel-1 radar imaging is especially valuable for tropical forests, as it can penetrate persistent cloud cover that often hampers optical sensors. When integrated with multi-temporal analysis, this approach can detect gradual forest degradation, such as selective logging, that may go unnoticed in single-date imagery.

By leveraging these interconnected technologies, GIS and remote sensing provide governments, NGOs, and researchers with powerful, actionable insights. These systems enable more proactive forest governance, rapid enforcement against illegal activities, and stronger global collaboration in addressing the intertwined crises of deforestation, forest degradation, and climate change.

Key Challenges and Policy Implications in Forest Monitoring

Monitoring and protecting forests face several persistent challenges that limit the full potential of GIS and remote sensing technologies. In tropical regions, persistent cloud cover restricts the effectiveness of optical satellites, delaying deforestation alerts and masking gradual forest changes. Integrating radar data from platforms like Sentinel-1 with AI-based gap-filling techniques offers a way to overcome this limitation. Another barrier is the high cost of high-resolution imagery, which can be prohibitive for developing nations. Expanding open-access datasets, such as ESA's RACE initiative, would democratize access to detailed monitoring data. Ground-truthing remains essential for validating remote sensing models, yet many regions suffer from shortages of trained field teams. This gap could be addressed by integrating citizen science efforts with drone-based validation campaigns. Policy enforcement also lags in many countries, allowing illegal logging to persist; blockchain-enabled timber tracking could help ensure transparent and traceable supply chains.

From a policy perspective, remote sensing is central to major global initiatives. REDD+ programs depend on satellite-based systems for Monitoring, Reporting, and Verification (MRV) to ensure credible carbon accounting. Similarly, voluntary carbon markets increasingly use satellite-derived biomass estimates to validate carbon credits (Verra, 2024). The United Nations Sustainable Development Goal 15 (Life on Land) sets an ambitious target of zero deforestation by 2030, complemented by the Bonn Challenge to restore 350 million hectares of degraded land within the same timeframe. Emerging technologies are also transforming enforcement. Brazil's AI-powered PREVINA system, for example, reduced illegal deforestation by 40% in 2023 by enabling rapid intervention. Blockchain technology, endorsed by the World Economic Forum, is being tested to secure transparency in global timber trade. Together, overcoming technical, financial, and governance barriers while integrating advanced technologies into policy frameworks will be critical to halting deforestation and restoring degraded ecosystems.

Conclusion

The fight against deforestation and forest degradation is at a pivotal moment. GIS and remote sensing technologies have revolutionized forest monitoring, providing unprecedented precision, speed, and scalability in detecting and analyzing forest cover changes. The integration of AI, sensor fusion, and cloud computing has made near-real-time monitoring possible, enabling more rapid and targeted interventions. Success stories, such as Indonesia's dramatic reduction in deforestation and Brazil's AI-driven enforcement systems, demonstrate the potential of combining technological innovation with strong governance.

Yet, challenges remain formidable. Persistent data gaps, high-resolution imagery costs, weak policy enforcement, and socio-economic pressures on forest-dependent communities continue to undermine conservation progress. Moreover, degradation, less visible than outright deforestation, poses an equally significant threat to carbon storage, biodiversity, and ecosystem health.

Moving forward, effective solutions will require bridging technology and policy. Expanding open-access data, enhancing ground-truthing through community participation, and embedding transparency tools like blockchain in timber supply chains can strengthen global forest governance. Aligning these tools with international frameworks such as REDD+, the Bonn Challenge, and the SDGs will be essential. Ultimately, reversing deforestation is not just a technological or policy challenge, it is a global responsibility requiring coordinated action, equitable resource sharing, and the empowerment of local communities.

References: FAO; Global Forest Watch; NASA; Nature Remote Sensing; WWF; World Economic Forum; Global Carbon Project; INPE; GFW; WRI; Science Advances; Dubayah et al.; Gorelick et al.; Verra

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Transforming Pakistan's Agricultural Labor Market

Explore the pivotal transformation of the agricultural labor market in Pakistan, shaped by demographic transitions, climate risks, and technological innovation. Discover how targeted reforms can create a more equitable and resilient agricultural sector, ensuring sustainability and economic growth.

Muhammad Hamza Saeed

8/18/2025

Agriculture remains a cornerstone of the global economy, employing more than 27% of the world's workforce (World Bank, 2023) and contributing 4.3% to global GDP (FAO, 2023). Beyond its economic weight, the sector underpins food security, rural livelihoods, and cultural traditions. Yet, the agricultural labor market is experiencing profound and rapid transformations. These shifts are shaped by multiple forces, including technological innovation, demographic changes, climate variability, and evolving national and international policy frameworks.

On the global stage, mechanization, artificial intelligence, and digital platforms are redefining the nature of farm work. Precision agriculture, robotics, and big data analytics are reducing dependence on manual labor, improving efficiency, and enabling more sustainable use of natural resources. At the same time, migration patterns and rural-to-urban transitions are reshaping labor availability, with younger generations often seeking non-farm opportunities. Climate change adds further complexity, with rising temperatures, unpredictable rainfall, and extreme weather events threatening both crop yields and working conditions, placing additional stress on already vulnerable agricultural labor systems.

In Pakistan, these global dynamics intersect with local realities. With nearly 38% of the national workforce employed in agriculture (PBS, 2023), the sector remains a lifeline for millions, particularly in rural communities. However, the country faces pressing challenges such as water scarcity, smallholder fragmentation, gender disparities in labor participation, and limited access to modern tools and training. While government initiatives and private-sector innovations are beginning to introduce digital agriculture, mechanized services, and skills programs, the transition is uneven.

This article explores the evolving trends, challenges, and opportunities in agricultural labor markets, with a particular focus on Pakistan, while situating them within broader global debates. Understanding these dynamics is essential for shaping policies and practices that ensure agricultural labor remains productive, equitable, and resilient in the face of change.

Shifting Dynamics in Agricultural Labor: Global and Pakistani Perspectives

The agricultural labor market is undergoing a dramatic transformation, shaped by demographic, technological, environmental, and social forces. These shifts are evident across the globe, but their impact is particularly acute in developing economies like Pakistan, where agriculture is not only a source of food but also a vital provider of livelihoods. Understanding these evolving labor dynamics is critical for crafting effective strategies that ensure sustainable productivity and equitable participation in the years ahead.

One of the most pressing challenges is the demographic shift within the farming community. Globally, the agricultural workforce is aging at an unprecedented pace. In the United States, the average farmer is now 57.5 years old (USDA, 2023), while in Japan, nearly 70% of farmers are above the age of 65 (MAFF, 2023). Younger generations increasingly view agriculture as a low-status, high-risk, and economically unstable career path, often opting instead for urban-based opportunities in services, trade, or manufacturing. Pakistan mirrors this trend, with agriculture still employing 37.4% of its labor force (PBS, 2023) yet facing a steady outflow of rural youth. Low wages, harsh working conditions, and limited access to modern tools have pushed young people toward urban migration, leaving behind an older workforce less equipped to adapt to technological innovation.

Compounding these demographic shifts are the structural issues of seasonality and informality. Agriculture remains one of the most seasonal forms of work, resulting in income volatility and instability. The International Labour Organization estimates that over 60% of farm workers in developing nations operate informally (ILO, 2023), lacking contracts, health protections, or social security. In Pakistan, informal labor arrangements are particularly widespread, disproportionately affecting women and marginalized communities. These workers, often invisible within policy frameworks, remain trapped in cycles of poverty and vulnerability despite being essential to the country's food system.

Meanwhile, technological advances are rapidly reshaping global agriculture. The agricultural automation market is projected to grow at a CAGR of 24.3% from 2023 to 2030 (Grand View Research, 2023), with developed nations deploying AI-driven tractors, drones, robotic harvesters, and Internet of Things (IoT) sensors. Such innovations significantly reduce dependence on manual labor while improving precision, efficiency, and sustainability. However, Pakistan lags behind: only 30% of its farms currently use mechanized equipment (Pakistan Economic Survey, 2023). Smallholder farmers, who

dominate the sector, often lack the financial resources to adopt expensive technologies. Addressing this digital divide requires government-backed subsidies, cooperative ownership models, and machinery rental services to ensure equitable modernization.

With automation rising, the nature of agricultural labor is also changing. Demand for unskilled labor is shrinking, while new opportunities are emerging in agri-tech fields such as drone operation, data analytics, and climate-smart farming. To meet these needs, Pakistan's agricultural universities and vocational programs must urgently revamp their curricula, integrating training in digital agriculture, agribusiness management, and climate resilience.

Climate change adds another layer of complexity to labor dynamics. The International Labour Organization warns that by 2030, global working hours in agriculture could decline by 2.2% due to heat stress (ILO, 2023). For Pakistan, the risks are already visible: the catastrophic floods of 2022 displaced 8 million people and destroyed nearly half of the country's cropland (UNDP, 2023). Rising temperatures and extreme weather events directly reduce farm productivity while jeopardizing rural employment. Adaptation strategies are therefore crucial, including the adoption of drought-resistant crops, the expansion of drip irrigation, and the scaling up of crop insurance schemes to protect vulnerable farmers.

Finally, any discussion of agricultural labor must address persistent gender disparities. Women make up 43% of the global agricultural workforce (FAO, 2023), yet their contributions remain undervalued and underpaid. In Pakistan, women are the backbone of the sector, performing 60–80% of farm labor, often in sowing, harvesting, and livestock care. Yet, they own less than 5% of agricultural land (UN Women, 2023) and face significant barriers in accessing credit, extension services, and decision-making platforms. Bridging this gender gap is not only a matter of equity but also a proven pathway to increasing productivity and strengthening food security.

The global and Pakistani agricultural labor markets thus stand at a crossroads. Demographic shifts, informal employment, technological disruption, climate risks, and gender inequalities collectively demand a comprehensive policy response. Unless these challenges are addressed with urgency, agriculture risks losing its most critical resource, its people. Yet, with targeted reforms and inclusive innovation, the sector can transform labor vulnerabilities into opportunities for resilience and growth.

Rethinking Agricultural Labor Policies for Inclusive and Sustainable Growth

The future of agricultural labor depends heavily on robust policies that address systemic inequalities, demographic pressures, and the vulnerabilities of those who sustain food systems. One of the most urgent reforms lies in empowering women, who form the backbone of agriculture yet remain marginalized. Land ownership reforms that provide women secure tenure can significantly boost productivity and ensure intergenerational stability. Coupled with gender-sensitive training programs and microfinance initiatives, such measures would not only enhance women's income opportunities but also uplift entire rural households and communities.

Another critical gap lies in the growing rural-to-urban migration that is draining farms of their workforce. Across the world, countries like Italy, Spain, and the U.S. rely on migrant workers to fill 30–50% of seasonal farm labor (UN Women, 2023). In Pakistan, however, rural depopulation is leaving agriculture understaffed and uncompetitive. Policies must therefore create incentives for youth engagement through subsidized farm mechanization, investment in rural infrastructure, and the promotion of agri-startups that merge innovation with entrepreneurship. Such approaches can rebrand farming as a modern, profitable career path rather than a last resort.

At the same time, agricultural workers continue to earn 20–40% less than non-farm workers globally (ILO, 2023), a disparity that undermines labor retention. Strengthening minimum wage enforcement, alongside pensions, health insurance, and accident coverage, would make agricultural employment more attractive and equitable. Health and safety must also be prioritized, especially in Pakistan where over 70% of farmworkers lack protective equipment (PAN, 2023). Enforcing safety training and distributing affordable protective gear is essential to safeguard human capital.

Ultimately, bridging global and regional labor divides requires visionary policies that integrate technological innovation, social protection, and inclusivity. By addressing these gaps, agriculture can transition from being labor-intensive and inequitable to becoming a driver of sustainable livelihoods and dignified employment.

Conclusion

The agricultural labor market is at a pivotal moment of transformation, shaped by demographic transitions, climate risks, gender disparities, and rapid technological innovation. While these forces present significant challenges, they also create opportunities for reimagining agriculture as a modern, equitable, and resilient sector. For Pakistan, where agriculture remains the backbone of rural livelihoods, the stakes are particularly high. Rising urban migration, low mechanization, and widespread informal employment threaten the sector's sustainability, yet targeted reforms can reverse these trends. Ensuring secure land rights for women, investing in youth-focused agri-startups, and strengthening labor protections are not only moral imperatives but also economic necessities for long-term growth.

At the same time, the integration of digital technologies, climate-smart practices, and safety measures can shift agriculture from a low-status occupation to a professionalized field with dignified opportunities. Global experiences from migrant labor protections in Europe to agri-tech booms in India offer valuable lessons for Pakistan to adapt and contextualize. Ultimately, the future of

agricultural labor depends on inclusive policies that empower marginalized groups, modernize skill sets, and build resilience against climate shocks. With bold action, agriculture can evolve into a sector that safeguards livelihoods, ensures food security, and sustains prosperity for generations to come.

References: FAO; ILO; World Bank; Pakistan Bureau of Statistics; UNDP; USDA; MAFF; Grand View Research; UN Women; UN Women

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Vertical and Urban Farming: Sustainable Solutions

Explore the transformative impact of vertical and urban farming on sustainable agriculture. Discover how these innovative systems enhance food security, conserve resources, and create economic opportunities in urban environments.

Alizeh Faisal

8/5/2025

Rapid urbanization, climate change, arable land scarcity, and growing food insecurity are profoundly transforming the agricultural landscape worldwide. In response, vertical farming (VF) and urban farming (UF) have emerged as groundbreaking innovations, integrating technology and sustainability to enhance food production in non-traditional spaces. These approaches allow controlled-environment agriculture (CEA), facilitating consistent, year-round crop cultivation while minimizing environmental degradation. As traditional farming faces mounting constraints, VF and UF offer practical alternatives that conserve resources, reduce food transportation emissions, and ensure proximity between food producers and urban consumers.

The evolution of these systems reflects a convergence of agricultural science, engineering, and smart technologies. VF utilizes stacked layers and hydroponic or aeroponic methods, often integrated with artificial intelligence (AI), the Internet of Things (IoT), and precision lighting to optimize growth cycles. UF, on the other hand, includes rooftop gardens, community plots, and indoor farms, supporting local food resilience and community engagement. Both methods drastically reduce water usage, by up to 95% compared to conventional farming, and limit post-harvest losses through proximity to consumers. They also generate significantly higher yields per unit area. For instance, VF can produce up to 100 times more lettuce per hectare than open-field methods (Nature, 2024).

Globally, policy momentum is growing. Singapore's "30 by 30" initiative and the EU Green Deal are investing in urban-agri systems to strengthen food sovereignty. Pakistan, however, is still in early stages, hindered by high setup costs, energy demands, and limited awareness. Nonetheless, private startups and academic research are gaining traction, especially in Lahore, Karachi, and Islamabad.

With the global vertical farming market expected to reach $20.3 billion by 2029 (Grand View Research, 2024), the critical question remains: can VF and UF become economically scalable models for mainstream agriculture, or will they remain niche trends in a fragmented food future?

Vertical and Urban Farming: Modern Methods for a Sustainable Food Future

Vertical farming (VF) is a revolutionary method of growing crops in vertically stacked layers, often in controlled indoor environments. It relies on cutting-edge technologies and soilless growing systems such as hydroponics (where crops grow in a nutrient-rich water solution), aeroponics (which nourishes roots through mist), and aquaponics (a closed-loop system combining fish farming with plant cultivation). These approaches minimize resource use while maximizing space efficiency and crop yields. Leafy greens like lettuce and spinach are the most common VF crops, yielding 50–80 kg per square meter annually with short 21–30-day growth cycles. Herbs such as basil, and even strawberries, are increasingly being grown through vertical farming due to the predictable conditions and rapid harvest turnaround. According to Agritecture (2024), this makes VF a highly productive model, especially in urban areas where land is scarce.

One of the biggest advantages of VF is land-use efficiency. A single acre of vertical farming can produce the same output as 10–20 acres of traditional farmland (Forbes, 2023). Additionally, the enclosed nature of these systems allows for pesticide-free cultivation, improving both food safety and environmental health.

Urban farming (UF), while less technologically intensive, plays a vital role in promoting food access and community resilience. UF includes rooftop gardens, vacant plot cultivation, balcony farming, and indoor microgreen production. Karachi's "Urban Greens" and Islamabad's "Grow Your Food" campaigns exemplify successful UF models, engaging citizens in localized food production. Microgreens, nutrient-dense crops harvested within 7–14 days, are especially popular due to their short cycles and high market value. Together, VF and UF offer scalable, eco-friendly solutions that contribute to urban sustainability, reduce food miles, and enhance food security in rapidly urbanizing regions like Pakistan.

Unpacking the Economics of Vertical and Urban Farming in Pakistan

Vertical and urban farming offer significant economic promise for Pakistan's evolving agri-food systems, especially in the face of urbanization, youth unemployment, and climate stress. Urban farming (UF) generates between 5 to 10 jobs per acre (ILO, 2023), providing employment in cities where job opportunities in traditional agriculture are limited. Moreover, locally grown herbs and produce often command a 20–30% price premium in urban markets due to freshness and reduced transportation costs (Pakistan Agri Journal, 2024).

On the other hand, vertical farming (VF) stands out for its year-round productivity. With 10–12 harvests annually compared to 2–3 in conventional open fields (MIT, 2023), VF maximizes land and time. However, energy remains a major operational cost, LED lighting alone can account for 60% of expenses (World Bank, 2024). The return on investment (ROI) varies by model: VF requires $500–1,000 per m² in setup costs with a 3–5 year payback period, while UF is relatively affordable at $50–200 per m² and pays back in 1–2 years (Statista, 2024).

Pakistan's VF/UF sector is constrained by high initial costs, import duties (up to 30% on hydroponic kits), and an unstable energy supply. Yet, there are signs of progress. Sindh's first VF farm (2016) grows over 2,500 plants per cycle, and UAF's hydroponics lab trains hundreds of farmers annually. Policy support exists in Punjab's 2023 Agri-Policy, while Karachi's rooftop gardening initiative has created over 1,000 green roofs to fight urban heat.

Globally, countries like Singapore, the U.S., and the Netherlands demonstrate scalable models through research grants, subsidies, and urban agri-zones. For Pakistan, recommended strategies include import duty waivers on agri-tech, PPPs to deploy smart monitoring tools, and solar energy integration to lower VF costs. With the right support, these innovations can drive urban food security and agri-entrepreneurship.

Conclusion

Vertical and urban farming represent transformative shifts in the agricultural paradigm, offering scalable, sustainable, and resource-efficient food production systems amid growing climate, land, and pressures of urbanization. Their potential to produce high yields in limited spaces, conserve water, reduce pesticide use, and shorten supply chains makes them powerful tools for future food security. Economically, these systems create employment, reduce transportation costs, and provide premium market opportunities, especially in urban centers. While vertical farming boasts technological sophistication and year-round productivity, urban farming offers affordability and strong community engagement.

For Pakistan, the journey toward widespread adoption is underway but faces notable hurdles, including high capital expenditure, inconsistent energy supply, limited public awareness, and absence of targeted policy support. Yet, encouraging examples, like Sindh's pioneering VF farm and Karachi's green rooftops, demonstrate feasibility. Academic institutions and pilot projects are laying the groundwork, and with strategic investments, duty reductions, public-private partnerships, and renewable energy integration, these innovations could scale rapidly.

Ultimately, vertical and urban farming are not just niche alternatives but essential components of a diversified, climate-resilient agri-food system. Their integration into Pakistan's agricultural future will depend on enabling policies, technological adaptation, and a shift in both public mindset and institutional priorities. Their success could mark a significant step toward greener cities and resilient food economies.

References: FAO; World Bank; Grand View Research; Punjab Agriculture Department; Khan; Nature; Agritecture; Forbes; ILO; MIT; Statista

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International Aid's Impact on Agricultural Development

Explore the complex role of international aid in agricultural development. Discover how aid contributes to food security, infrastructure, and productivity in low- and middle-income countries, while also examining the effectiveness of aid based on contextual factors.

Kashmala Iqbal

8/6/2025

International aid plays a pivotal role in agricultural development by offering financial support, technical know-how, and capacity-building to countries striving to modernize their agricultural sectors. According to the OECD (2023), global agricultural aid reached $13.5 billion in 2021. This support has helped fund rural infrastructure projects, promote the adoption of improved farming technologies, and enhance food security. However, the real impact of aid depends heavily on how well it aligns with national development priorities, local agroecological conditions, and long-term sustainability goals (World Bank, 2022).

In recent years, the nature of aid has evolved. Donor countries and international organizations have increasingly focused on cross-cutting themes such as climate resilience, nutrition-sensitive agriculture, gender equity, and digital farming solutions. Yet challenges remain. Critics argue that aid can create dependency, distort local markets, or favor donor-driven agendas rather than grassroots needs. For example, tied aid, and conditional assistance on the purchase of donor-country goods, can reduce cost-effectiveness and local ownership.

This chapter critically examines whether agricultural aid genuinely promotes lasting development or merely offers temporary relief. It evaluates trends in donor commitments, regional disparities in fund allocation, and the shifting focus from food production to broader rural livelihoods. Particular attention is given to the interaction between international aid and domestic policy frameworks, as weak institutions, corruption, and policy incoherence often dilute the benefits of aid.

Furthermore, the chapter explores how agricultural aid can be better positioned to address contemporary global challenges. These include climate change adaptation, biodiversity conservation, food insecurity, and the growing need for sustainable intensification. By drawing on recent empirical studies, policy reviews, and case examples, the chapter offers a nuanced understanding of aid's potential and limitations in catalyzing agricultural transformation and inclusive rural development.

The Impact of International Aid on Agricultural Development

International aid has significantly influenced agricultural development by providing financial resources, technical expertise, and targeted support to address both persistent and emerging challenges. One of its most tangible impacts lies in infrastructure development. Between 2010 and 2020, the World Bank alone allocated over $30 billion to agriculture-related projects, leading to notable improvements in irrigation, road connectivity, and post-harvest storage systems across Sub-Saharan Africa and South Asia (World Bank, 2021). These investments have boosted productivity and market access. However, the volatility of aid flows, marked by steep declines in the 1990s followed by a resurgence in the 2000s, continues to challenge long-term development planning (OECD, 2022).

Beyond infrastructure, aid facilitates the transfer of technical knowledge and capacity-building. Institutions such as the International Fund for Agricultural Development (IFAD) have trained over 50 million smallholder farmers in climate-resilient and sustainable farming practices since 2010 (IFAD, 2023). These initiatives have helped improve yields, build adaptive capacity, and promote environmentally sound techniques, although their success hinges on consistent, long-term support.

In the context of rising global challenges such as climate change and acute food insecurity, aid has increasingly focused on resilience. The Green Climate Fund (GCF) has committed $2.5 billion since 2015 to make agriculture more climate-resilient (GCF, 2023). Emergency humanitarian aid, such as the UN's $4.3 billion appeal for the Horn of Africa in 2022 (UNOCHA, 2022), underscores aid's vital role in crisis response.

Ultimately, the effectiveness of aid depends on several key factors: alignment with national policies, strong local ownership, stable long-term funding, and evidence-based interventions. For instance, Ethiopia's Agricultural Transformation Agency demonstrates how state-donor collaboration can drive real results. However, with only 40% of aid projects undergoing rigorous evaluations (CGD, 2021), improved accountability and learning mechanisms remain essential for maximizing impact.

Historical Evolution and Allocation Patterns in Agricultural Aid

The trajectory of international agricultural aid has mirrored global economic and political shifts, reflecting changing donor priorities and evolving development paradigms. During the 1970s and 1980s, agricultural aid reached an annual peak of $12 billion, largely driven by the momentum of the Green Revolution, which focused heavily on boosting crop yields through investments in high-yield varieties, fertilizers, and irrigation infrastructure (OECD, 2002). However, the 1990s and early 2000s saw a dramatic decline, funding dropped by nearly 50%

as donors shifted focus toward governance, health, and education (FAO, 2020). Since 2010, global concern over food security has reignited interest in agricultural support, exemplified by the U.S. Feed the Future Initiative, which has invested over $5 billion to enhance smallholder productivity and resilience (USAID, 2023).

A sectoral breakdown reveals varying levels of success. Irrigation, once a cornerstone of aid efforts, received $10.4 billion in World Bank loans between the 1960s and 1980s. Yet many projects underperformed due to neglect of long-term maintenance and community engagement (World Bank, 2018). Agricultural credit initiatives, such as those led by the Grameen Bank, made credit more accessible to rural communities but often lacked financial sustainability (UNDP, 2021). Meanwhile, agricultural research and extension, particularly through the CGIAR system, yielded strong returns, $10 in benefits for every $1 invested, though funding has remained inconsistent (CGIAR, 2022).

Comparative case studies further highlight how aid effectiveness is shaped by domestic policy alignment. India, which received primarily food aid (60%) from 1949 to 1982, leveraged this support alongside strong institutions and the Green Revolution to combat famine and achieve self-sufficiency. In contrast, Sub-Saharan Africa has received higher per capita aid in recent decades ($20–$50), but has struggled with fragmented programming and institutional weaknesses, limiting long-term impact (World Bank, 2020; OECD, 2023).

Conclusion

International aid has played a crucial, though complex, role in agricultural development. Its contributions to infrastructure, capacity-building, and technological innovation have helped improve productivity, food security, and rural livelihoods in many low- and middle-income countries. However, the long-term effectiveness of aid remains uneven and heavily dependent on contextual factors such as policy alignment, institutional strength, and the nature of donor-recipient relationships. Historical trends reveal how shifting global priorities have influenced the volume and focus of agricultural aid, from productivity-driven investments during the Green Revolution to the more recent emphasis on climate resilience, nutrition, and inclusive growth.

Case studies such as India's Green Revolution success and the mixed outcomes in Sub-Saharan Africa highlight the importance of strong domestic institutions, coordinated planning, and local ownership in maximizing aid outcomes. While initiatives like CGIAR and IFAD have delivered high returns, inconsistencies in funding and weak evaluation mechanisms continue to hamper learning and accountability. Moving forward, agricultural aid must be more strategic grounded in local realities, responsive to emerging global challenges like climate change and biodiversity loss and embedded within coherent policy frameworks. Only then can aid shift from temporary relief to becoming a transformative force that promotes sustainable, equitable, and resilient agricultural systems.

References: OECD; World Bank; IFAD; CGIAR; FAO; GCF; UNOCHA; CGD; USAID; UNDP; CGIAR

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Gene Revolution: Transforming Pakistan's Agriculture

Explore how the gene revolution can address chronic yield gaps in Pakistan's agriculture, conserve water, and adapt to climate change, unlocking new economic opportunities in crops and livestock.

Wajhullah Fahim

8/12/2025

Half a century ago, Pakistan joined the world in celebrating the Green Revolution, a period when improved seeds, fertilizers, and irrigation transformed agriculture, helping feed millions. Today, however, the benefits of that revolution are plateauing. Yields of major crops are stagnating, water resources are under strain, and climate change is taking an ever-tougher toll.

Enter the Gene Revolution. This new era is powered by biotechnology, the deliberate alteration, recombination, and transfer of DNA to create plants and animals with new, desirable traits. In agriculture, it means crops that can resist pests without chemical sprays, withstand extreme heat or drought, and deliver higher yields from the same or even less land. It also promises livestock that are healthier, more productive, and better suited to local environments.

For Pakistan, the potential is immense. Genetically engineered crops could help achieve Sustainable Development Goal 2 (Zero Hunger) by boosting yields, reducing losses, and cutting reliance on costly agrochemicals. With climate-resilient varieties, farmers could adapt to the floods, droughts, and temperature swings that are already reshaping the growing season. For consumers, the benefits could mean a more stable food supply at affordable prices.

Yet, despite the promise, Pakistan's agricultural system is struggling to capture the benefits of this revolution. The sector contributes around 24% of GDP and employs 37% of the labor force, but its productivity lags behind global competitors. Four intertwined challenges make the case for urgent transformation.

The Challenges Holding Back Pakistan's Agriculture

Pakistan ranks among the top ten global producers of wheat, rice, and sugarcane — yet its yields per hectare are among the lowest in the world. Farmers work hard but harvest less than their counterparts in countries like China, Egypt, or even neighboring India. This productivity gap translates into lost income for farmers and higher food prices for consumers.

Four crops, wheat, rice, sugarcane, and cotton, consume about 80% of Pakistan's available water, yet together contribute just 5% to GDP (Maqbool, 2022). In a country already facing severe water scarcity, continuing to grow these crops using traditional, water-intensive methods is economically and environmentally unsustainable.

Pakistan ranks among the top ten most climate-vulnerable countries (Eckstein et al., 2019). The 2022 floods alone caused an estimated US$3.7 billion in agricultural losses (GoP, 2023). Rising temperatures, erratic rainfall, and shifting seasons threaten both crop and livestock production, making resilience a top priority.

The livestock sector accounts for 61% of agricultural value added and about 15% of GDP (GoP, 2024). Yet productivity is low due to poor genetics, limited disease control, and inadequate investment. Farmers often face devastating losses from preventable diseases, and milk and meat yields remain far below international benchmarks (Ghafar et al., 2020).

Given these challenges, Pakistan's earlier "Green Revolution" tools, better irrigation, fertilizers, and conventional breeding, are no longer enough. What is needed is a Gene Revolution tailored to the country's unique needs.

The Barriers to a Gene Revolution in Pakistan

Globally, regulation of genetically modified organisms (GMOs) began in the late 20th century, with countries like the United States introducing biosafety rules in 1984 and China in 1997. Pakistan established its National Biosafety Committee (NBC) in 1994 and passed the Pakistan Biosafety Act in 2005. The Pakistan Environmental Protection Agency (Pak-EPA) then set up the National Biosafety Centre to oversee implementation.

However, the 18th Constitutional Amendment shifted environmental matters to the provinces, creating regulatory confusion and turf battles between federal and provincial authorities. The result: overlapping jurisdictions, lengthy approval processes, and a legal stalemate. In 2014, for example, the Lahore High Court directed the federal government to issue licenses for GM cotton and maize, but the Supreme Court suspended the order a month later (Ebrahim, 2014).

Today, GMO approval in Pakistan involves multiple layers of committees and agencies, a process so cumbersome it discourages innovation.

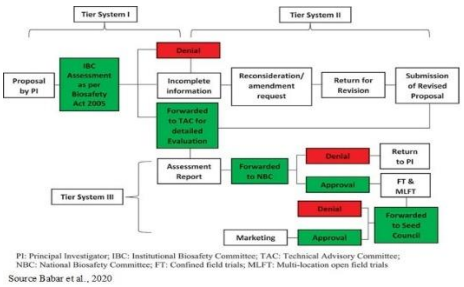

Figure 1: GMO Approval Process in Pakistan

Some religious leaders and communities view genetic modification as tampering with nature or divine creation. Without proper engagement, these concerns can turn into organized resistance, stalling adoption of beneficial technologies.

For private-sector innovators, patents and plant breeders' rights are essential incentives. While Pakistan passed the Seed (Amendment) Act 2015 and the Plant Breeders' Rights Act 2016, the requirement to submit seed samples to the National Agricultural Research Centre (NARC) for verification adds another bureaucratic hurdle, slowing commercialization.

The agriculture sector intersects with multiple ministries and departments from water and irrigation to livestock and climate change. After the 18th Amendment, some of these responsibilities shifted to provinces while others remained federal, weakening collaboration. Public-sector universities, research boards like PARB, and think tanks like PARC and PSF work on gene engineering projects, but without a robust information-sharing framework, efforts remain fragmented.

The Way Forward: Catalyzing Pakistan's Gene Revolution

Pakistan's biosafety framework needs an overhaul to eliminate unnecessary overlap between federal and provincial authorities. One option is to adopt internationally recognized third-party certification systems such as the International Organization for Standardization (ISO) or the Codex Alimentarius Commission (CAC).

E-governance can make applications faster and more transparent, reducing the discretionary power of bureaucrats. Federal agencies could focus on import/export regulation, while provinces develop and enforce locally relevant biosafety rules using modern tools like satellite imagery and drones.

Turkiye offers a successful example: by holding open dialogues, creating ethical review boards, and involving religious scholars in policy discussions, the government built public confidence in biotechnology. Pakistan can replicate this model, ensuring that genetic advancements align with cultural and religious principles while dispelling myths about genetic modification.

A National Gene Revolution Steering Committee could bring together agricultural scientists, environmentalists, livestock experts, economists, and representatives from federal and provincial governments. Meeting quarterly, this body would share data, track progress, and coordinate projects across the public and private sectors.

Biotechnology adoption depends on more than government approval; farmers need to understand its benefits and practical application. Demonstration plots, farmer field schools, and mobile-based advisory services could bridge the knowledge gap, ensuring that smallholders as well as large-scale producers' benefit.

Conclusion

The Green Revolution transformed Pakistan's agriculture once before, but the challenges of the 21st century demand new tools. The Gene Revolution, if pursued strategically, can help Pakistan overcome chronic yield gaps, conserve precious water, adapt to climate change, and unlock new economic opportunities in both crops and livestock.

Yet technology alone is not enough. Without streamlined regulations, strong public engagement, effective intellectual property protections, and robust institutional coordination, the promise of biotechnology will remain out of reach. By learning from global best practices and adapting them to local realities, Pakistan can make the leap from potential to practice, securing a food-secure, climate-resilient future for its people.

References: Babar et al.; Ebrahim; Eckstein et al.; Ghafar et al.; GoP; Maqbool; Sherin

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Understanding Agricultural Subsidies

Explore the complexities of agricultural subsidies in global economic policy. With over $850 billion allocated annually, these subsidies provide stability yet contribute to inefficiencies and environmental harm. Learn about their impact on food systems and global inequalities.

Ayesha Rashid

8/19/2025

Agricultural subsidies remain one of the most debated instruments in global economic policy. Designed to stabilize food prices, protect farmers' livelihoods, and safeguard food security, they have undeniably played a critical role in shaping modern agriculture. Yet, the benefits of subsidies are increasingly overshadowed by their unintended consequences, market distortions, ecological harm, and inequities between nations.

By 2024, worldwide agricultural subsidies had surged to an estimated $850 billion annually (OECD, 2024). Strikingly, evidence shows that nearly 87% of these supports are environmentally harmful (World Bank, 2024), perpetuating practices that deplete soil fertility, encourage overuse of chemical inputs, and accelerate greenhouse gas emissions. In high-income countries, subsidies are often funneled toward large-scale producers, reinforcing industrialized farming systems and creating barriers for smallholders in developing nations. This imbalance not only deepens rural poverty but also exacerbates global trade tensions, as subsidized exports undermine farmers in less-subsidized regions.

Recent policy debates highlight the urgent need for reform. Countries are exploring mechanisms to reorient subsidies toward climate-smart agriculture, biodiversity protection, and regenerative practices. For instance, the European Union's Common Agricultural Policy is gradually integrating "eco-schemes" to reward farmers for sustainable land management, while nations such as India are experimenting with direct income support in place of fertilizer and input subsidies. Such shifts represent early attempts to transform subsidies from environmentally harmful transfers into drivers of resilience and innovation.

Ultimately, the challenge lies not in eliminating subsidies but in redesigning them to align with sustainability goals. Redirecting even a fraction of current support toward green technologies, precision farming, and ecosystem services could accelerate progress toward climate targets while strengthening rural economies. Achieving this balance is essential for ensuring that subsidies serve as enablers of both food security and environmental stewardship in the decades ahead.

Global Agricultural Subsidies: Scale, Distortions, and Pathways for Reform

Agricultural subsidies have become one of the most powerful levers of economic and food policy worldwide, shaping how and where food is produced, traded, and consumed. In 2024, governments collectively spent more than $850 billion annually on farm support, a figure that continues to rise in response to climate shocks, food price volatility, and geopolitical uncertainty. Yet, while subsidies aim to stabilize markets and protect farmers, they often generate far-reaching distortions in trade, resource use, and environmental sustainability.

China remains the single largest subsidizer, channeling $212 billion annually into agriculture, largely to secure grain self-sufficiency and rural income stability (FAO, 2024). The European Union follows with €62 billion under its Common Agricultural Policy (CAP), of which 25% is earmarked for eco-schemes designed to support environmental sustainability (EC, 2024). Meanwhile, the United States expanded subsidies to $55 billion in 2024, with the Farm Relief Act injecting $15 billion to aid drought-affected farmers (USDA, 2024). The intensity of support varies sharply across countries: while Norway and Switzerland direct over half of farm revenues through subsidies, Brazil provides only 5% (OECD, 2024).

The structure of subsidies reveals additional complexity. Market price supports, such as those for EU dairy and U.S. cotton, inflate consumer prices by an estimated 3.5% in protected markets (WTO, 2024), while China's wheat subsidies depress world prices, hurting exporters in Africa (IFPRI, 2024). Direct payments, a hallmark of U.S. and EU systems, disproportionately benefit large farms, with the top 1% of U.S. producers capturing 26% of total subsidies (EWG, 2024). Input subsidies are equally problematic: India spends $28 billion annually on fertilizers, contributing to groundwater depletion and soil degradation (World Bank, 2024).

These systems impose major economic and trade distortions, valued at $620 billion annually, with price supports alone accounting for 60% (OECD, 2024). Tensions are evident in the U.S.-Mexico corn dispute, where Mexico's ban on GM corn threatens $6 billion in trade (USDA, 2024). Subsidies also widen inequities: smallholders in Africa and Asia receive less than 10% of total support (IFAD, 2024), while EU milk subsidies undercut Kenyan dairy farmers, costing $200 million annually in lost incomes (Trade Justice Africa, 2024).

The environmental costs are equally alarming. Beef and dairy subsidies are linked to 18% of global greenhouse gas emissions (FAO, 2024), while palm oil subsidies drive 30% of Indonesia's deforestation (Global Forest Watch, 2024). Redesigning subsidies presents a

transformative opportunity: shifting funds toward regenerative farming could sequester up to 5.1 Gt CO_2 annually (Nature Sustainability, 2024). Promising models exist, such as Andhra Pradesh's zero-budget farming initiative, which reduced input costs by 40% while sustaining yields (ICRISAT, 2024).

Case studies highlight the gap between policy ambitions and outcomes. In the U.S., the 2024 Farm Relief Act reinforced crisis-driven policy dependence, while crop insurance subsidies, costing $12 billion annually, flowed disproportionately to the wealthiest farms (USGAO, 2024). In the EU, eco-schemes covered just 15% of farmland despite receiving a quarter of CAP's budget, while dairy subsidies fueled overproduction, boosting exports by 7% in 2024 (Eurostat, 2024).

Taking it together, these trends reveal the paradox of global farm subsidies: while designed to safeguard food systems, they often deepen inequalities, distort markets, and fuel environmental decline. Meaningful reform will require not only reallocating funds toward sustainability but also addressing the political and institutional inertia that perpetuates harmful practices.

Policy Recommendations for 2025 and Beyond

As governments grapple with the economic, social, and environmental consequences of agricultural subsidies, the urgent need for reform has never been clearer. Evidence shows that while subsidies can cushion farmers against shocks, a large share of global support fuels market distortions, entrenches inequality, and accelerates environmental degradation. To realign subsidies with the objectives of sustainability, equity, and resilience, four key recommendations emerge for 2025 and beyond.

First, harmful subsidies must be phased out, particularly price supports and loopholes in crop insurance schemes that disproportionately benefit large-scale producers (OECD, 2024). These policies not only inflate consumer prices but also crowd out investment in more sustainable practices. Transitioning away from such subsidies requires careful sequencing, coupled with safety nets to ensure vulnerable farmers are not left behind.

Second, governments should invest in public goods rather than private subsidies, redirecting an estimated $200 billion annually toward agroecological research, infrastructure, and rural extension services (World Bank, 2024). These investments would deliver broad-based benefits, from climate resilience to biodiversity protection, while reducing dependence on chemical-intensive farming systems.

Third, global coordination is essential. Strengthening World Trade Organization (WTO) rules to cap trade-distorting subsidies could prevent the "subsidy races" currently seen between major producers (ICTSD, 2024). Greater transparency and enforcement mechanisms would also help developing nations, whose farmers often suffer most from depressed global prices.

Finally, support must shift directly to smallholders, who currently receive less than 10% of global subsidies (IFPRI, 2024). Direct cash transfers and income support are more efficient and equitable than input subsidies, which often encourage overuse of fertilizers and water. Empowering smallholders not only strengthens rural livelihoods but also enhances global food security.

Conclusion

Agricultural subsidies, once conceived as instruments to secure food systems and protect farmers, have evolved into one of the most complex and contentious elements of global economic policy. By 2024, their sheer scale, over $850 billion annually, underscores both their influence and their contradictions. On one hand, subsidies provide stability in the face of climate shocks, market volatility, and geopolitical disruptions. On the other, they fuel inefficiency, widen global inequalities, and accelerate environmental degradation, with nearly 87% categorized as harmful to ecosystems.

The evidence makes clear that the status quo is unsustainable. Subsidies that disproportionately favor industrial agriculture and large-scale producers undermine smallholder farmers, distort global trade, and lock food systems into high-emission, resource-intensive practices. Yet, the solution is not abolition but transformation. Redirecting even a fraction of global farm support toward public goods, such as agroecology, climate-smart technologies, and biodiversity protection, could deliver outsized benefits for both people and the planet.

Reform will require political courage, international cooperation, and a deliberate focus on equity. If governments commit to phasing out harmful subsidies, investing in resilience, and empowering smallholders, subsidies can shift from being barriers to progress into catalysts of a sustainable and inclusive global food system.

Key References: OECD; World Bank; USDA; IFPRI; EC; WTO; EWG; IFAD; Trade Justice Africa; Global Forest Watch; Nature Sustainability; ICRISAT; USGAO; Eurostat; ICTSD

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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IMF & World Bank: Evolving Roles in Agriculture

Explore the evolving roles of the IMF and World Bank from structural adjustment to fostering resilience, inclusion, and climate-smart agriculture. Discover how their collaboration can lead to a sustainable and equitable future for global agriculture, benefiting people and the planet.

Eman Saleem

8/20/2025

Agriculture remains the backbone of livelihoods for billions, yet it is deeply entangled with the global financial and policy frameworks shaped by international institutions. Among these, the International Monetary Fund (IMF) and the World Bank have exercised profound and lasting influence. While neither was founded with agriculture as its core mandate, their interventions from macroeconomic prescriptions to direct financing of rural projects have redefined how farming, food security, and rural development are understood and pursued across the developing world. This article examines their historical legacies, evolving roles, areas of collaboration, persistent critiques, and emerging directions in shaping the future of global agriculture.

Founded in 1944 at Bretton Woods, both the IMF and the World Bank emerged from the wreckage of World War II with complementary missions. The IMF's mandate centers on ensuring global monetary stability, offering policy advice and financial support to countries grappling with balance-of-payments crises. While not an agricultural development agency per se, its macroeconomic interventions such as enforcing fiscal discipline, managing exchange rates, and curbing inflation shape the enabling environment in which agricultural policies and investments unfold (IMF, 2023).

The World Bank, by contrast, took on the longer-term mission of ending extreme poverty and promoting shared prosperity. Its agricultural footprint has been extensive, with the International Development Association (IDA) and the International Bank for Reconstruction and Development (IBRD) committing $12.1 billion to agriculture and food security in FY2023 alone (World Bank Annual Report, 2024). Beyond financing, the Bank provides technical assistance, policy advice, and global data analysis that set benchmarks for national and regional agricultural strategies.

Historical Context: From Structural Adjustment to Rural Reforms

The 1980s and 1990s saw the joint imposition of Structural Adjustment Programs (SAPs), which remain one of the most controversial chapters in the IMF–World Bank legacy. Under SAPs, borrowing countries were required to cut subsidies, liberalize trade, and privatize state enterprises as conditions for receiving loans. While intended to stabilize economies and integrate them into global markets, these reforms often had devastating effects on rural communities. In Sub-Saharan Africa, for instance, fertilizer subsidy cuts led to a 15–20% decline in input use among smallholders, widening yield gaps and reducing food security (Binswanger-Mkhize, 2023).

Criticism of these programs catalyzed a strategic shift. The World Bank's 2008 *World Development Report: Agriculture for Development* openly acknowledged past missteps and called for more holistic approaches that integrated rural development, social protection, and sustainability (World Bank, 2008). This marked a turning point, signaling greater attention to poverty alleviation and climate resilience alongside macroeconomic reform.

The IMF's Evolving Role in Agriculture

The IMF's influence in agriculture is indirect but powerful, shaping the fiscal and monetary conditions that determine whether governments can invest in the sector. By stabilizing currencies and curbing hyperinflation, the Fund helps create environments conducive to long-term agricultural investments. For example, a 2023 IMF-supported program in Zambia focused on fiscal consolidation, which freed up resources for irrigation and rural infrastructure (IMF Country Report, 2023).

Debt sustainability is another critical dimension. With over 60% of low-income countries either at high risk of debt distress or already in it (IMF, 2024), the IMF's frameworks for debt restructuring directly affect the fiscal space available for agricultural investments. Without such measures, governments often divert scarce resources to debt servicing instead of investing in climate-smart infrastructure or farmer support.

A more recent innovation is the Resilience and Sustainability Trust (RST), which provides affordable, long-term financing to help countries adapt to climate change and future shocks. Several countries have already used RST funds to invest in climate-smart agriculture and food system resilience, illustrating how the IMF is broadening its role beyond traditional macroeconomic stabilization to explicitly address sustainability (IMF, 2024).

The World Bank's Direct and Expansive Role

Unlike the IMF, the World Bank has a direct and expansive footprint in global agriculture. It remains the world's largest multilateral financier of agricultural development. In FY2023, nearly 70% of its agricultural lending was directed toward climate adaptation

and mitigation (World Bank, 2024). This reflects a strategic alignment with global priorities around climate-smart food systems.

Key initiatives highlight this orientation. The *Food Systems 2030 Trust Fund*, a $300 million multi-donor facility, supports transformation projects aimed at making food systems more inclusive, nutritious, and sustainable. The *Africa Regional Integration Program*, meanwhile, works across 19 countries to enhance climate-smart agriculture, boost productivity, and improve cross-border trade in food staples.

Beyond financing, the Bank plays an important role in policy reform and technical assistance. In India, the World Bank's expertise contributed to the National Innovation on Climate Resilient Agriculture (NICRA), which fostered the development of drought-resistant crop varieties and improved water-use efficiency (World Bank, 2023). Additionally, through flagship publications such as the *Future of Food Report* (2023), the Bank provides data-driven insights that inform global investment flows and national agricultural strategies.

Collaborative Synergies and Country Success Stories

In recent years, the IMF and the World Bank have sought to harmonize their efforts, recognizing that macroeconomic stability and sectoral transformation must advance together. Country Climate and Development Reports (CCDRs) are a joint diagnostic tool that integrates climate priorities with national development planning. Ghana's CCDR, for example, recommended reinvesting cocoa revenues into diversified farming systems, ensuring both climate resilience and farmer welfare (World Bank–IMF, 2023).

Crisis response has also driven collaboration. During the global food crisis triggered by the war in Ukraine, the IMF offered budgetary support while the World Bank financed emergency food production and distribution projects. Together, their interventions exceeded $45 billion, showcasing how their complementary roles can mitigate both immediate shocks and long-term vulnerabilities (World Bank–IMF Joint Statement, 2023).

Vietnam's agricultural transformation offers perhaps the most striking example of successful synergy. Stabilized by IMF-supported macroeconomic policies and empowered by World Bank-funded projects, Vietnam shifted from food scarcity to becoming a leading agro-exporter. A recent $100 million digital agriculture initiative is providing half a million smallholders with access to real-time market data, financing, and climate advisory services, boosting farmer incomes by 18% and reducing post-harvest losses (World Bank Project Appraisal Document, 2024).

Persistent Criticisms and Challenges

Despite progress, criticisms endure. Policy conditionalities can still prioritize macroeconomic stability over local realities. Austerity measures, for instance, may reduce fiscal space for essential investments such as agricultural extension services or rural health programs. Similarly, the emphasis on public–private partnerships raise concerns that smallholders may be sidelined if agribusinesses dominate value chains (Oxfam, 2024).

Another critique concerns the pace of transformation. While sustainability rhetoric has grown stronger, significant financing still supports conventional, input-intensive farming models rather than fully transformative agroecological systems (IPES-Food, 2023). For critics, this raises doubts about whether institutional commitments are sufficiently bold to meet the scale of the climate and food security challenges ahead.

Future Directions

Both institutions are now articulating ambitious future agendas to reconcile inclusivity, sustainability, and economic growth. Four frontiers stand out. First, digital agriculture will be scaled up through fintech, satellite imagery, and mobile extension services, enhancing farmer access to markets and advisory tools. Second, nature-positive production is being mainstreamed, with lending increasingly tied to regenerative practices and payments for ecosystem services. Third, transition support is gaining traction, ensuring that communities dependent on high-emission agricultural practices are not left behind in the shift to greener systems. Finally, both institutions are tailoring agricultural programs for fragile and conflict-affected states, linking food system resilience to peacebuilding and economic recovery.

Conclusion

The IMF and the World Bank have traveled a long journey from the contested era of structural adjustment to their current focus on resilience, inclusion, and climate-smart agriculture. While their legacies remain mixed, their evolving roles demonstrate an increasing awareness of the need for integrated approaches. The IMF provides macroeconomic stability and debt relief that create fiscal space for investment, while the World Bank delivers targeted financing, technical expertise, and data-driven insights. Together, their synergies when responsive to local contexts and inclusive of smallholder voices have the potential to steer global agriculture toward a future that is not only more productive but also more sustainable and equitable. The challenge is to ensure that this transformation is both accelerated and truly inclusive, delivering for people, planet, and prosperity.

References: Binswanger-Mkhize; IMF; IPES-Food; World Bank; Oxfam

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Price Stabilization in Pakistan's Agriculture

Explore the critical role of price stabilization in Pakistan's agriculture sector. Understand the impact on farmers and consumers, the challenges of food inflation, and the need for policy reforms beyond just wheat and sugarcane.

Danish Masih

8/25/2025

Agriculture remains the bedrock of Pakistan's economy, contributing about 22.9% to GDP and employing 37.4% of the labor force (Pakistan Economic Survey, 2023-24). Yet, the sector continues to face severe price volatility, often triggered by climate shocks, water shortages, pest infestations, and global market fluctuations. Inefficient domestic market structures, poor storage facilities, and weak value chains further exacerbate instability. For farmers, this volatility translates into unpredictable incomes and heightened vulnerability, while for consumers it means erratic food prices and threats to food security. The broader economy is also affected, as volatile agricultural prices complicate inflation management and fiscal planning.

Recognizing these risks, the government frequently intervenes to stabilize prices. Key instruments include setting minimum support prices for staple crops like wheat and sugarcane, strategic imports or exports to balance domestic supply, and targeted subsidies. Procurement by public agencies such as the Pakistan Agricultural Storage and Services Corporation (PASSCO) helps secure farmer returns and stabilize supply chains. While these policies provide short-term relief, their long-term effectiveness remains debated. Delays in announcing support prices, inadequate procurement infrastructure, and political influence in commodity pricing often dilute intended benefits.

Recent case studies illustrate both progress and limitations. For example, wheat support programs have safeguarded producer incomes but at the cost of fiscal burdens and inefficiencies in storage and distribution. Similarly, interventions in the sugar sector have protected growers yet fueled consumer price hikes and distortions in trade. The challenge lies in balancing farmer protection with consumer welfare, while minimizing fiscal strain.

In the years ahead, Pakistan's agricultural price stabilization policies must evolve toward more market-oriented mechanisms, greater transparency, and improved storage and logistics. Only then can interventions move from reactive firefighting to building sustainable resilience across the food system.

The Imperative of Price Stabilization in Pakistan's Agriculture

The rationale for government intervention in agricultural pricing is both economic and social, rooted in the need to safeguard farmers, consumers, and the broader economy from destabilizing shocks. Farmers face risks not only from climate variability and pests but also from unpredictable price crashes when markets are oversupplied. Price guarantees, such as minimum support prices (MSPs), protect them from catastrophic income losses and encourage adoption of better inputs and technologies. On the consumer side, sudden spikes in staple food prices can quickly push millions below the poverty line, eroding purchasing power. The World Bank (2023) highlights that food price shocks remain a leading driver of poverty across South Asia. For governments, stable agricultural prices also reduce volatility in fiscal planning, limit emergency import expenditures, and contribute to macroeconomic stability. Most importantly, in rural Pakistan, home to the majority of the population stable farm incomes provide the foundation for poverty reduction and economic diversification.

To achieve these objectives, Pakistan employs a mix of policy instruments. MSPs serve as a critical price floor, especially for wheat and sugarcane. For the 2023-24 season, the wheat MSP was raised to PKR 3,900 per 40 kg, intended to offset high input costs and incentivize higher yields (Ministry of National Food Security & Research, 2023). Public procurement through institutions like PASSCO builds strategic reserves that can be released during shortages. In FY 2022-23, PASSCO procured over 1.8 million metric tons of wheat to bolster national stocks (PASSCO Annual Report, 2023). Trade measures such as export bans and import subsidies also serve as levers to regulate supply and prevent shortages. Following the 2022 floods, for example, exports of wheat and sugar were halted to prioritize domestic needs (Finance Division, 2022). Input subsidies on fertilizers, seeds, and electricity, alongside targeted transfers under the Benazir Income Support Program (BISP), further reduce production costs and stabilize prices indirectly.

The case of wheat illustrates both the strengths and weaknesses of Pakistan's stabilization policies. During 2020-21, timely procurement and buffer stock releases kept wheat flour prices relatively stable despite global COVID-19 disruptions. However, the catastrophic floods of 2022 destroyed nearly one-fifth of the wheat crop (FAO, 2022). Slow government response in arranging imports, coupled with hoarding, pushed flour prices to a record PKR 160 per kg in early 2023, sparking public protests (Trading Corporation of Pakistan Price Data, 2023). Eventually, aggressive interventions including higher MSPs, emergency imports, and anti-hoarding drives restored stability by 2024.

This cycle underscores both the necessity and the limits of price stabilization. While interventions remain indispensable to protect livelihoods and food security, they are often reactive, fiscally burdensome, and vulnerable to governance challenges.

Moving forward, Pakistan must strengthen early warning systems, improve procurement efficiency, and invest in storage and logistics. Only then can stabilization policies evolve from short-term firefighting to long-term resilience building for the country's food system.

Persistent Challenges and the Path to Reform

Despite the wide array of tools used to stabilize agricultural prices, Pakistan's system remains weighed down by chronic weaknesses. Large-scale procurement and subsidy operations impose a heavy fiscal burden, draining the national exchequer and adding to circular debt in the commodities sector. The political economy surrounding Minimum Support Prices (MSPs) further distorts outcomes, as decisions are often driven by electoral motives rather than sound economic reasoning. This has encouraged cropping patterns that are environmentally unsustainable, such as the over-cultivation of sugarcane in water-scarce regions.

Operational inefficiencies and corruption also undermine the credibility of stabilization efforts. Procurement agencies often fail to reach smallholders, while larger, politically connected landowners capture disproportionate benefits (IFPRI, 2021). The narrow crop focus of current policies compounds the issue. Wheat and sugarcane dominate the agenda, while essential crops such as pulses, oilseeds, and vegetables remain neglected, leaving consumers vulnerable to recurring food inflation. Trade policy adds another layer of uncertainty. Sudden export bans or import restrictions create volatility, deter private investment, and undermine the stability that policies are meant to provide.

Addressing these persistent challenges requires systemic reforms that shift the framework from reactive firefighting to long-term resilience building. Digitized farmer registries, integrated with NADRA, can improve targeting of subsidies and ensure support reaches smallholders directly. Developing market-based tools like warehouse receipt systems and commodity futures can give farmers private risk management options while reducing the state's fiscal exposure (World Bank, 2020). Trade policy must become transparent and rules-based, creating predictability for traders and investors. Expanding targeted safety nets like the Benazir Income Support Program is also essential, as universal price controls are fiscally unsustainable. Finally, building climate-resilient infrastructure spanning water storage, cold chains, and climate-smart farming practices addresses the root causes of volatility, offering a sustainable path toward stable agricultural markets.

Conclusion

Price stabilization in Pakistan's agriculture is not simply an economic exercise it is a lifeline for millions of farmers and consumers. The evidence shows that while interventions like MSPs, procurement, and trade controls can provide temporary relief, their fiscal burden, inefficiencies, and political distortions prevent them from offering durable solutions. Wheat and sugarcane may dominate the policy space, but ignoring pulses, oilseeds, and vegetables has kept food inflation stubbornly high and left dietary diversity neglected. At the same time, abrupt trade restrictions and poor procurement governance continue to erode confidence in government policy.

The path forward requires moving away from reactive, ad-hoc firefighting toward systemic reforms that build resilience. Targeted digital transfers, farmer registries, and safety nets must ensure that support actually reaches smallholders and poor households. Market-based instruments like futures trading and warehouse receipt systems can provide private risk management options, reducing reliance on costly government intervention. Above all, investment in climate-smart infrastructure and sustainable cropping systems is vital to address the structural drivers of price volatility.

Pakistan's agricultural future depends on a shift from short-term stabilization to long-term resilience. Without this transition, price volatility will keep undermining farmer incomes, consumer welfare, and national food security.

References FAO; IFPRI; Ministry of Finance, Government of Pakistan; Ministry of National Food Security & Research; PASSCO; TCP; World Bank

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Taxation Policy's Impact on Agriculture in Pakistan

Taxation policy plays a crucial role in shaping the future of agriculture in Pakistan. Current challenges include fragmented systems and inequitable burdens on smallholders, which hinder productivity and innovation. Learn how smart fiscal tools can transform the sector and enhance farmer incomes.

Hadia Zia

8/26/2025

Agriculture remains the backbone of Pakistan's economy, contributing 22.9 percent to GDP and employing 37.4 percent of the national labor force (Pakistan Economic Survey, 2023–24). Beyond its direct economic role, the sector underpins food security, sustains rural livelihoods, and anchors the broader socioeconomic stability of the country. Yet, it stands at a crossroads. Climate change is reshaping weather patterns and accelerating water scarcity, while rapid population growth is intensifying demand for food, fiber, and livestock products. At the same time, international market volatility and rising input costs are exerting new pressures on farmers and agribusinesses. Meeting these challenges requires not only technological modernization but also a more supportive policy environment that fosters investment, innovation, and competitiveness.

Among the policy instruments available, taxation is a critical but often neglected lever. Tax liabilities influence farm profitability, determine the pace of mechanization, and shape investment choices in areas such as irrigation, seed technology, and processing. In Pakistan, however, the current tax framework is often seen as fragmented, inconsistent, and cumbersome. High effective rates, coupled with complex compliance requirements, discourage small and medium-sized farmers from entering formal markets and limit their capacity to scale up operations. This environment inadvertently reinforces informality and underinvestment.

By contrast, a well-designed, sector-specific tax policy can play a transformative role. Targeted reliefs, simplified procedures, and incentives for adopting climate-smart technologies could encourage reinvestment, raise productivity, and enhance export competitiveness. Strategic tax reforms could also help align agricultural growth with broader national objectives such as food security, rural development, and sustainable resource management. For policymakers, investors, and farmers alike, understanding and reforming the tax regime is not a peripheral concern, it is central to unlocking the true potential of Pakistan's agriculture and securing its future resilience.

How Tax Policies Shape Investment Behavior in Pakistan

The tax environment in Pakistan's agriculture sector presents a paradox. While agriculture contributes 22.9 percent to GDP and remains the largest source of rural employment, its share in national tax revenue is less than 1 percent (World Bank, 2022). This underrepresentation stems from the devolution of agricultural income tax to provinces, where implementation has been inconsistent. Most provincial systems still rely on outdated notional income assessments rather than actual earnings, creating inefficiency and inequity (PATA, 2021). As a result, large landholders often remain undertaxed, while smaller farmers are discouraged from entering the formal system.

Tax policy has a direct bearing on investment behavior in agriculture. Predictable and well-targeted measures can unlock capital flows into mechanization, value addition, and climate-smart farming practices. Incentives such as tax holidays for agribusiness startups or accelerated depreciation of modern machinery encourage both domestic and foreign investors to channel resources into large-scale projects. Similarly, exemptions or reduced rates on inputs like seeds, fertilizers, and irrigation equipment can lower production costs and spur innovation.

On the other hand, poorly designed or unpredictable tax regimes create hesitation. Uncertainty surrounding provincial income tax laws, combined with cumbersome compliance procedures, acts as a disincentive to formal investment. Farmers and agribusinesses may choose to under-invest, avoid formal registration, or divert capital into non-productive assets as a hedge against policy risk. This undermines growth potential and perpetuates inefficiency.

In essence, taxation is not merely a tool for revenue collection but a signal to investors about the government's priorities. A clear, equitable, and investment-friendly tax framework could help Pakistan shift agriculture from subsistence to commercial competitiveness, ensuring that the sector not only feeds the population but also drives sustainable economic growth.

Effects of Taxation Policies on Agricultural Productivity and Innovation

Taxation policies play a decisive role in shaping the pace of agricultural modernization and innovation in Pakistan. At present, the sector receives only limited targeted tax incentives, leaving farmers with few financial levers to adopt advanced technologies. If carefully designed, measures such as tax deductions or exemptions for the purchase of precision agriculture equipment, GPS-guided tractors, drip

irrigation systems, solar-powered tubewells, and certified high-yield seed varieties, could drastically lower upfront costs. Such incentives would not only accelerate technology adoption but also expand productivity, reduce post-harvest losses, and enhance competitiveness in both domestic and international markets.

The structure of provincial agricultural taxation, however, often creates distortions. Smallholders, who already struggle with tight margins, end up bearing a disproportionate share of the tax burden. In contrast, large landowners frequently escape meaningful taxation due to outdated notional income assessments and weak enforcement mechanisms. This inequity limits the reinvest able surplus of small-scale farmers, trapping them in cycles of low productivity and poverty (International Growth Centre, 2020). By failing to channel resources toward those most in need of support, current taxation policies inadvertently stifle innovation and reinforce existing inequalities.

Beyond modernization and equity, taxation can also act as a lever for promoting sustainability. Well-crafted "green" tax incentives could encourage farmers to adopt environmentally friendly practices such as laser land leveling to conserve scarce water resources, organic farming to reduce chemical dependence, and agroforestry to improve soil fertility and carbon sequestration. Aligning tax policies with climate adaptation and environmental goals would not only build resilience but also position Pakistan's agriculture sector to respond to global market shifts where sustainability standards are increasingly decisive.

In short, taxation can either hold back or accelerate progress. A strategic, equitable, and sustainability-focused framework could make it a driver of innovation, productivity, and resilience in Pakistan's agriculture.

Regional and Global Variations: Lessons for Pakistan

Comparing taxation and incentive models from other countries provides valuable insights for Pakistan as it seeks to reform its agricultural sector. India, for instance, has demonstrated how state-level tax benefits and subsidies targeted at smallholders can lift rural incomes and improve farm productivity. Concessional loans, tax deductions on essential farm inputs, and state-specific relief measures have helped millions of Indian farmers transition toward more commercially viable agriculture. Pakistan, with a similar smallholder-dominated structure, could adapt these measures to strengthen rural livelihoods and reduce poverty.

Brazil offers another compelling example. By strategically using tax incentives to encourage investment in sugarcane for ethanol production, Brazil has transformed itself into a global leader in biofuels. This model is highly relevant for Pakistan, which possesses significant untapped potential in bioenergy crops such as sugarcane and maize. A carefully designed fiscal framework could stimulate investment in renewable energy, reduce dependence on imported fuels, and open new revenue streams for rural communities.

The Netherlands illustrates the transformative power of fiscal support for agricultural research and development. Tax incentives for innovation, coupled with close linkages between research institutions and the private sector, have propelled the country into the ranks of the world's most productive and technologically advanced agro-sectors. Pakistan could emulate this by aligning tax incentives with R&D investment, particularly in areas like climate-resilient crops, water-efficient farming, and advanced agro-processing.

However, Pakistan faces several risks that complicate the adoption of such models. Policy uncertainty, particularly due to inter-provincial disparities in agricultural income tax laws, erodes investor confidence and discourages long-term commitments. An inefficient and inequitable system increases production costs, leaving Pakistani exports less competitive against regional rivals like India and Vietnam. Moreover, widespread tax evasion and the narrow base of agricultural taxation highlight the urgent need to shift from outdated notional levies to income-based systems supported by stronger enforcement.

The potential of targeted incentives can be seen clearly in the dairy sector. Despite having the world's largest herd size, Pakistan's dairy productivity remains among the lowest globally. A well-designed tax framework, offering credits or exemptions for modern milking parlors, cold chain facilities, and high-yield animal imports, could unlock large-scale private investment. This would increase milk yields, raise farmer incomes, and reduce costly imports of milk powder, easing pressure on foreign exchange reserves.

To move forward, Pakistan needs a harmonized and simplified nationwide taxation framework, targeted incentives for modernization, green tax credits to encourage sustainable practices, stronger enforcement capacity, and above all, policy stability. A coherent and transparent fiscal roadmap would provide the certainty investors require while ensuring equity, competitiveness, and sustainability in Pakistan's agriculture.

Conclusion

The evidence is clear: taxation policy is not a marginal issue for agriculture in Pakistan but a central determinant of its future trajectory. At present, fragmented provincial systems, outdated notional assessments, and inequitable burdens on smallholders constrain both productivity and innovation. This imbalance not only suppresses farmer incomes but also prevents the sector from realizing its full potential as a driver of food security, rural development, and economic growth. By contrast, international examples, from India's targeted support for smallholders to Brazil's biofuel tax incentives and the Netherlands' R&D-driven framework, demonstrate how smart fiscal tools can transform agriculture into a competitive, technology-enabled, and sustainable sector.

For Pakistan, the path forward lies in building a coherent, equitable, and forward-looking tax framework. Incentives for mechanization, renewable

energy, and climate-smart practices can unlock productivity gains, while harmonize laws and streamlined compliance will attract investment and expand the tax base. Equally important is shifting taxation away from symbolic notional levies toward income-based systems that promote fairness and accountability. If policymakers can provide stability, transparency, and direction, taxation will cease to be a barrier and instead become a catalyst, channeling investment, fostering innovation, and positioning Pakistan's agriculture to compete, adapt, and thrive in the decades ahead.

References: Government of Pakistan; World Bank; Pakistan Agricultural Coalition & Pakistan Business Council; IGC; Spička et al.;Sridhar et al.; Van Kooten et al.; PATA

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Disaster Management in Pakistan's Agriculture

Effective disaster management in Pakistan's agriculture is crucial for resilience against floods, droughts, and heatwaves. Investing in preparedness can prevent costly recovery and promote stability and growth in the food system.

Huma Murtaza

8/27/2025

Agriculture is the lifeblood of Pakistan's economy, contributing 22.9% to the GDP and employing 37.4% of the national labour force (Economic Survey of Pakistan, 2023-24). Yet this cornerstone of livelihoods and national prosperity is increasingly fragile under the weight of climate-induced disasters. Pakistan ranks among the ten most climate-vulnerable countries in the world (Global Climate Risk Index, 2021), and each passing year intensifies the warning. Floods, droughts, heatwaves, and glacial melt are no longer occasional shocks but recurring realities. From the 2010 super floods to the devastating 2022 deluge, the period since 2000 has revealed how quickly climate extremes can cripple the agricultural economy. What was once viewed as episodic misfortune has now become a structural risk, making disaster management a central pillar of economic planning rather than an afterthought.

The economic consequences of these disasters extend well beyond damaged crops. Losses ripple through national food prices, export revenues, rural employment, and fiscal stability. When wheat fields drown in Sindh or cotton yields collapse in Punjab, households face inflation, industries lose raw material, and the government diverts scarce resources to emergency imports and relief. This cascading effect makes clear that proactive disaster management is not only an environmental or humanitarian need but an economic imperative.

This report therefore focuses on the economic dimensions of disaster management in agriculture. It will quantify both the direct destruction of assets and the indirect costs borne by markets and households. It will analyze the financial returns of investing in early warning systems, flood-resilient infrastructure, and climate-smart farming practices. It will also assess the strengths and weaknesses of Pakistan's current response and recovery frameworks. By synthesizing global and local best practices, the report aims to provide strategies for building a resilient agricultural economy capable of sustaining food security, macroeconomic balance, and long-term development despite the rising tide of climate risks.

The Spectrum of Disasters and Their Economic Footprint in Pakistan

Pakistani agriculture is exposed to a wide spectrum of disasters, each striking with its own set of economic costs and social consequences. Among them, hydro-meteorological disasters remain the most devastating. The 2022 monsoon floods stand as a grim reminder, submerging 4.4 million acres of cropland and inflicting direct agricultural damages valued at nearly $4 billion (Post-Disaster Needs Assessment, 2022). Entire rural communities were uprooted, while cotton, rice, and sugarcane crops, the backbone of national exports, suffered heavy losses. At the other extreme, prolonged droughts, especially in Sindh and Balochistan, deplete already scarce water resources, slash wheat and fodder yields, and weaken the livestock sector, which contributes more than 60% to agricultural value-added. These slow-onset disasters often receive less attention than sudden floods, yet their cumulative impact quietly erodes productivity and rural resilience.

Biological disasters have also emerged as serious threats. The locust swarms of 2019–2020 devoured standing crops in Punjab and Sindh, threatening food security and rural incomes. The state spent millions on pesticide spraying campaigns and surveillance operations, highlighting both the cost of delayed response and the need for preventive monitoring systems. Such outbreaks underscore how ecological imbalances, often worsened by climate variability, can magnify agricultural vulnerabilities.

Human-made disasters add another layer of complexity. Political instability, conflicts, and supply chain disruptions can paralyze the flow of agricultural goods, while poor water governance intensifies the damage of natural hazards. Mismanagement of irrigation canals and groundwater over extraction, for instance, leave farming systems less capable of coping with droughts and floods alike.

The economic footprint of disasters in Pakistan is thus diverse and subsector specific. While floods wipe out rice and cotton, droughts cripple wheat and fodder production, and heatwaves stress livestock and fruit orchards. This calls for hazard-specific, tailored management strategies that move beyond generic responses and address the unique vulnerabilities of each subsector.

Quantifying the Multifaceted Economic Costs

The economic toll of agricultural disasters in Pakistan is both staggering and multifaceted, cutting across direct and indirect costs that reverberate throughout the economy. Direct costs represent the most visible impact. The 2022 floods, for instance, wiped out 4.4 million acres of cropland, destroyed vital irrigation channels and storage facilities, and led to the death of more than 1.16 million livestock (PDNA, 2022). Such destruction instantly reduces farmers' incomes, undermines exportable surpluses, and destabilizes local markets. Infrastructure losses compound the crisis, as damaged roads and canals delay recovery and weaken long-term productivity.

Indirect costs, though less immediate, are often more enduring. Disasters dismantle rural livelihoods, forcing families into poverty and displacing communities. Food

security suffers dramatically, pushing the country toward costly imports to fill supply gaps. Following the 2022 floods, vegetables and grains had to be imported in large volumes, placing additional pressure on foreign reserves. Downstream industries amplify the burden. The textile sector, heavily reliant on cotton, faced acute shortages, while sugar mills struggled with raw material scarcity. At the macroeconomic level, these shocks drag down agricultural GDP, accelerate inflation, and force the government into unsustainable relief expenditures that widen fiscal deficits.

A critical structural weakness lies in the protection gap. Agricultural insurance coverage in Pakistan remains negligible, leaving farmers exposed to catastrophic losses and shifting the financial responsibility to already strained public funds. This lack of pre-disaster financial mechanisms ensures that recovery remains slow and heavily reliant on emergency relief rather than resilience-building.

Historical records underscore the scale of these challenges. From the $5 billion agricultural damages during the 2010 mega floods to the $2.5 billion locust-related losses in 2019–2020, Pakistan's rural economy has repeatedly absorbed devastating shocks. Without systemic reforms, each disaster risks becoming a cycle of destruction, relief, and renewed vulnerability.

The Economic Imperative of Proactive Investment

The economics of disaster management in Pakistan's agriculture is unambiguous: investing before disaster strikes delivers far greater returns than pouring resources into post-disaster relief. Evidence from global and local experiences shows that every dollar spent on preparedness and resilience pays back several times in avoided losses, stabilized livelihoods, and sustained economic growth. Relief, by contrast, is short-lived, reactive, and drains fiscal resources without addressing underlying vulnerabilities.

One of the most cost-effective areas for investment lies in early warning systems. Advanced meteorological forecasting, satellite-based monitoring, and community-level dissemination networks can significantly reduce losses by giving farmers the time and knowledge to act. The Food and Agriculture Organization (FAO) estimates that each dollar invested in such systems generates up to seven dollars in avoided damages. In Pakistan, where floods, droughts, and heatwaves repeatedly strike, the payoff from robust early warning infrastructure would be immense, protecting both rural livelihoods and national food security.

Climate-resilient agriculture is another crucial frontier. Developing and adopting drought-tolerant wheat and cotton, heat-resistant mango varieties, and water-saving technologies like laser land leveling and drip irrigation offers resilience that translates directly into economic gain. These practices lower input costs, reduce crop failures, and provide stable yields even under climatic stress. By scaling up such innovations, Pakistan can build resilience at the farm level, the very foundation of its food economy.

Equally vital is resilient infrastructure. The principle of "building back better" must move from rhetoric to practice, with investments in stronger river embankments, water storage structures, and climate-proof irrigation channels. Such infrastructure reduces future disaster losses, ensures continuity of production, and saves billions in repeated rehabilitation costs.

The economics of response and recovery highlight another area for reform. Current aid mechanisms, while essential, are often inefficient. Direct distribution of inputs tends to be slow and costly. Alternatives like agricultural input vouchers not only reach farmers faster but also restore local market functioning. Similarly, scaling up agricultural insurance is indispensable. Pakistan's Crop Loan Insurance Scheme is a useful step, but coverage remains limited. Expanding to weather index-based insurance, where payouts are triggered by rainfall or temperature thresholds, would reduce assessment delays and transaction costs. To make such schemes viable for smallholders, government subsidies on premiums are critical.

Institutional and policy frameworks form the backbone of resilience. The National Flood Protection Plan IV and the National Food Security Policy provide a roadmap, but consistent funding and stronger federal–provincial coordination is urgently needed. Clear policies can also encourage private sector participation, particularly in financing insurance and resilient technologies. International partners such as the World Bank, FAO, and UNDP already contribute technical and financial assistance, but alignment with national priorities remains uneven. Better coordination could magnify the impact of these resources.

The 2022 floods stand as a grim reminder of what inaction costs. With $4 billion in agricultural damages and total losses exceeding $9.2 billion, the floods devastated food security, displaced millions, and exposed the fragility of Pakistan's agricultural base. Aid arrived, but the delays and scale of losses demonstrated the urgent need for pre-disaster investment. The lesson is clear: resilience is not a luxury but an economic necessity.

Moving forward, Pakistan must prioritize proactive investment in climate-resilient crops, early warning systems, and infrastructure, expand innovative insurance mechanisms, strengthen institutional coordination, and mainstream climate-smart agriculture across policies and extension services. The economic case is overwhelming: resilience saves lives, protects livelihoods, and shields national growth from the recurring shocks that have too long defined Pakistan's agricultural economy.

Conclusion

Disaster management in Pakistan's agriculture cannot remain a reactive exercise. The evidence is overwhelming: the financial and social costs of inaction far exceed the investments required for preparedness and resilience. Floods, droughts, heatwaves, and biological outbreaks will continue to test the limits of Pakistan's food system, but the outcome does not have to be collapse followed by costly recovery. By treating resilience as an

economic priority, the country can shift from cycles of loss and relief to cycles of stability and growth.

The path forward requires a blend of technology, infrastructure, finance, and governance. Early warning systems and climate-smart farming are not abstract ideals but proven strategies with strong economic returns. Resilient infrastructure, insurance mechanisms, and well-coordinated institutions provide the backbone for lasting protection. Equally important is embedding disaster preparedness into agricultural policy and budgeting, ensuring that resilience is mainstreamed rather than sidelined.

The floods of 2010 and 2022 stand as stark reminders of what failure to act costs in lives, livelihoods, and national prosperity. The choice before Pakistan is clear: invest in resilience today or continue paying exponentially higher prices tomorrow. For an economy so deeply tied to agriculture, proactive disaster management is not optional, it is the foundation of future security and development.

References: Government of Pakistan; World Bank; FAO; Eckstein et al.; State Bank of Pakistan; IFPRI; NDMA; Global Climate Risk Index; PDNA

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Agroforestry & Reforestation: Climate Solutions

Discover how agroforestry and reforestation serve as cost-effective strategies for carbon sequestration, improving soil health, enhancing water security, and protecting biodiversity. Explore their vital role in sustainable development and climate policies.

Ahtisham Ul haq, Shahid Hafeez Khan & Musfira Maqbool

8/4/2025

Global warming, primarily caused by anthropogenic greenhouse gas emissions, necessitates immediate and widespread decarbonization across energy, industrial, and land-use sectors. Although the global climate agenda often emphasizes energy transitions such as renewable energy adoption and fossil fuel reduction, nature-based solutions (NBS) represent an equally vital component of climate mitigation. Among these, agroforestry and reforestation stand out for their dual capacity to remove atmospheric carbon and deliver significant ecological and socio-economic co-benefits (IPCC, 2022).

Agroforestry, which involves the strategic integration of trees with crops or livestock, not only enhances agricultural productivity but also sequesters considerable amounts of carbon in both biomass and soil. Prominent agroforestry models include alley cropping, where rows of trees are planted alongside intercrops; silvopasture, which combines trees with pasture and livestock systems; and multilayered home gardens situated near homesteads, which provide food, fuel, and shade.

Reforestation, on the other hand, focuses on restoring tree covers on degraded or deforested lands, helping to combat soil erosion, improve water retention, and rebuild biodiversity. Together, these practices contribute directly to multiple Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action), SDG 15 (Life on Land), and SDG 2 (Zero Hunger) (FAO, 2022). The potential of these nature-based interventions is further amplified by advances in geospatial technologies such as GIS, remote sensing, and LiDAR. These digital tools enable scientists and policymakers to identify optimal tree-planting sites, monitor carbon sequestration through vegetation indices like NDVI, and assess climate resilience using predictive models driven by satellite data and machine learning.

This study explores key dimensions of climate-smart land use by evaluating carbon sequestration rates in various agroforestry and reforestation systems, identifying co-benefits such as biodiversity enhancement, water conservation, and livelihood support, and analyzing the role of GIS and digital technologies in scaling these interventions. It also considers the importance of enabling policy frameworks and market-based mechanisms to support widespread adoption. We argue that the integration of agroforestry and reforestation, guided by advanced spatial analytics and grounded in socio-ecological realities, offers a robust strategy to maximize climate mitigation while simultaneously advancing sustainable development goals.

Unlocking Climate and Development Synergies Through Agroforestry and Reforestation

Agroforestry and reforestation offer substantial potential for carbon sequestration and sustainable development, particularly when guided by geospatial technologies. Research shows that agroforestry systems can sequester between 2 and 9 tons of CO_2 per hectare per year (Zomer et al., 2022), while tropical reforestation efforts can capture between 10 and 25 tons of CO_2 per hectare annually (Griscom et al., 2020). These figures highlight the critical role these practices can play in global climate mitigation strategies. The integration of Geographic Information Systems (GIS), LiDAR, and satellite imagery such as Sentinel-2 has transformed how biomass growth and carbon storage are tracked over time (Hansen et al., 2023). Furthermore, machine learning models now utilize climatic and soil data to predict carbon yield potentials with increasing accuracy (Nature4Climate, 2024), enhancing strategic planning and targeting.

Beyond carbon capture, these land-use strategies provide co-benefits that contribute to ecosystem resilience and human well-being. Agroforestry improves soil health by increasing organic carbon levels by 15–30% (Cardinael et al., 2022), while reforestation reduces flood risk in watershed areas by up to 40% (WWF, 2023). Biodiversity also benefits, with mixed-species plantations boosting wildlife habitats by 50% (Vieira et al., 2021). On the socio-economic front, agroforestry diversifies farm income through the sale of timber, fruits, and fodder, raising household revenues by 20–40% (FAO, 2023). Moreover, access to voluntary carbon markets, where carbon credits sell for $30–50 per ton of CO_2, offers additional financial incentives (Gold Standard, 2023). GIS tools play a vital role in these markets by verifying carbon baselines and ensuring transparency for Payment for Ecosystem Services (PES) schemes.

However, barriers to adoption persist. Land tenure insecurity remains a major issue, affecting 30% of smallholder farmers in the Global South (World Bank, 2023). High initial costs, estimated between $500 and $1,000 per hectare for reforestation, also hinder implementation (CIFOR, 2022). Digital extension platforms such as the FarmTree App are helping to close knowledge gaps and increase adoption (ICRAF, 2023).

Policy support is crucial. India's Sub-Mission on Agroforestry (SMAF) has

increased national tree cover by 2.5 million hectares since 2016 (MoEFCC, 2023), while the EU's Carbon Farming Initiative links agroforestry practices to subsidies under the Common Agricultural Policy (EC, 2023). Real-time monitoring platforms like Global Forest Watch ensure compliance and adaptive management. For maximum impact, a GIS-guided integrated landscape management approach should prioritize agroforestry on farmlands, focus reforestation on degraded lands, and use community dashboards to increase transparency and participation in forest benefits.

Strategic Recommendations for Scaling Nature-Based Climate Solutions

Agroforestry and reforestation represent transformative, nature-based climate solutions with immense potential to mitigate emissions, restore degraded landscapes, and enhance socio-economic resilience. However, realizing their full potential requires strategic, inclusive, and data-informed implementation. First and foremost, strengthening land tenure security is essential, particularly in the Global South, where unclear land rights discourage long-term investments in tree-based systems. Empowering local communities through training and institutional support further enhances adoption and stewardship. Geographic Information Systems (GIS) must be mainstreamed into landscape planning and monitoring efforts. Precision tools such as remote sensing, LiDAR, and satellite imagery can optimize tree placement, assess biomass growth, and ensure transparency in carbon credit verification and ecosystem service tracking.

Expanding access to carbon markets and blended finance is also crucial. Financial incentives, such as those offered in voluntary carbon markets, can offset high initial costs and create new income streams for smallholders. Integrating these with public-private financing models will make large-scale reforestation and agroforestry financially viable. Community engagement should remain at the core of these initiatives. Participatory mapping not only improves spatial planning accuracy but also fosters local ownership and social equity.

From Pakistan's water-stressed plains to the biodiverse Amazon, harmonizing indigenous knowledge with modern digital technologies can yield climate-smart, culturally grounded solutions. The future of land-based climate mitigation depends on strategies that are both ecologically sound and economically just. Prioritizing digital innovation, community empowerment, and inclusive governance will be key to unlocking the full promise of agroforestry and reforestation in the fight against climate change.

Conclusion

Agroforestry and reforestation stand out as cost-effective, scalable, and multifunctional strategies to address the climate crisis while advancing sustainable development. As demonstrated, their carbon sequestration potential, ranging from 2 to 25 tons of CO_2 per hectare annually, makes them indispensable tools in the global mitigation portfolio. However, the true value of these interventions extends beyond carbon storage. They improve soil health, enhance water security, protect biodiversity, and strengthen rural livelihoods, offering a compelling case for their integration into national climate policies and local development agendas.

With the aid of geospatial technologies such as GIS, LiDAR, and satellite imagery, these practices can be effectively targeted, monitored, and evaluated for both environmental and economic outcomes. The fusion of digital innovation with ecological restoration creates new pathways for data-driven landscape management, ensuring transparency and accountability, especially in carbon credit markets and Payment for Ecosystem Services schemes.

Despite existing challenges like insecure land tenure, high upfront costs, and knowledge gaps, emerging digital extension services and supportive policies, like India's SMAF and the EU's Carbon Farming Initiative, are paving the way for broader adoption. Ultimately, investing in agroforestry and reforestation not only helps combat climate change but also nurtures resilient communities and ecosystems. These rooted solutions are vital for a just and regenerative future.

References: Cardinael et al.; FAO; Griscom et al.; IPCC; Nature4Climate; World Bank; Zomer et al.,; Hansen et al.; Gold Standard; CIFOR; ICRAF; MoEFCC; EC

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Transforming Farming with Precision Agriculture

Explore how precision agriculture is revolutionizing sustainable farming. Discover the benefits of smart farming technology in boosting yields, conserving resources, and enhancing farm profitability while addressing challenges faced by smallholders in developing countries.

Aftab Ashraf

8/7/2025

Precision agriculture is revolutionizing how food is produced, enabling farmers to make data-driven decisions that optimize input use, reduce waste, and increase yields. By integrating technologies such as the Internet of Things (IoT), artificial intelligence (AI), drones, and big data analytics, precision agriculture transforms traditional farming into a high-efficiency system responsive to real-time field conditions. This innovation is especially critical as the world's population heads toward 9.7 billion by 2050 (UN, 2022), while climate change continues to shrink available farmland, an estimated 12 million hectares are lost each year to land degradation (FAO, 2023).

Economically, the benefits of precision agriculture are multi-scalar. At the farm level, precision tools allow for site-specific application of water, fertilizers, and pesticides, reducing input costs while boosting productivity and quality. Studies indicate that farms using precision technologies can achieve yield increases of 10–20% and input cost reductions of up to 30% (OECD, 2023). On a broader scale, these gains contribute to national food security, export competitiveness, and rural income growth. Countries investing in precision agriculture have seen positive shifts in agricultural GDP and employment in agri-tech services.

However, widespread adoption of precision agriculture faces barriers, especially among smallholder farmers. High upfront costs, lack of digital infrastructure, limited technical know-how, and inadequate extension services constrain accessibility. To overcome these challenges, targeted policy interventions are essential. These include subsidies for precision tools, public-private partnerships for digital infrastructure, farmer training programs, and inclusive financing schemes. Moreover, open-access data platforms and localized R&D can ensure technologies are adapted to regional contexts.

Precision agriculture is not just a technological upgrade; it is a strategic imperative for building climate-resilient and economically vibrant food systems. With the right policies and investments, it holds the potential to reshape agriculture into a more efficient, equitable, and sustainable sector globally.

Transforming Farms, Economies, and Labor Markets

Precision agriculture stands as a cornerstone of modern farming, integrating technology to manage spatial and temporal variability in agriculture with unprecedented accuracy. Central to precision agriculture are GPS/GNSS-guided machinery that allows planting and seeding with centimeter-level precision, drones and satellite systems that use NDVI imaging to assess crop health in real time, AI-powered predictive analytics that can forecast pest outbreaks with up to 90% accuracy, and soil sensors that optimize irrigation, reducing water usage by 20–30%. While adoption rates are high in regions like the US, Canada, and the EU, ranging from 65% to 80% among large-scale farms, developing countries such as India and Kenya still lag behind, with adoption below 15% due to cost and infrastructure barriers.

At the microeconomic level, precision agriculture offers clear benefits. Input savings range from 15–25% in fertilizer and pesticide use, while smart irrigation systems cut water consumption by as much as 30% in water-scarce areas. Additionally, AI-guided planting methods have been shown to boost yields by 10–20%. For large farms, the return on investment (ROI) typically materializes within 3–5 years. However, smallholders face a different reality: initial investment costs ranging from $5,000 to $20,000 may delay ROI beyond seven years, making adoption financially challenging without subsidies or shared-service models.

Macroeconomically, the spread of precision agriculture can significantly boost agricultural GDP and trade. A 1% increase in adoption has been linked to a 0.3–0.7% rise in GDP in agriculture-dependent nations. Brazil's soy industry, driven by precision agriculture, contributed an additional $12 billion to national exports in 2023 alone. However, the rise of automation brings labor market shifts. Manual farm labor has declined by 5–8% in the US and EU, while agri-tech job opportunities have surged by 22%, signaling a transformation in workforce needs toward digital skills.

Environmental Gains, Barriers, and Global Lessons

Precision agriculture is not only reshaping how food is produced but also how environmental and health goals are met. It offers powerful tools for climate-smart farming. For instance, precision nitrogen application can cut nitrous oxide emissions equivalent to 50 million tons of CO_2 per year, easing agriculture's climate footprint (Climate Watch, 2024). Water savings are equally remarkable, with precision agriculture technologies conserving 250 billion cubic meters annually, enough to meet the needs of 200 million people (UN Water, 2024). Despite these benefits, precision agriculture adoption still faces significant hurdles, particularly in the Global South.

The foremost barrier is high upfront cost: smallholders bear costs five times higher

per hectare than large farms (Gates Foundation, 2024). Additionally, the digital divide remains acute, with 60% of rural Africa lacking the broadband infrastructure necessary to deploy precision agriculture tools (GSMA, 2024). Data privacy also presents a challenge; 42% of farmers express distrust in cloud-based agri-data platforms, fearing misuse or lack of control over their information (Deloitte, 2024). To overcome these obstacles, countries are launching support initiatives. India's "Digital Agriculture Mission" subsidizes half the cost of precision agriculture technologies for smallholders, while the EU has allocated €8 billion under its CAP 2023–27 for precision agriculture training and outreach.

Recent case studies underline precision agriculture's global impact. In the United States, farms in the Corn Belt using AI and drone monitoring achieved $100 per acre in additional profits (USDA, 2024). In Kenya, solar-powered soil sensors helped 50,000 tea smallholders raise yields by 18% (AGRA, 2024). Meanwhile, the Netherlands combined vertical farming with precision agriculture to reduce land use by 90% and double production (WUR, 2024). Looking ahead, emerging trends include driverless tractors, expected on 30% of US farms by 2027, blockchain-enabled supply chains, and global partnerships like FAO's 1000 Digital Villages, aiming to reach 1 million smallholders by 2025.

Conclusion

Precision agriculture represents a transformative leap toward a more sustainable, productive, and resilient global food system. As the world grapples with population growth, climate change, and environmental degradation, precision agriculture offers a high-tech pathway to smarter farming, reducing input waste, conserving water, cutting emissions, and boosting yields. It has already proven its economic value by improving farm profitability, supporting agricultural GDP, and opening new job markets in agri-tech. Yet, its full potential remains unevenly realized due to structural barriers like high upfront costs, digital infrastructure gaps, limited farmer training, and data privacy concerns, especially among smallholders in developing countries.

The experiences of nations like the U.S., Kenya, and the Netherlands demonstrate that, when tailored to local contexts and supported by enabling policies, precision agriculture can deliver exceptional economic and environmental returns. Future gains lie in scaling up AI-driven tools, expanding digital infrastructure, and building inclusive financing and knowledge ecosystems. Importantly, precision agriculture is not a one-size-fits-all solution, it requires adaptive, inclusive strategies that bridge technological divides. With the right mix of innovation, investment, and inclusive policy, precision agriculture can redefine farming as a driver of prosperity, environmental health, and equitable rural development in the decades to come.

References: FAO; World Bank; McKinsey; AGRA; EC; UN; OECD; Climate Watch; UN Water; Gates Foundation; GSMA; Deloitte; USDA; AGRA; WUR

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Agri-Tech Startups: Modernizing Pakistan's Agriculture

Explore how agri-tech startups can transform Pakistan's agricultural sector, addressing challenges like low productivity and climate vulnerability. Discover the potential for economic growth through precision farming and digital innovations that enhance yields and reduce wastage.

Amna Shahbaz

8/8/2025

Agriculture has long been the backbone of Pakistan's economy, contributing 22.7% to GDP and employing 37.4% of the labor force (Economic Survey of Pakistan, 2023–24). It also generates over 70% of the country's export earnings (State Bank of Pakistan, 2023), making it a vital driver of economic stability and rural livelihoods. However, the sector is burdened with persistent challenges, including price volatility, food insecurity, water scarcity, the impacts of climate change, and limited access to modern technology. In a developing economy like Pakistan, where agriculture remains the primary livelihood for millions, modernization is not just desirable but essential for sustainable revenue generation and resilience against shocks.

Globally, Agri-Tech (Agricultural Technology) has emerged as a transformative force, leveraging artificial intelligence, Internet of Things (IoT) devices, satellite imaging, and digital marketplaces to improve efficiency and profitability. In India, for instance, over 6,000 Agri-Tech startups are redefining how farmers produce, market, and distribute crops, driving remarkable growth and inclusion (NASSCOM, 2023). These ventures provide precision farming tools, weather prediction services, automated irrigation systems, and digital credit solutions, enabling farmers to make data-driven decisions that reduce costs and boost yields.

Pakistan is now experiencing its own Agri-Tech wave. Innovative startups are introducing AI-powered crop health monitoring, IoT-enabled soil sensors, e-commerce platforms connecting farmers directly with buyers, and mobile-based advisory services in local languages. These solutions are not only enhancing productivity and market access but also improving financial inclusion by offering micro-loans and crop insurance. Furthermore, Agri-Tech plays a crucial role in climate adaptation by promoting water-efficient irrigation, resilient seed varieties, and sustainable farming methods.

If nurtured through supportive policies, investment incentives, and rural digital infrastructure, Pakistan's Agri-Tech ecosystem has the potential to transform agriculture into a high-tech, climate-smart, and globally competitive sector, ensuring food security and long-term economic growth.

The State of Agriculture and the Need for Innovation

Pakistan's agricultural sector, while historically the backbone of the national economy, remains largely traditional in its practices. Smallholder farmers, who make up most of the sector, face low crop yields, significant post-harvest losses, reaching up to 40% for perishable goods, and poor access to reliable markets (FAO, 2023). These challenges are compounded by unpredictable weather patterns, water scarcity, and the absence of modern farming tools. However, Agri-Tech startups are emerging as powerful drivers of transformation, introducing solutions that enhance productivity, reduce waste, and strengthen market linkages.

One of the most promising developments is precision farming, which uses AI, satellite imagery, and soil sensors to provide real-time, location-specific insights. By tailoring irrigation, fertilization, and pest control based on exact crop requirements rather than applying inputs uniformly, farmers can achieve far greater efficiency. Technologies such as Variable Rate Application (VRA) have been shown to boost yields by 35–90% (World Bank, 2023) while conserving resources.

Another game-changer is the rise of digital marketplaces that connect farmers directly with buyers, cutting out middlemen who traditionally erode profit margins. Platforms such as Tazah Technologies and Bazaar not only facilitate direct trade but also leverage e-commerce tools like SEO and mobile apps to expand farmer reach. E-commerce adoption in agricultural markets has grown by 45% in Pakistan since 2020 (Karandaaz, 2023).

Supply chain efficiency is another critical area of innovation. Poor storage facilities and inadequate transport networks have historically caused major wastage, especially in perishable goods. Startups are now deploying blockchain-enabled traceability systems and IoT-based cold storage units, reducing spoilage by up to 30% (UNDP, 2023) while also improving compliance with export standards.

Given Pakistan's ranking among the top 10 most climate-vulnerable nations (Global Climate Risk Index, 2024), climate resilience technologies are essential. IoT-enabled smart irrigation systems and climate-adaptive sensors are helping farmers reduce water usage by 25% without compromising yields (ICIMOD, 2023).

Equally important is financial inclusion. Many farmers lack access to formal banking, relying instead on informal lenders who charge exorbitant rates. Platforms like Kissan Dukan are

providing digital microloans and weather-indexed insurance, protecting farmers from financial shocks due to crop loss or climate events (State Bank of Pakistan, 2023).

Several Pakistani startups stand out for their contributions: PakAgri Market, Crop2X, Agridunya Technologies, Tazah Technologies, and Kissan Dukan. Together, they are not only boosting productivity, AI-driven insights alone can lift yields by 30–50% (LUMS AgriTech Report, 2024), but also adding billions to GDP, creating more than 50,000 jobs (IGNITE Pakistan, 2023), empowering women farmers, and attracting foreign investment.

By improving traceability, these innovations also enable Pakistan to meet stringent international food safety requirements, enhancing exports of rice, mangoes, and citrus. In 2023 alone, Agri-Tech ventures drew $25 million in venture capital, marking a 200% increase since 2020 (Invest2Innovate, 2024).

The transformation of Pakistan's agriculture will hinge on embracing such technologies. With targeted policies, strategic investment, and farmer education, Agri-Tech can become the catalyst for a more sustainable, profitable, and resilient agricultural economy.

Challenges and Opportunities for Pakistan's Agri-Tech Ecosystem

Pakistan's Agri-Tech sector holds immense potential, but several structural and operational challenges hinder its rapid growth and large-scale adoption. One major obstacle is limited access to financing, with only 15% of Agri-Tech startups securing institutional funding (Karandaaz, 2023). This restricts innovation and the ability to scale operations, especially in rural regions. Low digital literacy is another barrier, over 60% of farmers lack smartphone access (GSMA, 2023), limiting the reach of mobile-based solutions, AI tools, and digital marketplaces. Infrastructure deficiencies such as unreliable electricity and poor internet connectivity further impede IoT deployment, while policy uncertainty and inconsistent regulations slow down scalability and investor confidence.

A regional comparison reveals valuable lessons. India's Agri-Tech sector experienced explosive growth, expanding from just 50 startups in 2014 to over 6,000 by 2023 (NASSCOM). This transformation was fueled by robust funding, $1.6 billion in 2022 alone (Tracxn, 2023), and tangible farmer benefits, including a 25–35% increase in incomes due to digital market linkages (FAO, 2023). Pakistan can emulate this trajectory by creating an enabling environment for innovation.

Government initiatives such as the Prime Minister's Agriculture Emergency Program and the Kissan Package provide a promising foundation. However, targeted measures are essential for unlocking the sector's potential. These include subsidies for adopting Agri-Tech solutions such as IoT devices and AI-powered analytics, public-private partnerships to boost digital literacy among rural farmers, and tax incentives to attract domestic and foreign investment in Agri-Tech ventures.

With a coordinated approach combining financial incentives, skill development, and infrastructure upgrades, Pakistan can bridge the gap between innovation and adoption, transforming its agricultural landscape into a more productive, sustainable, and technology-driven sector.

Conclusion

Agri-Tech startups represent a pivotal opportunity for Pakistan to modernize its agricultural sector, address structural inefficiencies, and drive inclusive economic growth. As the backbone of the economy, agriculture sustains millions of livelihoods, yet persistent challenges, ranging from low productivity and post-harvest losses to climate vulnerability, continue to limit its potential. By adopting precision farming, digital marketplaces, and climate-smart innovations, Pakistan can significantly boost yields, reduce wastage, and enhance export competitiveness.

The global and regional success stories, particularly from India, demonstrate that with robust funding, supportive regulations, and strong digital infrastructure, Agri-Tech can rapidly transform rural economies. Pakistan's growing pool of innovative startups is already making headway in areas such as AI-driven crop monitoring, IoT-enabled irrigation, blockchain-based traceability, and digital financial services. However, realizing the sector's full potential requires overcoming financing gaps, digital literacy barriers, and infrastructure limitations.

Strategic policy interventions such as targeted subsidies for Agri-Tech adoption, public-private partnerships for farmer training, and tax incentives for investors, can accelerate growth. If nurtured through coordinated government, private sector, and community efforts, Agri-Tech has the capacity to make Pakistan's agriculture more resilient, sustainable, and globally competitive, ensuring food security while unlocking new avenues for economic development and rural prosperity.

References: Economic Survey of Pakistan; FAO; World Bank; NASSCOM; Karandaaz; GSMA; State Bank of Pakistan; UNDP; ICIMOD; LUMS AgriTech Report; IGNITE Pakistan; Invest2Innovate

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Transforming Global Farming with Precision Agriculture

Explore how precision agriculture and AI-driven tools are revolutionizing farming systems worldwide. Discover the challenges faced by smallholder farmers in developing countries like Pakistan and their solutions.

Sami Ullah, Neelam Rana, Wardah Naqvi & Raza Ullah

8/12/2025

The agricultural sector is experiencing an unprecedented transformation, driven by the integration of precision agriculture and artificial intelligence (AI). These technologies are revolutionizing farming by enabling data-driven decision-making, improving efficiency, and supporting sustainable practices. Through AI-driven analytics, drones, and Internet of Things (IoT) sensors, farmers can monitor crops in real time, optimize inputs, and predict yields with remarkable accuracy (World Economic Forum, 2023). This shift is not only enhancing productivity but also providing solutions to some of the most urgent agricultural challenges, including climate change, water scarcity, and soil degradation (FAO, 2022).

Precision agriculture uses satellite imagery, soil moisture sensors, and machine learning algorithms to offer tailored field management strategies. AI-based platforms can process vast datasets to forecast weather conditions, assess soil health, and generate customized irrigation and fertilization schedules. These recommendations can cut resource wastage by up to 30% while improving crop quality (McKinsey, 2023). In parallel, drones with multispectral cameras can identify pest or disease outbreaks at early stages, enabling timely and targeted interventions that reduce pesticide use and associated environmental impacts (USDA, 2023).

However, the benefits of these innovations are not evenly distributed. The digital divide remains a significant barrier, especially in developing nations where smallholder farmers form the backbone of food production. Many lack access to the necessary infrastructure, training, and financial resources to adopt these tools. The International Telecommunication Union (ITU, 2023) reports that only 35% of rural residents in low-income countries have reliable internet access, compared to 85% in wealthier nations. This technological gap risks widening global inequalities, with farmers in digitally advanced regions gaining a competitive edge while others are left behind. Bridging this divide through affordable connectivity, training programs, and supportive policies is essential to ensure that the agricultural revolution benefits all producers, regardless of location or scale.

The Global Landscape: A Tale of Two Agricultures

The global agricultural landscape reveals a stark divide in the adoption of precision agriculture between developed and developing regions. In high-income economies, the integration of artificial intelligence (AI) and Internet of Things (IoT) technologies into farming has advanced rapidly. In the United States, for instance, 70% of large farms and 52% of midsize farms now rely on AI and IoT-based tools for tasks such as crop monitoring, yield prediction, and precision input application (USDA, 2023). The European Union has also witnessed a 25% increase in smart farming adoption since 2020, largely driven by policy incentives and subsidies (European Commission, 2023). These advancements have yielded tangible environmental benefits, including a 20% reduction in water consumption and a 15% decrease in pesticide use, significantly improving sustainability outcomes (Nature Sustainability, 2023).

In contrast, smallholder farmers, who operate 80% of the world's farms (FAO, 2022), face substantial challenges in accessing and using these technologies. Adoption rates remain alarmingly low in many low- and middle-income countries. For example, in Sub-Saharan Africa, only about 5% of farmers use digital farming tools (World Bank, 2023). The barriers are multifaceted. High upfront costs are a major deterrent, with agricultural drones priced between $2,000 and $10,000 and AI software subscriptions costing $500 to $5,000 per year (AgFunder, 2023). Poor connectivity further limits access, with 60% of rural South Asia lacking reliable internet service (ITU, 2023). Additionally, limited technical training means that even when digital tools are available, many farmers struggle to interpret and apply AI-driven recommendations effectively (Gates Foundation, 2023).

Bridging this technological gap requires targeted interventions, including affordable financing models, infrastructure development, and widespread capacity-building programs to ensure that the benefits of precision agriculture are shared equitably across the global farming community.

The Situation in Pakistan: Opportunities and Challenges

Agriculture remains the backbone of Pakistan's economy, contributing 19% to the national GDP and providing livelihoods for around 40% of the workforce (Pakistan Bureau of Statistics, 2023). Yet, the sector struggles with mounting challenges such as chronic water scarcity, widespread soil degradation, and stagnant productivity levels. Precision agriculture, integrating advanced tools like AI, IoT sensors, and satellite imagery, offers a promising pathway to transform Pakistan's farming systems. However, despite its potential, adoption remains minimal, with only about 2% of farmers currently using these technologies (PBS, 2023).

Some promising initiatives are beginning to emerge. Ricult, for example, delivers

satellite-based crop monitoring and microloans through a mobile application, directly benefiting more than 50,000 farmers (Ricult, 2023). Telecom giants like Telenor and Jazz provide SMS-based weather forecasts and real-time market price updates, reaching over one million farmers across the country (GSMA, 2023). Additionally, the Precision Agriculture Research Centre is piloting AI-driven solutions tailored to the needs of smallholders (Ministry of National Food Security, 2023).

Despite these advancements, several barriers continue to slow progress. High costs are a significant hurdle; for smallholders working on thin profit margins, investing in a single sensor node costing around $200, alongside recurring AI analytics fees, is often unfeasible (World Bank, 2023). Infrastructure limitations compound the problem, only 25% of rural areas have 4G coverage (PTA, 2023), and frequent power outages disrupt the functioning of digital tools. Knowledge gaps remain equally critical, with an estimated 70% of farmers lacking formal training in digital agriculture methods (PARC, 2023). Addressing these obstacles will require targeted policies, subsidies, improved connectivity, and large-scale farmer training programs to unlock the full potential of precision agriculture in Pakistan and ensure its benefits are widely shared.

Bridging the Divide: Policy and Innovation

Closing the gap in precision agriculture adoption requires coordinated efforts between the public and private sectors. Government intervention is crucial to make advanced farming technologies accessible and affordable. Providing subsidies and low-interest loans, like India's Kisan Drone Scheme, could help farmers invest in drones, sensors, and AI platforms without overwhelming their limited resources. Expanding rural broadband under Pakistan's Digital Vision 2025 would address connectivity challenges, ensuring that even remote areas can access real-time agricultural data. In parallel, large-scale farmer training programs, developed through partnerships between the government, NGOs, and agri-tech startups, could equip farmers with the skills needed to interpret and apply digital insights effectively.

The private sector also has a vital role to play in scaling adoption. Offering affordable, pay-per-use drone services, modeled after Kenya's Aerobotics, can help smallholders access high-tech solutions without large upfront costs. Similarly, developing offline AI tools that work without continuous internet access would make precision agriculture viable in areas with poor connectivity. These tools could provide locally stored recommendations based on preloaded weather data, crop models, and pest management guides.

By combining supportive policies, strong digital infrastructure, targeted capacity-building, and innovative private sector solutions, Pakistan can overcome existing barriers to precision agriculture. This integrated approach not only boosts productivity and farmer incomes but also strengthens resilience against climate change, contributing to national food security and long-term agricultural sustainability.

Conclusion

The rapid advancement of precision agriculture and AI-driven tools presents a transformative opportunity for global farming systems, offering solutions to persistent challenges such as resource inefficiency, climate variability, and low productivity. However, as the article highlights, the benefits of these innovations are unevenly distributed, with smallholder farmers in developing countries, particularly in Pakistan lagging due to high costs, limited connectivity, and inadequate technical training. Without targeted action, this technological disparity risks deepening rural inequality and undermining the sector's potential for sustainable growth.

Pakistan's emerging initiatives, from satellite-based crop monitoring to SMS weather alerts, demonstrate that progress is possible when innovation is paired with accessibility. Yet, scaling these successes will require a multi-pronged strategy. Public policy must prioritize rural digital infrastructure, affordable financing mechanisms, and widespread farmer training, while the private sector should focus on adaptable, low-cost solutions such as pay-per-use drone services and offline AI applications.

Bridging the digital divide is not merely a matter of technology adoption, it is an investment in the future of food security, climate resilience, and rural livelihoods. By ensuring that advanced agricultural tools are available, affordable, and usable for all farmers, Pakistan can unlock the full potential of digital agriculture and secure a more equitable and sustainable future.

References: FAO; ITU; World Bank; USDA; Pakistan Bureau of Statistics; World Economic Forum; McKinsey; USDA; European Commission; Nature Sustainability; AgFunder; Gates Foundation; Ricult; GSMA; PARC; Ministry of National Food Security; PARC; PTA

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Transforming Agriculture in Pakistan with Big Data

Explore how big data is revolutionizing agriculture in Pakistan, enhancing productivity through precision farming and innovative solutions. Discover successful initiatives like IoT-based irrigation and soil sensors that are helping farmers adapt to climate change and improve resource management.

Arshine Ahmed

8/15/2025

Big data, the collection, processing, and analysis of vast datasets to identify patterns and trends, is rapidly reshaping agriculture worldwide, and Pakistan is no exception. With 65% of the country's population relying on agriculture for their livelihoods (World Bank, 2024) and climate change posing severe threats to crop productivity, data-driven decision-making is becoming an indispensable tool for safeguarding food security.

Currently, adoption remains limited. Only 12% of Pakistani farmers use digital agriculture tools such as satellite imagery, soil sensors, and farm management software (PARC, 2024). This low uptake is due to barriers like limited internet access in rural areas, low digital literacy, and the high upfront costs of technology. Yet, the potential benefits are immense. Studies show that precision farming techniques, enabled by big data, could increase yields by 20–30% while cutting water use by 25% (FAO, 2023). This is particularly crucial in Pakistan, where water scarcity is intensifying and irrigation inefficiencies are rampant.

The economic stakes are high. Climate-related shocks already cause agricultural losses worth $3.2 billion annually (UNDP, 2024). Big data tools can help mitigate these losses through early warning systems for pests and extreme weather, optimized planting schedules, and targeted resource use.

To fully harness this potential, Pakistan needs coordinated action. Investments in rural broadband, farmer training programs, and affordable digital solutions are essential. Public–private partnerships can bridge technology gaps, while government-backed subsidies for precision agriculture tools could accelerate adoption.

In short, big data offers Pakistan a pathway to not only protect but also enhance its agricultural productivity. The challenge lies in moving quickly from pilot projects to nationwide implementation, turning raw data into a powerful driver of climate resilience, efficiency, and rural prosperity.

Harnessing Big Data for a Smarter Agricultural Future in Pakistan

Big data in agriculture refers to the systematic collection and analysis of large-scale information from diverse sources to guide farming decisions. In Pakistan, multiple initiatives are already generating valuable datasets that can transform how farmers grow, protect, and sell their produce. Satellite imagery from the CPEC Agri-Monitoring Project now covers 45% of Punjab's farmlands, enabling real-time crop health assessments and drought prediction. Soil sensors, deployed in over 500 Sindh farms under the LUMS AgriTech Pilot, deliver live updates on soil moisture and nutrient levels, helping farmers fine-tune irrigation and fertilizer use. Meanwhile, drones in Punjab's "Smart Farming" initiative monitor 8,000 hectares, identifying pest infestations and mapping water distribution. Weather data from the Pakistan Meteorological Department's 72 automated stations provide hyperlocal forecasts, while the Zarai Taraqiati AgriPortal gives 1.2 million users live mandi prices for over 25 crops.

The benefits are substantial. In Bahawalpur, IoT-based irrigation reduced water waste by 40% (WWF, 2023). In Okara, precision fertilizer application guided by soil sensors boosted wheat yields by 18% while cutting urea use by 30% (PARC, 2024). Historical data-driven flood prediction models saved 200,000 acres of rice crops in 2023 (NDMA, 2024), showing the power of climate risk mitigation through data analytics.

Market access is another area where big data can disrupt traditional systems. Currently, 75% of smallholders rely on middlemen, often selling at significantly lower prices. Digital platforms could help farmers secure 15–20% higher earnings by connecting them directly to buyers (State Bank of Pakistan, 2024).

To maximize these gains, Pakistan needs a coordinated expansion of data infrastructure, farmer training, and public–private partnerships. If these efforts are scaled effectively, big data can move from pilot projects to a nationwide revolution enhancing productivity, reducing losses, and ensuring resilience in the face of climate change. This transition would not only strengthen food security but also transform rural livelihoods across the country.

Overcoming Barriers to Pakistan's Agricultural Data Revolution

Pakistan's agricultural big data ecosystem holds immense promise, yet several structural, social, and policy-related challenges are slowing its growth. Infrastructure gaps remain a major hurdle, with only 28% of rural Pakistan enjoying 4G coverage (PTA, 2024), severely limiting real-time data collection and dissemination. The high cost of technology, such as IoT sensors priced at $200 per acre, remains out of reach for 85% of smallholders (LUMS AgriTech Report, 2024), reinforcing the digital divide between large and small farms.

Capacity barriers further compound the problem. An estimated 92% of farmers lack digital literacy (PIDE, 2023), meaning even when technology is available, its use is often limited. The

gender divide is stark, only 5% of female farmers have access to AgriTech tools (UN Women, 2024), leaving a large segment of the agricultural workforce excluded from the benefits of big data.

Data privacy concerns are also emerging as a critical issue. Without a national policy on farm data ownership (Ministry of IT, 2023), farmers face uncertainty over who controls and profits from the information collected on their land and operations.

Addressing these challenges will require a multi-pronged approach. Expanding Punjab's 50% drone subsidy nationwide and offering tax exemptions for IoT sensor imports, like India's Kisan Drone Scheme, could accelerate adoption. Strengthening rural 4G networks under "Digital Pakistan Phase-II" and developing Urdu/Hindi voice-based advisory tools would bridge the infrastructure and literacy gaps. Public–private partnerships are key, with models like Jazz Smart Farming's SMS-based advisories and potential collaborations with China's BeiDou Navigation System offering scalable solutions.

Real-world successes, such as Telenor's *Khushhal Zamindar* project which provides free weather alerts and pest warnings to 350,000 farmers and has cut pesticide overuse in cotton belts by 22% (GSMA, 2024), prove that targeted digital interventions can deliver measurable impact.

Looking ahead to 2025–2030, the integration of AI-powered advisories could reach 15 million farmers by 2027, blockchain-based pricing pilots like those with Sindh's onion growers could improve market fairness, and the proposed National Agri-Data Cloud under Vision 2035 could provide a unified platform for agricultural intelligence. With the right mix of policy, technology, and inclusion, Pakistan can transform its agri-data landscape into a driver of rural prosperity and climate resilience.

Conclusion

Big data presents a transformative opportunity for Pakistan's agricultural sector, offering solutions to boost productivity, conserve resources, and build resilience against climate change. From precision farming to real-time market access, the potential economic, environmental, and social gains are immense. Successful pilots such as IoT-based irrigation in Bahawalpur, soil sensor–guided fertilizer use in Okara, and Telenor's Khushhal Zamindar weather advisory system demonstrate that targeted interventions can deliver measurable impact.

However, scaling these successes requires overcoming persistent barriers, including limited rural internet coverage, high technology costs, low digital literacy, gender inequality in access, and the absence of clear data ownership policies. The path forward demands coordinated investments in rural broadband expansion, farmer training, affordable AgriTech solutions, and inclusive public–private partnerships.

Policies like nationwide drone subsidies, tax exemptions for IoT sensors, and development of local-language advisory tools can accelerate adoption. If implemented effectively, these measures could take big data from isolated pilot projects to a nationwide agricultural intelligence system, enabling informed decision-making, reducing losses, and enhancing incomes for millions of farmers. By acting decisively now, Pakistan can harness the full potential of big data to secure its food systems, strengthen rural economies, and position itself as a leader in climate-smart agriculture.

References: PARC; State Bank of Pakistan; PTA; Ministry of IT; World Bank; FAO; UNDP; WWF; NDMA; LUMS AgriTech Report; PIDE; UN Women; GSMA

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Economic Implications of Genetically Modified Crops

Explore the economic implications of genetically modified crops, highlighting their transformative role in enhancing farm profitability, improving rural livelihoods, and contributing to food security.

Aimen Nazir

8/19/2025

Genetically modified (GM) crops, developed through modern biotechnology, are designed to incorporate specific traits such as pest and disease resistance, drought and salinity tolerance, improved nutritional content, and compatibility with selective herbicides. Since their introduction in the mid-1990s, GM crops have profoundly transformed the agricultural landscape. Today, they are cultivated in over 25 countries, covering millions of hectares, and remain a central subject in global debates on food production, sustainability, and trade (ISAAA, 2023).

Economically, GM crops have demonstrated significant contributions to farm profitability and rural livelihoods. Studies reveal that pest-resistant varieties, such as Bt cotton, have reduced the reliance on chemical pesticides, cutting input costs while safeguarding yields. Similarly, herbicide-tolerant crops have enabled more efficient weed control, lowered labor requirements and allowing farmers to expand cultivated areas. For smallholder farmers in developing nations, these innovations can be especially impactful, as they help mitigate risks posed by climate change and resource scarcity.

At the same time, GM crops are reshaping food security narratives. By improving yield stability and reducing crop losses, they contribute to greater availability of staple foods and support nutritional interventions, such as biofortified maize and rice enriched with essential vitamins and minerals. Trade policies are also evolving, with GM adoption influencing market access, export competitiveness, and global regulatory frameworks.

However, challenges persist. Concerns over biosafety, environmental impacts, and consumer acceptance remain contentious in many regions. Furthermore, issues of intellectual property rights, seed pricing, and equitable access often raise questions about inclusivity and long-term sustainability.

This paper examines these complex economic implications by integrating recent data and case studies from both developed and developing economies. By doing so, it highlights the dual nature of GM crops as powerful tools for agricultural growth and food security, but also as sources of regulatory, ethical, and socio-economic challenges that demand balanced policy responses.

Economic Benefits and Socio-Economic Impacts of GM Crops

Genetically modified (GM) crops have emerged as one of the most transformative innovations in modern agriculture, delivering substantial economic and social benefits to farmers and consumers worldwide. A growing body of evidence demonstrates that these crops not only improve farm profitability but also enhance food security, reduce poverty, and shape global trade dynamics. Between 1996 and 2021, GM crops contributed an estimated $261.7 billion in global farm income, with developing countries capturing more than half of these gains, underscoring the importance of biotechnology for smallholder farmers in resource-constrained settings (Brookes & Barfoot, 2023). In India, for example, Bt cotton adoption has significantly increased net profits for smallholders, in some cases by 50–100% compared to conventional varieties, while African farmers cultivating GM maize and cotton report income increases of 30–60% due to reduced pest-related losses (Kathage & Qaim, 2023; African Agricultural Technology Foundation, 2023).

The yield improvements associated with GM crops are equally significant. Bt corn has been shown to deliver yield gains of 13–25% over non-GM varieties, while herbicide-tolerant soybeans in Argentina and Brazil increase yields by 9–12% (Klümper & Qaim, 2023; USDA, 2023). In sub-Saharan Africa, drought-tolerant maize varieties have boosted productivity by 20–35%, directly strengthening food availability and household resilience in regions highly vulnerable to climate shocks (AGRA, 2023). At the same time, GM adoption reduces input and labor costs by minimizing pesticide applications and decreasing weeding requirements. For instance, herbicide-tolerant crops cut weeding labor by as much as 50%, translating into cost savings of $25–50 per hectare (FAO, 2023). In South Africa alone, GM maize adoption has delivered $2.7 billion in benefits, derived largely from higher yields and lower production expenses (Brookes, 2023).

Beyond farm-level economics, GM crops carry wider socio-economic implications. In Bangladesh, Bt eggplant has reduced pesticide use by 80% while raising yields by 30%, improving both farm profitability and consumer health outcomes (IFPRI, 2023). Brazil's rapid expansion of GM soybean cultivation has helped lift nearly two million rural households out of poverty, demonstrating the broader development impacts of biotechnology adoption (World Bank, 2023). Gender equity also emerges as a positive outcome, with female farmers in India and Kenya reporting labor savings of 10–15

working days per season. This freed-up time allows women to engage in diversified livelihoods, such as agro-processing and off-farm employment, contributing to rural economic empowerment (Gates Foundation, 2023).

Nevertheless, global trade dynamics reveal persistent challenges. Stringent GM regulations in the European Union have resulted in annual trade losses of $1.5 billion for African exporters, while Mexico's recent ban on GM corn imports threatens $5 billion worth of U.S. exports and risks raising domestic food prices (WTO, 2023; USDA-ERS, 2024). Regulatory delays in Africa alone are estimated to cost $1.2 billion annually, constraining both innovation and competitiveness (Alliance for Science, 2023). Conversely, streamlined biosafety and approval processes could boost agricultural GDP in Africa by as much as 4%, highlighting the untapped potential of more efficient regulatory systems (AUDA-NEPAD, 2023).

Taken together, the evidence underscores that GM crops are not merely an agronomic tool but a driver of broader economic development, poverty alleviation, and market transformation. Yet, realizing their full benefits requires balanced policies that promote safe adoption, equitable access, and harmonized trade regulations.

Challenges and Ethical Considerations in GM Crop Adoption

While genetically modified (GM) crops offer undeniable economic and agronomic benefits, their adoption raises significant challenges and ethical concerns that must be addressed to ensure sustainability and equity. A key issue lies in the concentration of corporate power within the global seed industry. Four multinational firms, Bayer, Corteva, Syngenta, and BASF collectively control around 60% of GM seed sales worldwide (ETC Group, 2023). This concentration raises concerns over market monopolization, pricing power, and farmer dependency on proprietary technologies. High royalty fees and restrictive licensing agreements often place a disproportionate burden on smallholder farmers, particularly in developing nations where affordability and access are critical. This has prompted growing advocacy for open-source biotechnology models and farmer-led innovation to democratize access to GM technologies (Cornell University, 2023).

Environmental risks also accompany the widespread use of GM crops. The reliance on herbicide-tolerant varieties has accelerated the emergence of glyphosate-resistant weed populations, with U.S. farmers increasing herbicide applications by an estimated 30% in response (NASEM, 2023). Such trends raise concerns about chemical overuse, ecological imbalance, and the sustainability of current weed management practices. Furthermore, the risk of pest resistance to Bt crops threatens to erode long-term productivity gains. Strategies such as refuge planting, where farmers maintain non-GM crop areas to slow pest adaptation, have been promoted as essential mitigation measures. At the same time, advances in gene-editing technologies, including CRISPR-based traits, are being explored to create crops with more durable resistance, potentially reducing the environmental footprint of GM adoption (Science, 2024).

These challenges highlight the importance of balancing innovation with ethical responsibility, ensuring that technological progress does not exacerbate inequality or ecological harm. A robust regulatory framework, coupled with inclusive innovation models, will be crucial to making GM crops a sustainable component of future food systems.

Conclusion

The economic implications of genetically modified (GM) crops illustrate their dual role as both transformative agricultural tools and sources of complex challenges. On one hand, they have significantly enhanced farm profitability, strengthened rural livelihoods, and contributed to food security through higher yields, reduced input costs, and resilience to climate stresses. Case studies from India, Brazil, South Africa, and Bangladesh demonstrate how GM adoption can lift millions out of poverty, improve household nutrition, and promote gender equity by reducing labor burdens. Moreover, their influence on global trade underscores biotechnology's capacity to reshape markets and competitiveness.

Yet, the benefits are tempered by persistent concerns over equity, environmental sustainability, and governance. Concentrated corporate control of GM seeds, rising royalty fees, and regulatory asymmetries raise important ethical questions about access and fairness, particularly for smallholder farmers in developing nations. At the same time, environmental risks such as herbicide resistance and pest adaptation signal the need for more sustainable management practices.

Ultimately, GM crops are neither a panacea nor a peril, but a powerful innovation whose potential depends on responsible governance. Balanced policies that ensure biosafety, equitable access, and transparent trade regulations will be critical to integrating GM technology into sustainable and inclusive food systems for the future.

References: Brookes & Barfoot; ISAAA; USDA; World Bank; Kathage & Qaim; African Agricultural Technology Foundation; Klümper & Qaim; AGRA; Brookes; FAO; IFPRI; Gates Foundation; WTO; Alliance for Science; AUDA-NEPAD; ETC Group; Cornell University; NASEM; Science

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AI Transforming Agriculture for a Sustainable Future

Discover how artificial intelligence is revolutionizing agriculture with precision irrigation, disease detection, and efficient resource use. Learn how AI enhances food security and promotes environmentally responsible farming practices.

Hafsa Shahzad

8/21/2025

The global agricultural sector is undergoing a deep technological shift, one shaped by the intersecting pressures of rapid population growth, climate change, and dwindling natural resources. Central to this transformation is Artificial Intelligence (AI), which is no longer an experimental idea but a practical force reshaping how food is produced and distributed. The stakes are high: by 2050, the global population is expected to reach 9.7 billion, demanding nearly 60 percent more food than is produced today (United Nations, 2022). Meeting this target through traditional methods alone is impossible, given the growing strain on water, land, and ecosystems. AI steps into this gap by enabling precision and efficiency on a scale never seen before.

Farmers now rely on AI-powered tools for yield prediction, soil health analysis, and real-time pest detection. These applications help maximize productivity while minimizing waste and input use, reducing both costs and environmental footprints. Beyond the farm, AI is optimizing supply chains, forecasting market demands, and improving storage and logistics, ensuring that food reaches consumers with fewer losses. By processing massive datasets that humans cannot handle alone, AI strengthens resilience against climate shocks and supports better planning at every stage of production.

Yet, the integration of AI is not without its challenges. High implementation costs, lack of digital infrastructure in many rural regions, and concerns about data ownership and privacy continue to slow adoption. Bridging the gap between advanced technologies and smallholder farmers, who produce a significant share of the world's food, remains a critical hurdle. For AI to realize its full potential in agriculture, policies, investment, and capacity-building must move in step with innovation. Only then can AI help secure a more productive, sustainable, and resilient food system for the future.

From Core Technologies to Real-World Impact

Artificial Intelligence is no longer a distant concept in agriculture but an active force reshaping how food is grown, managed, and distributed. At its core, AI refers to systems that replicate aspects of human intelligence to process vast datasets and generate actionable insights. Unlike traditional methods of farm management, which rely heavily on experience, intuition, and manual observation, AI systems integrate information from satellites, drones, IoT sensors, and historical records to provide precision-based recommendations. This fusion of digital tools is enabling farmers to respond faster and smarter to complex challenges that affect productivity, profitability, and sustainability.

The backbone of agricultural AI lies in its technological components. Machine Learning (ML) algorithms allow systems to identify patterns and improve predictions over time, helping farmers anticipate everything from rainfall patterns to pest outbreaks. Computer vision extends these capabilities by analyzing images, detecting plant diseases, or estimating yields with accuracy beyond human capability. Natural Language Processing (NLP) is making agricultural technology more accessible, letting farmers communicate with platforms in their own language through mobile devices or use unstructured data from reports for quick insights. Robotics and automation add another layer, enabling machinery to plant, weed, and harvest autonomously, reducing labor needs and human error.

These technologies converge in powerful applications across the agricultural value chain. One of the most significant is crop monitoring and disease detection. With drone and satellite imagery analyzed through AI-powered computer vision, farmers can detect early signs of nutrient deficiencies, pest infestations, or water stress long before they become visible to the naked eye. Tools such as Plantix and Taranis deliver real-time diagnostics and recommendations, with studies showing disease detection accuracy above 95 percent, dramatically reducing yield losses.

Water management is another critical frontier. Agriculture consumes nearly 70 percent of global freshwater, making efficiency non-negotiable. AI-driven irrigation systems draw on soil sensors, weather forecasts, and evapotranspiration models to determine precisely how much water each field needs. Companies like Prospera and CropX have shown that these technologies can cut water use by up to 30 percent while maintaining or even boosting yields. For regions facing chronic water stress, such precision agriculture represents both an economic and ecological breakthrough.

Equally vital is AI's role in yield prediction. By integrating data from satellites, soil maps, climate models, and management practices, AI can generate highly accurate forecasts that aid planning at multiple scales. Google's AI initiative in the U.S. Midwest, for instance, achieved a 99 percent accuracy rate in soybean yield predictions,

offering farmers the confidence to plan logistics, secure credit, and negotiate better market positions. Governments also benefit by anticipating shortfalls and managing reserves proactively.

AI is also driving innovations in pest and weed management. Robots like Carbon Robotics' Laser Weeder use computer vision to differentiate between crops and weeds in real time, eliminating the latter with lasers or micro-sprays. This reduces herbicide use by up to 90 percent, cutting costs, preserving ecosystems, and limiting herbicide resistance.

Beyond the farm, AI enhances supply chain management and market intelligence. Predictive analytics can account for weather disruptions, geopolitical shifts, or transport bottlenecks, helping farmers and traders anticipate demand and price movements. Platforms such as AgriDigital streamline provenance tracking and payments, while Intello Labs applies AI to assess produce quality objectively, reducing disputes and ensuring fair pricing.

Together, these developments underscore that AI is not just a support tool but a transformative force across agriculture. By merging advanced analytics with practical applications, it is strengthening resilience, reducing inefficiencies, and creating opportunities for farmers at every scale. While challenges remain in cost, access, and infrastructure, the direction is clear: AI is poised to become one of the most important drivers of agricultural decision-making in the decades ahead.

Challenges and Future Pathways for AI in Agriculture

The promise of Artificial Intelligence in agriculture is immense, but its widespread adoption is far from straightforward. Several challenges stand in the way, particularly for smallholder farmers who form the backbone of global food production. The digital divide remains one of the most pressing issues. High implementation costs and limited access to reliable rural broadband leave millions excluded from these technologies. According to the FAO (2022), more than three-quarters of the world's poor and food-insecure rely on agriculture, yet they are the least equipped to benefit from AI-driven solutions. This inequality risks widening productivity gaps between technologically advanced farms and those left behind.

Data quality and bias further complicate matters. AI systems depend on vast datasets, but when these are skewed or not representative of local realities, the resulting recommendations can be inaccurate or even harmful. Farmers working in underrepresented regions may find themselves following advice that is irrelevant or counterproductive. Algorithmic transparency adds another layer of difficulty. Many AI systems function as "black boxes," providing results without clear explanations. For farmers, especially those making high-stakes decisions about irrigation, pest control, or market timing, trust is hard to build when they cannot see how recommendations are generated.

Another hurdle is the lack of technical expertise. In many parts of the developing world, digital literacy remains limited, and the specialized skills needed to interpret AI outputs are scarce. Without adequate training and support, even the most advanced tools risk being underutilized.

Looking ahead, the trajectory of AI in agriculture suggests a gradual narrowing of these gaps. Hyper-localized models tailored specific crops and climates will increase relevance. The convergence of AI with IoT and blockchain will enhance transparency and traceability across supply chains. Subscription-based AI-as-a-Service models may reduce costs, while policy interventions such as subsidies and incentives could accelerate adoption. Together, these developments point to a future where AI becomes both more inclusive and more impactful in shaping resilient food systems.

Conclusion

Artificial Intelligence is redefining the way agriculture is practiced, offering tools that are not only innovative but essential for meeting the mounting pressures of food security, climate resilience, and sustainable resource use. From precision irrigation and disease detection to supply chain optimization and market forecasting, AI has shown its potential to make farming more efficient, productive, and environmentally responsible. The evidence is clear: when deployed effectively, AI can reduce water use, cut chemical inputs, increase yields, and provide farmers with actionable insights that were once unimaginable.

Yet the full promise of AI will only be realized if its benefits extend beyond technologically advanced farms to the smallholders who produce much of the world's food. Issues such as affordability, data equity, algorithmic transparency, and technical literacy cannot be overlooked. Bridging the digital divide is as critical as advancing the technology itself. Without deliberate efforts to improve infrastructure, expand training, and ensure inclusivity, AI risks deepening existing inequalities rather than solving them.

Looking ahead, the trajectory of AI in agriculture points toward integration, localization, and accessibility. With the right investments, policies, and collaborative frameworks, AI can become not just a tool of innovation, but a cornerstone of global food security and sustainable agricultural development.

References: Carbon Robotics; FAO; Google AI Blog; IWMI; Zhang & Wang; United Nations; World Bank

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Boosting Agriculture in Pakistan with Extension Services

Agriculture in Pakistan can reach its true potential by enhancing extension services. Access to timely knowledge and technologies for farmers is vital for productivity, efficient resource use, and stable incomes, ultimately contributing to national growth, poverty reduction, and food security.

Meerub Riaz

8/28/2025

Agriculture is the cornerstone of Pakistan's economy, sustaining millions of households while underpinning national stability and economic growth. The sector contributes 22.9% to the GDP and employs 37.4% of the labor force, demonstrating its centrality not only to economic indicators but also to social well-being (Economic Survey of Pakistan, 2023-24). For a country where more than 60% of the rural population depends directly on farming and allied activities, the performance of agriculture dictates food availability, income distribution, and the resilience of entire communities. Strong agricultural growth not only ensures food security but also fuels rural development, curbs poverty, and generates demand across industries linked to farming, such as input supply, logistics, and food processing.

Understanding the economic principles governing production, distribution, and consumption is therefore essential. Without this lens, interventions risk being misaligned with farmer realities or broader national priorities. Sound agricultural economics informs resource allocation, price stabilization, and trade policies, while also addressing vulnerabilities such as water scarcity, land inequality, and volatile input markets. In this context, agricultural extension services become indispensable. They function as the bridge between research institutions, policy frameworks, and farmers in the field. By translating scientific innovations and economic strategies into accessible practices, whether it is adopting improved seed varieties, precision irrigation, or market-oriented cropping patterns, extension services directly enhance farm productivity and profitability.

However, in Pakistan, this potential remains underutilized. Extension systems are chronically underfunded, understaffed, and often disconnected from farmer needs. Coupled with a constrained economic environment, these weaknesses form a critical nexus that limits agricultural progress. Strengthening extension services with adequate investment, capacity building, and farmer-centered approaches can help overcome these barriers. Only by aligning economic insights with practical field-level solutions can Pakistan achieve sustainable agricultural transformation, improve farmer welfare, and secure its food future.

The Scope of Agricultural Economics in the Pakistani Context

Agricultural economics in Pakistan is an applied discipline that grapples with how best to optimize the production, distribution, and consumption of food and fiber in an environment marked by structural constraints and untapped potential. Its scope goes far beyond farm-level management, extending into questions of rural finance, markets, policies, and environmental sustainability. Limited access to formal credit continues to hinder smallholders, who rely heavily on informal lenders at exploitative rates. Inefficiencies in agricultural supply chains exacerbate post-harvest losses, which reach as high as 40% for perishables, while price volatility undermines farmer incomes and consumer affordability (Pakistan Cold Chain Summit, 2023). Policy frameworks, ranging from subsidies to trade restrictions and water-use regulations, shape outcomes across the sector, often with uneven results. Meanwhile, Pakistan faces acute water scarcity and widespread land degradation, placing environmental and resource economics at the center of its agricultural challenges. At its core, agricultural economics in Pakistan is about making choices, allocating scarce land, water, capital, and labor in ways that maximize efficiency, sustainability, and farmer welfare.

The four factors of production illustrate this challenge. Land, though abundant in potential, is under severe pressure. Rapid urbanization consumes thousands of hectares of fertile farmland each year; while waterlogging and salinity affect over six million hectares, reducing productivity (PCRWR, 2022). Highly skewed land ownership further limits equitable access and efficient use. Labor, though abundant, suffers from underemployment, informal conditions, and low productivity. Outmigration of rural youth and the lack of vocational training restrict the adoption of modern practices. Building human capital is vital to harnessing labor more effectively.

Capital is another limiting factor. Public spending on agriculture remains below 1% of GDP (World Bank, 2022), and smallholders struggle to access affordable credit. Without investment in machinery, irrigation systems, and storage, farmers remain trapped in low-productivity cycles. Finally, technology adoption is constrained by a weak extension system. Extension services are meant to transfer innovations, high-yielding varieties, precision agriculture, mobile-based advisories, from research centers to the farm, yet the worker-to-farmer ratio remains an inadequate 1:1500 compared to the recommended 1:400 (FAO, 2021). Poor training, limited resources, and institutional neglect slow the diffusion of innovation, leaving vast economic gains unrealized.

In Pakistan, agricultural economics thus sits at the intersection of resource management, policy, and farmer empowerment. Addressing weaknesses in land use, labor productivity, capital formation, and technology diffusion is essential if the sector is to deliver on its promise of food security, rural prosperity, and national growth.

The Critical Economic Role of Extension Services

Extension services are not an administrative overhead but a strategic investment that shapes the economics of agriculture at every level of production and distribution. Their role begins with productivity. By translating scientific research into field-level practices, extension workers enable farmers to achieve higher yields and improve the quality of their produce. This transfer of knowledge makes agricultural research truly valuable, ensuring that improved seed varieties, integrated pest management, or precision tools do not remain confined to laboratories but reach the farm where they matter most.

Extension services also enhance resource use efficiency, a critical concern in a country like Pakistan where both water and fertilizers are scarce and costly. Guidance on optimal irrigation, nutrient management, and soil health not only lowers input costs but also safeguards long-term resource sustainability. Beyond production, extension has a vital role in reducing post-harvest losses. Simple yet effective training in handling, grading, and storage can prevent significant economic waste, particularly in fruits and vegetables where losses often exceed 30 percent. By improving post-harvest practices, extension services directly increase farmers' incomes and strengthen national food security.

Another dimension is market connectivity. Farmers often lack access to reliable information on prices and market trends, leaving them vulnerable to exploitation by intermediaries. Extension workers, especially when supported by digital platforms and mobile applications, can bridge this gap by linking producers to better markets and providing timely price signals. At the same time, extension services have become increasingly important for building resilience to climate change. From promoting drought-tolerant crop varieties to teaching soil conservation and adaptive practices, extension is a frontline defense against climate shocks that threaten livelihoods.

For Pakistan to fully harness this economic potential, revitalization of the extension system is essential. This means greater public funding, retraining staff in modern practices such as climate-smart agriculture and adopting digital technologies like mobile advisories and radio outreach to expand coverage. Complementary reforms in rural finance, water management, and land governance will amplify these gains. If pursued with intent, investment in extension can transform Pakistan's agriculture into an engine of sustainable growth, raising productivity while securing livelihoods and food systems for the future.

Conclusion

Agriculture in Pakistan cannot achieve its true potential without a stronger economic foundation, and at the heart of that foundation lies extension services. The evidence is clear: when farmers have access to timely knowledge, technologies, and markets, productivity rises, resource use becomes more efficient, and incomes stabilize. Conversely, when extension systems remain underfunded and poorly connected to farmers, research stays on paper, credit remains underutilized, and the rural economy falters. The sector's share in GDP and employment underlines how deep national growth, poverty reduction, and food security depend on effective agricultural economics and its application in the field.

The path forward is not simply about increasing yields but about transforming the entire value chain, from resource management and post-harvest handling to market integration and climate adaptation. This transformation requires political will, targeted investment, and the recognition that extension is not a cost but an enabler of growth. By aligning policies, capital, and human resources with farmer-centered extension, Pakistan can unlock higher efficiency and resilience across its agricultural sector. Doing so will not only strengthen rural livelihoods but also ensure national food security, protect natural resources, and secure agriculture's role as the backbone of the economy.

References: Government of Pakistan; World Bank; FAO; PCRWR; IFPRI; Ali, & Abdulai; Qaim; Pakistan Cold Chain Summit; Dorosh & Malik

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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Agricultural Infrastructure in Türkiye: A Complete Ecosystem

Explore the critical role of agricultural infrastructure in Türkiye, focusing on water efficiency, land consolidation, and credit access. Discover how these interconnected systems impact farmers' productivity and resilience in the agricultural sector.

Mithat Direk

8/29/2025

The often-repeated phrase *"when agricultural infrastructure problems are solved"* is frequently used as a catch-all prescription yet rarely unpacked in its full depth. Too often, it is reduced to images of roads connecting villages, electricity powering irrigation pumps, or water fields feed. These are indeed vital, but they represent only the most visible layers of a far more complex system. In the 21st century, infrastructure in agriculture must be understood in a broader sense. It extends well beyond bricks, wires, and pipelines to include the institutional structures that sustain production: education systems that equip farmers with knowledge, health services that safeguard rural labor, financial institutions that provide credit on fair terms, and legal frameworks that enforce property rights and contracts.

These pillars are no less critical than highways or reservoirs because they form the very foundation of a resilient agricultural economy. When this holistic view is applied to Türkiye agriculture, the magnitude of the challenge becomes clear. The sustainability and competitiveness of the sector depend not only on physical facilities but also on the quality and accessibility of institutional support. Farmers require reliable extension services, affordable loans, transparent markets, and functioning cooperatives alongside adequate transportation and irrigation. Without these, productivity gains remain limited, and rural communities are left vulnerable to market volatility, climate shocks, and structural inequalities.

Defining agricultural infrastructure as the entire ecosystem of physical and institutional factors helps to ground the discussion. It reminds us that every step of the value chain, from planting and harvesting to storage, processing, and delivery to consumers, rests on this foundation. Understanding and addressing the specific infrastructure problems farmers face is therefore not optional. It is the cornerstone for shaping a sustainable, competitive, and future-oriented agricultural sector in Türkiye.

Farming Viability and the Infrastructure Deficit in Türkiye

The viability of farming and the adequacy of farm income are inseparable from the quality and reliability of agricultural infrastructure. While debates around farming often emphasize input subsidies or price interventions, the deeper issue lies in how well the physical and institutional frameworks support farmers throughout the production cycle. In Türkiye, this challenge can be understood in two interconnected phases: the pre-production stage and the post-production stage. Both are essential, yet both remain hindered by gaps that reduce productivity, increase vulnerability, and limit farm incomes.

In the pre-production stage, the focus rests on input and biophysical infrastructure. Seeds, fertilizers, machinery, and water access remain the cornerstones of productivity. The Türkiye government continues to allocate substantial resources to these areas, with agricultural support payments reaching 81.5 billion TL in 2023 (Ministry of Agriculture and Forestry, 2024). While such figures are impressive, they do not mask the persistent inefficiencies that farmers face on the ground. Water security illustrates this clearly. Agriculture consumes about 70% of Türkiye's water resources, yet irrigation efficiency hovers around only 50% (TÜİK, 2023). The widespread reliance on flood irrigation wastes scarce water and undermines long-term sustainability. Shifting to pressurized systems like drip and sprinkler irrigation is urgent, but smallholder farmers, who dominate the sector, often lack the financial means to make such investments. Without affordable credit and targeted infrastructure programs, this modernization will remain out of reach.

Land fragmentation compounds the problem. With average farm sizes around 6.2 hectares (TÜİK, 2023), mechanization and the adoption of advanced technologies are constrained. Fragmented plots prevent economies of scale and keep productivity below potential. While land consolidation policies have been attempted, progress is slow and politically sensitive, leaving farmers caught in a cycle of high input costs and low returns.

If the pre-production stage determines what goes into farming, the post-production stage decides whether farmers can capture fair value for their efforts. This stage is arguably more critical, yet it has historically been neglected in Türkiye. Once crops leave the field, they encounter a chain of structural weaknesses that erode farm incomes. Post-harvest losses, estimated at 25–40% for perishable fruits and vegetables (TZOB, 2022), represent one of the most pressing issues. The lack of adequate cold storage facilities means products spoil before reaching consumers, while poor logistics and weak rural road networks increase transport costs and delays.

Equally troubling is the role of intermediaries. Farmers often lack direct access to urban or export markets, forcing them into dependency on middlemen who set terms to their

advantage. In some cases, farmers retain only 20–30% of the final consumer price (Agricultural Economics Research Institute, 2023). This imbalance discourages production, weakens bargaining power, and fuels rural poverty.

Finally, limited agro-processing capacity restricts opportunities for value addition. Instead of transforming raw produce into higher-value goods like juices, sauces, or packaged foods, much of Türkiye's agricultural output is sold fresh. This dependence exposes farmers to price volatility and market shocks. Expanding processing industries in rural areas could not only reduce waste but also generate employment and stabilize incomes.

Taken together, these pre- and post-production bottlenecks illustrate that Türkiye's agricultural difficulties are not simply about producing more. They are about creating a system where infrastructure both physical and institutional supports farmers at every stage, ensuring that productivity gains translate into viable and sustainable livelihoods.

Recommendations: Towards a Holistic Infrastructure Policy

Addressing the "infrastructure problems" of Türkiye agriculture requires a broader vision that goes well beyond inputs at the farm gate. Infrastructure must be seen as a complete system, connecting the farmer not only to seeds, water, and machinery but also to markets, financial services, and knowledge networks. A narrow focus on production alone has led to repeated cycles of inefficiency and waste. The future of Türkiye's agricultural sector depends on moving towards a holistic, dual-track policy that gives equal weight to both production and post-production stages.

First, the policy focus needs to shift. While input subsidies and production support remain necessary, they cannot be the centerpiece of agricultural strategy. A significant share of public investment should be channeled into post-harvest systems. Cold storage facilities, efficient logistics, and regional food processing plants are no longer optional but essential. Farmers who can store, process, and market their produce retain greater control over prices and reduce their exposure to middlemen. Strengthened cooperatives can further level the playing field, enabling smallholders to collectively access infrastructure, negotiate fairer prices, and compete in larger markets.

Second, regional value-added processing industries must be prioritized. Instead of transporting raw produce long distances to distant markets, regional facilities can convert perishable crops into storable, higher-value goods such as juices, pastes, or packaged products. This not only minimizes post-harvest losses but also creates employment opportunities and generates steady rural incomes. By balancing supply and demand throughout the year, such processing hubs stabilize prices for both producers and consumers.

Third, modernizing institutional infrastructure is indispensable. Agricultural development is not only about physical assets but also about knowledge, finance, and governance. Farmers need greater access to affordable credit tailored to their needs, strong agricultural education and extension programs to diffuse new technologies, and reliable digital platforms to access price information and connect directly with buyers. Such reforms would improve transparency, reduce information asymmetry, and empower farmers to make informed decisions.

Ultimately, only by addressing infrastructure as an interconnected chain, from input provision to final sale, can Türkiye secure a competitive, resilient, and sustainable agricultural sector. Farmers' efforts deserve a system that values their work at every stage, ensuring their livelihoods are protected while the nation's food security is strengthened.

Conclusion

The question of agricultural infrastructure in Türkiye cannot be reduced to roads, irrigation systems, or electricity alone. It is about recognizing infrastructure as a complete ecosystem where physical assets and institutional structures reinforce one another. Farmers operate at the intersection of these systems, and their productivity, incomes, and resilience depend on how well each component functions. Current gaps in water efficiency, land consolidation, and access to credit at the pre-production stage combine with post-harvest weaknesses such as storage deficits, poor logistics, weak processing capacity, and exploitative market structures to hold back the sector's potential.

A meaningful response requires moving beyond piecemeal interventions. Investments must balance production support with post-harvest infrastructure, encourage regional processing industries, and strengthen cooperatives so that farmers can capture more value. At the same time, institutional reforms in education, finance, and digital governance are essential for equipping farmers with the tools to compete in modern markets. Addressed together, these measures can close the infrastructure deficit and create a more competitive, resilient, and inclusive agricultural economy. The path forward is clear: Türkiye must treat infrastructure as the backbone of sustainable farming, ensuring that farmers are not left behind but positioned at the center of national growth and food security.

References: Ministry of Agriculture and Forestry; TÜİK; TZOB; Agricultural Economics Research Institute; World Bank; Özertan & Aerni

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Empowering Pakistan's Forestry with Grassroots Solutions

Discover how grassroots solutions like farm and social forestry are transforming Pakistan's forestry landscape. By embedding tree planting into local livelihoods, these initiatives not only restore degraded landscape but meet the ever-growing timber demand.

Ahtisham Ul haq

8/11/2025

Pakistan faces a pressing dual challenge, meeting its growing demand for timber and fuelwood while also combating climate change and reversing decades of forest degradation. Forests play a pivotal role in carbon sequestration, biodiversity conservation, and sustaining rural livelihoods, yet the country's forest cover remains alarmingly low at just 5.1% of total land area (FAO, 2020), far short of the 25% recommended for ecological stability.

While state-managed forests have largely stagnated, showing no significant increase in forest cover over the past two decades despite vast land holdings, legal authority, and substantial budgets (World Bank, 2021), farm forestry and social forestry have emerged as resilient, community-driven solutions. Farm forestry where farmers integrate trees into agricultural landscapes already supplies an estimated 60% of the nation's timber and 90% of its fuelwood (PFFA, 2022). Social forestry initiatives, often led by communities and NGOs, not only supplement wood production but also restore degraded lands, improve microclimates, and generate income for marginalized groups.

The stark contrast in outcomes highlights a critical policy gap. State forestry has been hampered by bureaucratic inefficiencies, restrictive regulations, and a lack of innovation, while farm and social forestry thrive despite limited institutional backing. Providing farmers and communities with targeted incentives such as subsidized seedlings, technical training, secure land tenure, and streamlined market access could rapidly scale up tree planting efforts.

By empowering local stakeholders, Pakistan can meet its wood demand sustainably, reduce dependence on dwindling natural forests, and enhance resilience to climate change. Strengthening farm and social forestry is not only an environmental necessity but also an economic opportunity one that can create rural jobs, improve livelihoods, and bring the country closer to its climate and biodiversity goals. The path to a greener Pakistan lies in putting trees back into the hands of the people.

Pakistan's Forestry Crisis: Rising Demand and Climate Pressures

Pakistan's forestry sector is under mounting strain as population growth, at 2.4% annually (UN, 2023), and rapid urbanization fuel an annual 3–4% increase in wood demand (Pakistan Economic Survey, 2023). This demand surge is occurring alongside intensifying climate pressures, erratic monsoon patterns, and prolonged droughts (IPCC, 2022) that are degrading ecosystems, accelerating soil erosion, and threatening rural livelihoods. Forests, vital for carbon sequestration, biodiversity, and watershed regulation, now cover just 5.1% of the country's land area (FAO, 2020), far below the recommended 25% for ecological stability. Historically, the Forest Department has been the custodian of the nation's food supply and conservation efforts. Yet, despite its budget allocations, professional staff, and extensive land holdings, it has failed to meaningfully expand forest cover due to weak governance, corruption, illegal logging, and the absence of effective community engagement (IUCN, 2021).

In stark contrast, farm forestry where farmers integrate fast-growing species such as eucalyptus, poplar, shisham, and mulberry into agricultural land has emerged as the backbone of Pakistan's wood supply. Without formal incentives, it now contributes around 60% of the country's timber and 90% of its fuelwood, sustaining over 2 million rural households (Pakistan Farm Forestry Association, 2022). These trees provide not only timber and fuel but also fodder, fruit, and shade, making them integral to diversified farm incomes and climate adaptation strategies. Similarly, social forestry community-led restoration of degraded lands, roadside plantations, and village commons has shown impressive results. Initiatives like the Billion Tree Tsunami (2014–2017) demonstrated that local ownership and participation can accelerate reforestation, improve soil fertility, enhance water retention, and bolster carbon sequestration (KP Government, 2018). However, these successes require secure land tenure, equitable benefit-sharing, and sustained technical support to remain viable in the long term.

Comparative performance indicators underscore the contrast: while farm forestry continues to expand on private land, state-managed forests have seen virtually no net gain in cover over the past two decades (World Bank, 2021). This disparity reveals a clear policy lesson decentralized forestry systems aligned with local livelihoods are more adaptive, efficient, and resilient than centralized bureaucratic models. By empowering farmers and communities with targeted incentives, improved market access, and technical assistance, Pakistan can meet its rising wood demands, strengthen climate resilience, and alleviate pressure on dwindling natural forests. The path forward lies not in expanding state control, but in recognizing and scaling the quiet revolution already happening in the hands of rural stewards.

Overcoming Barriers to Sustainable Forestry in Pakistan

While farm and social forestry have become vital to meeting Pakistan's timber and fuelwood needs, their potential is constrained by systemic and structural challenges. One of the most pressing issues is the lack of formal recognition in national forest accounts, which undervalues their contribution and limits resource allocation for their growth. Without being integrated into official forestry statistics and policy frameworks, these community-driven models remain outside the purview of strategic planning.

Unclear land and tree tenure rights further discourage long-term investment in forestry by farmers and communities. When ownership and harvesting rights are uncertain, individuals are less likely to plant trees that take years to mature. Additionally, limited market access, coupled with the dominance of middlemen in the timber trade, significantly reduces farmers' profit margins. This weakens incentives for sustainable tree management and replanting.

Another concern is the over-reliance on exotic species like eucalyptus, which, while fast-growing and economically attractive, have been linked to soil degradation and depletion of groundwater. Such monocultures undermine ecological sustainability, especially in already water-stressed regions.

To address these barriers, policymakers must formalize farm forestry in the upcoming National Forest Policy 2025, ensuring it receives institutional recognition and support. Strengthening land and tree tenure rights will provide the security needed for long-term investments in diverse forestry systems. Expanding extension services and establishing nurseries for indigenous species will improve access to high-quality planting material while promoting biodiversity. Market reforms such as cooperative marketing platforms can connect smallholders directly with buyers, ensuring fair prices.

Lastly, promoting agroforestry models that integrate climate-resilient, multi-purpose indigenous species will not only secure livelihoods but also restore degraded landscapes. With the right policy environment, farm and social forestry can become cornerstones of Pakistan's climate resilience and rural prosperity.

Conclusion

Pakistan's forestry future depends on recognizing and scaling the grassroots solutions that are already delivering results. Farm and social forestry have demonstrated that when tree planting is embedded in local livelihoods, it thrives producing the bulk of the nation's timber and fuelwood, restoring degraded landscapes, and supporting millions of rural households. These models work because they align ecological restoration with economic incentives, making trees an asset rather than a burden for farmers and communities.

In contrast, decades of centralized, state-managed forestry have yielded little measurable increase in forest cover, underscoring the limitations of top-down approaches. Bureaucratic inefficiencies, weak enforcement, and a lack of community engagement have hindered progress, even in the face of growing environmental urgency. With wood demand rising and climate pressures intensifying, Pakistan cannot afford to ignore the proven capacity of its rural stewards.

The path forward lies in integrating farm and social forestry into national policy, securing land and tree tenure, improving market access, and diversifying species selection toward climate-resilient indigenous trees. By empowering local actors with the tools, rights, and markets they need, Pakistan can meet its timber needs sustainably, safeguard biodiversity, and strengthen climate resilience. In doing so, the country can turn its forestry crisis into a green growth opportunity.

References: FAO; IPCC; IUCN; KP Government; PFFA; World Bank; Pakistan Economic Survey; UN; Pakistan Farm Forestry Association

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Sustainable Agriculture for Global Population Growth

As global population growth drives demand and strains agricultural systems, we must evolve our farming practices. To effectively feed nearly 10 billion people by 2050, it's crucial to balance productivity with sustainability, ensuring resource preservation and ecosystem health.

Asmatullah

8/22/2025

Global population growth, the steady rise in the number of people inhabiting the Earth, stands as one of the most powerful forces shaping the future of food and resource management. With the global population expected to approach 10 billion by 2050 (United Nations, 2022), the demand for food, water, and energy will increase at unprecedented levels. This demographic surge places extraordinary pressure on agriculture, which remains the foundation of human survival and economic stability. Arable land is shrinking due to urban expansion, soil degradation, and deforestation, while freshwater availability is declining under the combined stress of overuse and climate change. Fertile soil, built over centuries, are being exhausted faster than they can regenerate.

Agriculture finds itself in a paradoxical position. On one hand, it suffers the consequences of population growth through rising demand and environmental strain. On the other, it contributes to resource depletion through unsustainable practices such as excessive irrigation, chemical fertilizer use, and greenhouse gas emissions. This dual role underscores the urgency of reshaping agricultural systems to be more efficient, resilient, and environmentally sound.

The interplay between demographic expansion and agricultural capacity is not merely a question of producing more food, but of producing it sustainably. Feeding nearly 10 billion people will require innovations in crop science, precision farming, water management, and renewable energy integration. At the same time, policies must address inequalities in food distribution, ensuring that productivity gains benefit not only advanced economies but also vulnerable regions where hunger persists. Understanding this dynamic is essential for balancing human needs with ecological limits, and for charting a path toward global food security that safeguards both people and the planet.

The Multifaceted Impact on Agricultural Resources

Rapid population growth places mounting pressure on agricultural systems, not only through greater demand for food but also through the cascading effects it creates on land, water, soil, forests, and the climate. One of the most pressing challenges is land pressure and fragmentation. Expanding cities and infrastructure projects consume vast tracts of fertile farmland, with the FAO (2022) estimating that over 2,000 hectares of prime agricultural land are lost to urbanization every day. This reduces the total land available for cultivation and fragments the remainder, making efficient farming practices more difficult to sustain.

Water scarcity is another critical dimension. Agriculture already accounts for nearly 70 percent of global freshwater withdrawals (UN Water, 2021), and rising populations drive higher demand for both municipal consumption and crop irrigation. The over-extraction of groundwater depletes aquifers at unsustainable rates, creating long-term risks for food production. Meanwhile, soil degradation worsens as farmers intensify cultivation to meet demand. Without adequate recovery periods, soils lose nutrients, erode, or become salinized. More than a third of the world's soils are already degraded to some degree (FAO, 2022).

Deforestation compounds these stresses as forests are cleared to create new farmland, particularly in tropical regions. This practice accelerates biodiversity loss, disrupts ecological services, and releases large amounts of carbon dioxide, adding fuel to climate change (WWF, 2022). Climate change itself magnifies these pressures, as more frequent droughts, floods, and heatwaves destabilize crop yields and agricultural productivity (IPCC, 2022).

Together, these interconnected pathways illustrate how population growth amplifies strain across multiple agricultural resources. Addressing them requires not only producing more food but doing so in ways that safeguard land, water, soils, and ecosystems while mitigating climate risks for future generations.

Consequences of Intensified Resource Pressure

The relentless overexploitation of agricultural resources is driving profound socioeconomic and environmental consequences that threaten both global food security and social stability. One of the most visible outcomes is stagnating or even declining crop yields. As soils lose fertility, water becomes scarce, and climatic extremes intensify, productivity for staple crops such as wheat, rice, and maize plateaus despite rising demand (Ray et al., 2019). This stagnation undermines efforts to feed a growing population and heightens vulnerability to shocks.

Scarcity also fuels food price volatility. When production falls short due to degraded resources, global markets react with price spikes, disproportionately hurting low-income households that

spend the majority of their earnings on food (World Bank, 2023). Such volatility translates directly into hunger and malnutrition. Despite adequate global food production, structural inequalities and resource pressures leave over 828 million people hungry, while micronutrient deficiencies persist across much of the developing world (FAO et al., 2022).

The impacts extend beyond households to entire societies. Resource scarcity often becomes a "threat multiplier," intensifying local and regional tensions over access to land and water (US National Intelligence Council, 2021). Conflicts tied to resource competition destabilize communities and can escalate into broader insecurity. Meanwhile, smallholder farmers, already vulnerable to degradation and climate shocks, face dwindling livelihoods. Many are forced to abandon farming altogether, migrating to urban areas in search of alternatives. This rural-to-urban migration places new burdens on cities already struggling with infrastructure, housing, and employment challenges.

Ultimately, the unchecked strain on agricultural resources risks setting off a cycle of declining productivity, rising inequality, and deepening instability. Without urgent shifts toward sustainable practices and smarter resource management, the consequences of intensified pressure will reverberate far beyond farms, shaping the future of economies, societies, and ecosystems worldwide.

The Critical Role of Governance and International Cooperation

Transforming agriculture to meet the dual challenges of feeding a growing population and protecting natural resources requires more than technological innovation; it demands strong governance and coordinated international action. Governments, multilateral organizations, and the private sector all play indispensable roles in shaping the policies, investments, and partnerships that determine the future of global food systems.

Effective governance begins with evidence-based policy formulation. Clear legal frameworks for land tenure, water rights, and environmental safeguards are essential to prevent exploitation and mismanagement. At the same time, policies must actively promote sustainability by rewarding climate-smart practices through targeted subsidies, tax incentives, or carbon credits. Such measures not only encourage farmers to adopt resilient methods but also align national agricultural strategies with global climate goals.

Equally critical is investment in research and development. Public and private funding must be directed toward innovations such as drought-tolerant crop varieties, low-emission fertilizers, precision irrigation systems, and efficient post-harvest storage. These technologies reduce waste, improve productivity, and offer scalable solutions to food insecurity in both developed and developing economies.

Farmer-centric support systems form the backbone of any sustainable transition. Smallholders, who produce a large share of the world's food, often lack access to credit, crop insurance, and extension services. Strengthening these safety nets ensures that farmers can take calculated risks, adopt new technologies, and withstand shocks caused by climate change or market instability.

Finally, fostering global partnerships is indispensable. Food security and climate change are borderless issues that no country can resolve alone. International frameworks like the UN Sustainable Development Goals (SDGs) provide platforms for cooperation, enabling the sharing of technology, knowledge, and resources. Stronger global collaboration can harmonize efforts, scale innovations, and create a more resilient and equitable agricultural system for all.

Conclusion

Global population growth has emerged as both a driver of demand and a source of strain on agricultural systems, exposing the fragility of land, water, soil, and ecosystems. The pressures outlined in this analysis show that feeding nearly 10 billion people by 2050 cannot rely on conventional methods of production that exhaust resources and destabilize climates. Instead, agriculture must evolve into a system that balances productivity with sustainability, ensuring that short-term gains do not come at the cost of long-term survival.

The path forward requires decisive action on multiple fronts. Scientific innovation must deliver breakthroughs in resilient crops, water-saving practices, and renewable energy integration. Equally, governance must establish clear rules and incentives that discourage resource depletion and reward sustainability. Farmers, especially smallholders, need financial tools, training, and safety nets to adopt these innovations without undue risk. Above all, global cooperation is essential, because food security and climate stability are challenges that cross every border.

If governments, institutions, and communities align their efforts, the strain of population growth can become an opportunity to redesign agriculture in ways that are efficient, equitable, and ecologically sound. The stakes are high, but the tools and knowledge exist to create a food system capable of nourishing both people and the planet.

References: FAO; IFAD; UNICEF; WFP; WHO; IPCC; Ray et al.; United Nations; UNFPA; US National Intelligence Council; World Bank; World Economic Forum

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Agricultural Insurance in Türkiye: Progress & Gaps

Explore the advancements and challenges of agricultural insurance in Türkiye, focusing on TARSIM's role in enhancing coverage and affordability for farmers. Discover the ongoing issues such as underinsurance and product diversity that affect the agricultural sector.

Mithat Direk

8/22/2025

Risk, defined as exposure to uncertainty about potential damage, loss, or harm, is an unavoidable element of all economic activity. Insurance emerged as the principal financial tool to reduce these impacts by pooling risks across participants and transferring the burden from individuals to institutions. While this model works across industries, agriculture stands apart in its vulnerability. The sector relies heavily on biological processes, natural cycles, and weather patterns, all of which are inherently uncertain and largely uncontrollable. This dependence makes farming one of the riskiest enterprises, where a single shock can wipe out months or even years of investment and labor.

Because of this complexity, creating a comprehensive insurance system that protects farmers from every possible risk is not realistic. Unlike in manufacturing or services, where hazards can be quantified and isolated, agricultural risks are often interconnected and systemic. Traditional insurance products therefore tend to focus on specific perils that can be clearly defined and measured, such as hailstorms, frost damage, floods, droughts, or fire. These perils are relatively easier to assess, price, and compensate.

Yet, the real challenge lies in the fact that farm-level risks rarely occur in isolation. Drought may weaken crops, making them more susceptible to pests, while market price fluctuations can compound losses already triggered by climatic shocks. This interaction of multiple risk factors stretches beyond the capacity of conventional insurance models, which are not designed to address cascading or systemic failures. For this reason, the conversation around agricultural insurance increasingly emphasizes the need for innovative approaches, such as index-based insurance, public–private partnerships, and state-supported risk-sharing mechanisms. Without such adaptations, traditional insurance alone cannot adequately safeguard farmers against the mounting uncertainties shaping modern agriculture.

The Fundamental Challenge of Agricultural Insurance

The viability of agricultural insurance depends on accurately assessing risks and translating them into affordable premiums. This is straightforward in sectors where risks are discrete and predictable, but agriculture poses a unique challenge. The risks farmers face is diverse, interrelated, and often widespread. A scheme that attempts to cover every potential peril quickly becomes too expensive for the very farmers it aims to protect. Insurance works on the principle of contributing many small sums so that the few who suffer loss can be compensated. Yet in agriculture, disasters like drought, frost, or floods can affect entire regions simultaneously, overwhelming insurers and creating systemic exposure that private markets cannot absorb without government backing.

Insurers attempt to manage this vulnerability through reinsurance, spreading risk across larger pools. However, when claims are frequent or the insurance base is too small, premiums must increase. Higher premiums discourage participation, which shrinks the risk pool further, pushing costs even higher. This creates a cycle where coverage becomes less accessible, farmers remain unprotected, and the insurance market struggles to expand. Breaking this cycle requires broadening participation, diversifying risk, and stabilizing premium levels objectives essential to building trust and ensuring long-term viability.

The Turkish agricultural sector illustrates this dilemma vividly. With its reliance on smallholder farmers operating under tight margins, the sector is deeply exposed to climate shocks, pests, and price volatility. Yet uptake of insurance products remains low. Limited awareness, financial constraints, and skepticism about claim processes discourage participation. Farmers often view premiums as an unaffordable cost rather than a necessary safeguard. When payouts fall short of expectations, trust erodes further. This underinsurance keeps premiums high, reinforcing reliance on post-disaster government aid. While such aid provides immediate relief, it inadvertently discourages investment in proactive risk management, leaving the agricultural economy vulnerable to the next inevitable shock.

Global and Domestic Insurance Context: Latest Trends

The global insurance market is during a gradual but notable transformation. Non-life insurance, which includes agriculture, has been growing faster than life insurance, reflecting rising demand for protection against increasingly volatile risks. In 2023, global insurance premiums expanded by 2.1% in real terms, according to Swiss Re’s Sigma report, showing resilience despite economic headwinds. A key innovation in reshaping agricultural insurance is the adoption of parametric models. Unlike traditional indemnity-based systems, parametric insurance triggers payouts based on measurable indices such as rainfall levels or wind speeds without the

delays and disputes tied to field assessments. This approach improves transparency, accelerates payouts, and reduces administrative costs, making it particularly well-suited to agriculture where timeliness can determine recovery.

In Türkiye, agriculture's exposure to climate shocks, pests, and market volatility made the need for tailored insurance urgent. The creation of the Turkish Agricultural Insurance Pool (TARSIM) in 2005 marked a turning point. As a public-private partnership, TARSIM spreads risk across a national pool, aligns premium setting with government subsidies, and secures international reinsurance, providing stability that individual insurers could not manage alone. The model has produced measurable outcomes. By the end of 2023, agricultural insured value stood at ₺415.2 billion, with over 2.3 million active policies and ₺12.1 billion in premiums collected. A central driver of this progress has been the state's premium subsidy, which typically covers half of the farmer's contribution and sometimes more for high-risk regions or products.

Despite progress, structural challenges remain. Coverage is still concentrated in a narrow set of commodities and risks, leaving many farmers underinsured. Expanding into revenue-based and index-linked products is a priority, alongside boosting participation of smallholders. Success will depend on sustained investment in awareness campaigns, training, and smoother claims procedures to build lasting trust in the system.

Conclusion

Agricultural insurance in Türkiye has advanced significantly over the past two decades, yet the system still faces critical gaps that limit its ability to fully protect farmers. The establishment of TARSIM stands out as a landmark reform, enabling wider access, government-backed affordability, and international risk-sharing. Its success in expanding coverage and stabilizing the market demonstrates the value of public–private cooperation. However, the persistence of underinsurance, limited product diversity, and unequal adoption between large and small farms shows that progress has been uneven.

Traditional indemnity-based products cannot alone address the layered and systemic risks inherent in agriculture. Parametric and index-based insurance, along with revenue-linked models, offer promising pathways to enhance transparency, affordability, and timeliness of payouts. Yet technology and product design are only part of the solution. Building trust, particularly among smallholder farmers, is just as important. This requires education, awareness campaigns, and simplified claims procedures that ensure insurance is seen not as a financial burden but as an essential safeguard.

Looking ahead, Türkiye's agricultural insurance sector will need to blend innovation with inclusivity. If policymakers, insurers, and farmers align around this vision, the system can evolve from a safety net into a cornerstone of agricultural resilience in an era of mounting uncertainty.

References: Swiss Re Institute; TARSIM; Turkish Insurance Association; Öztaş & Karaman; 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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Agriculture's Role in Pakistan's Economy and Food Security

Explore the critical importance of agriculture in Pakistan, which sustains rural life, supports over a third of the labor force, and contributes significantly to food security and GDP. Learn about the challenges faced by the rural sector of Pakistan.

Mariam Nadeem

8/28/2025

Agricultural development remains the cornerstone of Pakistan's economy, particularly in its rural landscapes where a significant share of the population depends directly on farming and allied activities for survival. As the largest employment sector, agriculture engages 37.4% of the national labor force and provides the primary source of livelihood for rural households (Economic Survey of Pakistan, 2023-24). Beyond its role in producing food, agriculture forms the foundation of rural life, shaping social structures, cultural traditions, and community interactions. In regions where industrial opportunities remain scarce, agricultural development functions as the principal driver of economic growth, poverty reduction, and social cohesion.

Over the past few decades, Pakistan has witnessed significant agricultural transformation. The introduction of high-yielding crop varieties, better access to inputs like fertilizers and pesticides, and improved irrigation practices such as drip systems and laser land leveling have contributed to productivity gains. Mechanization and digital tools are gradually reshaping farming practices, offering prospects for higher efficiency and reduced labor intensity. These changes have boosted household incomes, expanded rural employment opportunities, and improved national food security.

Yet, these achievements are increasingly challenged by complex vulnerabilities. Climate change has intensified the frequency of floods, droughts, and heatwaves, directly affecting yields and livestock health. Water scarcity is becoming a structural constraint, particularly in arid regions where groundwater reserves are rapidly depleting. Meanwhile, volatile international trade dynamics, input price fluctuations, and weak market access leave smallholders especially exposed. Even within rural economies, gains from agricultural growth are uneven, as marginalized farmers and landless laborers often struggle to benefit equally.

Therefore, agricultural development today must be seen not only as a growth strategy but as a pathway toward inclusive and sustainable rural transformation. The challenge lies in balancing productivity with resilience, ensuring that agricultural progress uplifts all segments of the rural economy.

Agriculture and the National Economy

The symbiotic relationship between agriculture and Pakistan's macroeconomy is both profound and deeply interwoven with the country's broader development trajectory. Despite gradual structural shifts toward services and industry, agriculture remains a cornerstone of national stability and resilience. Its importance extends beyond fields and farms, shaping employment, food security, trade, and rural development in ways that directly influence the lives of millions.

Agriculture contributes 22.9% to Pakistan's GDP (Economic Survey of Pakistan, 2023-24). While this share has declined in relative terms, the sector's foundational role remains irreplaceable. A good harvest season fuels growth, stabilizes inflation, and strengthens foreign exchange reserves, whereas poor output triggered by droughts, floods, or rising input costs can disrupt the entire economy. The sector's performance is, therefore, a bellwether for national economic health.

Equally significant is its role in employment. Agriculture is the largest employer in Pakistan, engaging over 37% of the national labor force and serving as the primary livelihood source for more than 60% of the rural population (World Bank, 2022). Its reach extends far beyond farming, supporting a web of industries that include food processing, transportation, storage, machinery, and retail. This employment generation makes agriculture indispensable for social stability and rural well-being.

Food security remains another critical dimension. Pakistan is self-sufficient in staples like wheat and rice, yet production shortfalls or supply chain disruptions trigger price hikes that hit vulnerable households hardest. With 36.9% of the population experiencing food insecurity (National Nutrition Survey, 2018), the sector's productivity directly determines both the affordability and availability of nutritious food.

Agricultural growth also has a multiplier effect on poverty alleviation and rural development. Rising farm incomes increase spending power, stimulate rural businesses, and fund community investments in education, health, and infrastructure. Research confirms that growth in agriculture reduces poverty more effectively than expansion in other sectors (Dorosh & Malik, 2016).

Significant Impact: A Focus on Pakistan

Agriculture continues to shape Pakistan's economic and social landscape in ways that extend well beyond the farm. The adoption of modern farming practices, improved seed varieties, and better irrigation techniques has led to significant gains in productivity. Wheat production alone reached 28.2 million tonnes in 2022-23 (Economic Survey of Pakistan, 2023-24). Yet, while output is improving, yields remain below potential when compared to regional peers, leaving considerable room for growth through targeted interventions in technology transfer, soil management, and mechanization.

The sector's influence on economic growth and poverty reduction is equally striking. Rural households benefit directly from rising productivity, and initiatives such as the Benazir Income Support Program (BISP) further highlight the centrality of agriculture in reducing poverty and vulnerability. As incomes increase, rural communities gain greater purchasing power, stimulating demand for goods and services and generating multiplier effects across the local economy.

Job creation is not confined to farming alone. The agriculture-based value chain provides employment in areas like rice milling, textile manufacturing, dairy processing, input supply, and logistics. Strengthening these linkages is essential for absorbing Pakistan's growing labor force and for easing migration pressures on cities. Agricultural growth also drives infrastructure investment, from irrigation projects to the expansion of rural roads under initiatives like the China-Pakistan Economic Corridor (CPEC), which in turn improve access to markets and services.

The broader social benefits are equally important. Rising rural incomes supports spending on health and education, building stronger communities and enhancing human capital. At the same time, investment in nutrient-rich crops like pulses, fruits, and vegetables is essential for addressing Pakistan's paradox of being a food-producing nation where malnutrition persists. In this way, agriculture not only sustains the economy but also underpins social development and national food security.

Limitations and Challenges of Agricultural Development in Pakistan

Agriculture remains at the heart of Pakistan's economy, but its growth is constrained by a complex web of structural, environmental, and policy-related challenges. One of the most pressing issues is environmental degradation. Harmful practices such as over-irrigation and poor water management have led to soil salinity, waterlogging, and rapid depletion of groundwater resources, making Pakistan one of the most water-stressed countries globally. Climate change compounds these pressures, as floods, droughts, and heatwaves increase in frequency and intensity. The catastrophic floods of 2022 alone inflicted nearly $4 billion in agricultural damage, exposing the sector's vulnerability to climate extremes.

Land ownership patterns further deepen inequality, as large landholders continue to capture the lion's share of subsidies and state support, while smallholders and tenant farmers remain trapped in cycles of poverty and indebtedness. At the same time, poor market access and the dominance of middlemen prevent farmers from securing fair prices for their produce. Inadequate storage and transportation facilities worsen the problem, contributing to high post-harvest losses and reduced farm incomes. Limited access to modern technologies, including precision farming tools, quality seeds, and efficient irrigation systems, also holds back productivity, particularly among small-scale farmers who lack both the financial resources and the technical know-how to adopt them.

The rural economy's over-dependence on farming heightens its exposure to shocks, while weak rural infrastructure, unreliable electricity, poor road networks, and a lack of cold storage, reduce competitiveness. Meanwhile, inconsistent policies, abrupt import-export restrictions, and underinvestment in research and development discourage long-term growth. Labor shortages present another emerging challenge, as rural youth migrate to cities in search of better opportunities, leaving behind an aging farming population and insufficient labor during peak agricultural seasons. Adding to these internal pressures are global trade barriers, such as sanitary and phytosanitary (SPS) measures, that restrict Pakistan's agricultural exports and reduce competitiveness in international markets.

Addressing these constraints requires a shift toward sustainable and climate-smart agriculture, improved infrastructure, stronger farmer organizations, and policy consistency. Without such reforms, Pakistan risks seeing its most vital sector weakened by forces that could otherwise be managed through innovation, resilience, and inclusive development strategies.

Conclusion

Agriculture remains Pakistan's most vital sector, not only because it feeds the nation but because it sustains rural life, employment, and economic stability. Its contribution to GDP, its role in engaging over a third of the labor force, and its direct link to food security make it indispensable for national progress. The sector's growth has already demonstrated its power to reduce poverty, stimulate local economies, and strengthen social development through better education and health outcomes. Yet, these gains are fragile. Climate change, water scarcity, land inequality, weak infrastructure, and inconsistent policies threaten to erode progress unless addressed with urgency and foresight.

The way forward lies in embracing climate-smart practices, investing in rural infrastructure, expanding access to technology, and ensuring that benefits reach smallholders and marginalized communities. Equally important is strengthening value chains and improving market access so that rural producers can secure fair returns and drive inclusive growth. Agriculture must no longer be seen as a traditional occupation but as a dynamic driver of resilience, equity, and

sustainability. By transforming agriculture into a modern, innovative, and inclusive sector, Pakistan can not only safeguard rural livelihoods but also lay the foundation for long-term national stability and prosperity.

References: Government of Pakistan; World Bank; Dorosh & Malik; Khan; Hussain; IFPRI; FAO; Azam & Shafique

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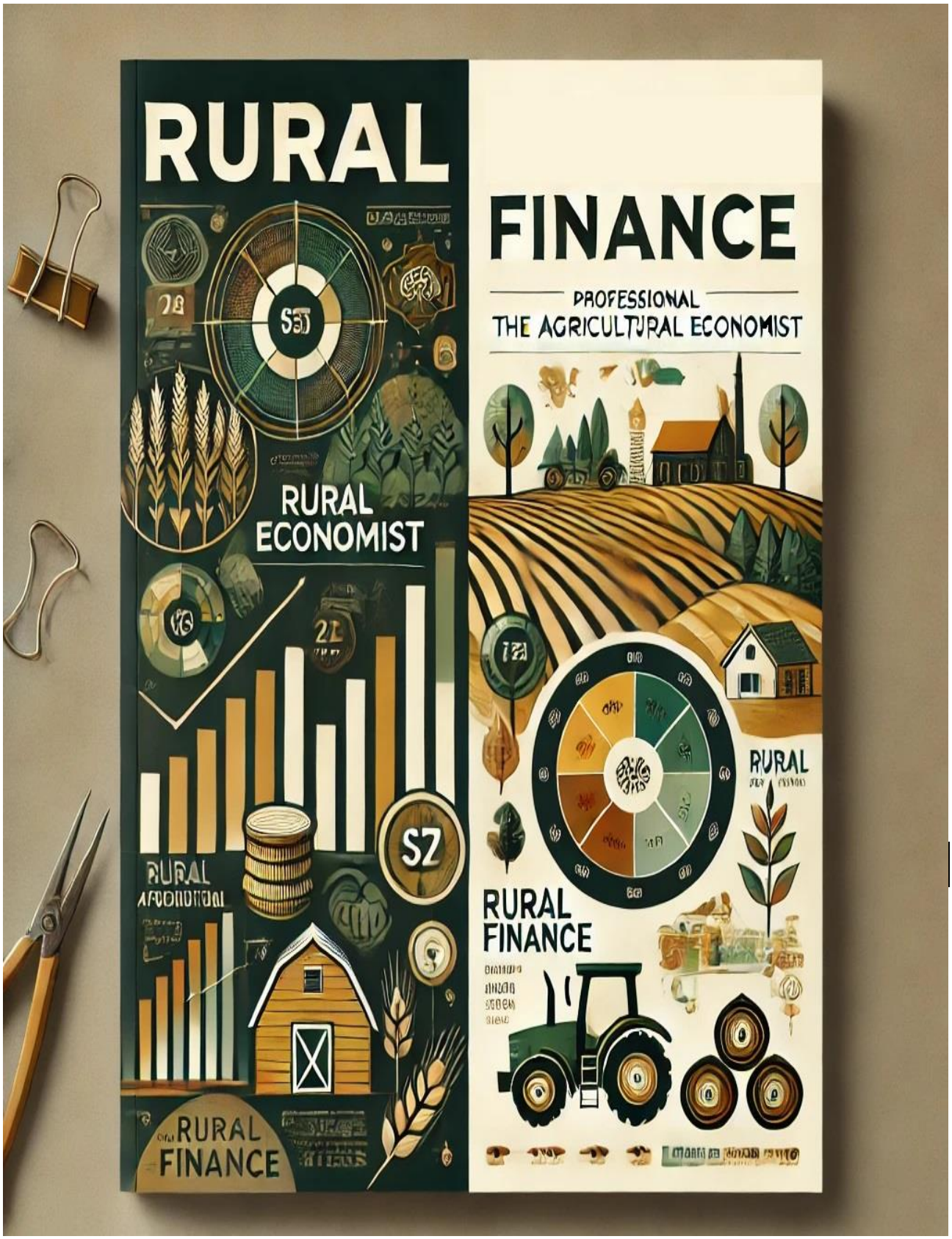

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Impact of Middlemen on Pakistan's Agriculture

Explore how middlemen in Pakistan's agricultural markets affect farmer welfare and consumer prices. Discover the challenges faced by smallholders and the implications for food security and rural poverty.

Zameer Ahmed

8/5/2025

Agriculture stands as the backbone of Pakistan's economy, contributing 22.7% to GDP and providing employment to 37.4% of the labor force (Economic Survey of Pakistan, 2023). Yet, the sector remains burdened by systemic inefficiencies, foremost among them, the dominance of middlemen. These intermediaries, primarily commission agents (arthis), wholesalers, and informal lenders, act as gatekeepers to markets. They control the flow of goods, set prices, and provide informal credit, often trapping smallholder farmers in cycles of debt and dependency. As a result, farmers typically receive only 20–30% of the final retail price of their produce (World Bank, 2023), a figure that starkly illustrates the inequity within the supply chain.

The core of the problem lies in Pakistan's largely informal and poorly regulated agricultural marketing system. A lack of cold storage, inefficient transportation, and minimal direct linkages between farmers and consumers severely limit market efficiency. Most farmers, particularly smallholders, are forced to rely on middlemen for pre-harvest loans and market access. Consequently, they have little bargaining power and are often compelled to sell at prices far below market value.

Previous reform efforts, including farmer markets (Kissan Mandis), government procurement programs, and contract farming, have largely failed to bring systemic change. These initiatives suffered from weak regulatory oversight, institutional inertia, and political interference (IFPRI, 2022). The effects are deeply felt post-harvest losses exceed 30–40% for perishables (FAO, 2023), farmer incomes remain stagnant, and consumers face frequent price hikes fueled by artificial scarcity and speculation.

This article investigates the structural role of middlemen in distorting Pakistan's agricultural markets, exposes the resulting disparities in farm-to-fork pricing, and explores policy innovations aimed at restructuring supply chains to ensure fairer, more transparent agricultural trade that empowers farmers and benefits consumers alike.

Middlemen in Pakistan's Agricultural Supply Chain

Middlemen play a dominant role in Pakistan's agricultural supply chain, particularly within the mandi (wholesale market) system, where they serve as gatekeepers between farmers and consumers. These intermediaries, commonly known as arthis or commission agents, facilitate transactions but often exploit their position. Although the officially sanctioned commission is 3–5% for grains and 5–8% for fruits and vegetables, actual profits are much higher due to hidden charges, under-weighing practices, and delayed payments, which reduce farmers' actual earnings while boosting middlemen's margins (PARC, 2023).

Farmers' reliance on middlemen is driven by a combination of financial, infrastructural, and systemic constraints. Informal credit is a critical factor, over 70% of smallholder farmers borrow from arthis at exorbitant interest rates ranging from 24% to 36%, with loan agreements often requiring farmers to sell their produce exclusively to the lender at pre-agreed, below-market prices (State Bank of Pakistan, 2023). This not only limits market competition but traps farmers in cycles of debt and dependency.

Market access remains another critical barrier. Only about 15% of farmers have direct linkages with retailers, food processors, or consumers. The vast majority rely on intermediaries due to a lack of awareness, contacts, or resources to navigate direct sales (USAID, 2023). Additionally, weak infrastructure compounds the issue. Poor rural roads, inadequate cold storage facilities, and fragmented logistics prevent farmers from preserving and transporting perishable goods efficiently. These conditions force many to accept distress sale prices, further reinforcing the control of middlemen over agricultural trade and reducing farmers' ability to benefit from their own produce.

Breaking the Monopoly: Enhancing Farmers' Share in Agricultural Markets

In Pakistan's agricultural economy, a striking imbalance persists between what farmers earn and what consumers pay. Data from the Punjab Agriculture Department (2024) highlights that for staple vegetables like tomatoes, onions, and potatoes, farmers receive only 20–30% of the final retail price. For example, tomatoes sell at Rs. 15/kg at the farm gate but reach consumers at Rs. 60–80/kg. The situation is even worse for perishable crops such as mangoes and chilies, where farmers' share drops to as low as 15% due to high spoilage risks and dependency on intermediaries (FAO, 2023).

This disparity is largely the result of middlemen dominating the supply chain. Around 60% of farmers are caught in debt cycles with these intermediaries, borrowing at exorbitant interest rates that bind them to sell produce at unfair prices (SBP, 2023). As a result, only 12% of smallholders can reinvest in improved input like certified seeds and quality fertilizers (IFPRI, 2023). On the consumer end, price manipulation by middlemen, especially during supply shocks, drives up costs by 30–50%, contributing to national food insecurity that affects 38% of the population (WFP,

2023). Moreover, poor infrastructure results in 40% post-harvest losses in fruits and vegetables (FAO, 2023), exacerbating inefficiencies.

While government initiatives like Punjab's Digital Mandis and Sindh's urban farmer markets show promise, their impact has been minimal due to middlemen resistance and inadequate enforcement. In contrast, international examples such as India's e-Choupal and Kenya's M-Farm offer scalable, tech-driven alternatives for bypassing intermediaries and ensuring transparent pricing (World Bank, 2023).

To address this systemic issue, several policy interventions are essential. Direct farmer-to-consumer markets should be expanded, with examples like Lahore's Sunday Bazaar already demonstrating 20% cost reductions (Govt. of Punjab, 2023). Digital platforms, such as a proposed "Kisan Dost" app, could provide real-time price updates and facilitate direct transactions. Blockchain technology may further ensure traceability and fairness in pricing (UNDP, 2023). Strengthening farmer cooperatives, like the Amul model in India, which boosted member incomes by 35%, alongside enforcing the Sindh Cooperatives Act, could shift bargaining power toward producers. Improving cold storage and logistics through public-private partnerships and offering formal credit through ZTBL and microfinance institutions like Karandaaz will help reduce dependency on informal lending networks and enhance market access for smallholders. These reforms are not only essential for improving farm incomes but also for ensuring fair, stable food prices for consumers.

Conclusion

The entrenched role of middlemen in Pakistan's agricultural markets has long undermined both farmer welfare and consumer affordability. Farmers, particularly smallholders, receive a disproportionately low share of consumer prices, often just 20–30%, due to exploitative intermediary practices, informal credit traps, and inadequate infrastructure. This structural imbalance stifles farmers' ability to invest in improved technologies, perpetuates rural poverty, and contributes to food insecurity across the country. Meanwhile, consumers face inflated prices caused by artificial shortages and price manipulation, especially during supply disruptions.

Despite well-intentioned government interventions, such as Digital Mandis and urban farmer markets, implementation gaps and resistance from entrenched intermediaries have limited their success. However, global innovations like India's e-Choupal and Kenya's M-Farm show that inclusive, technology-driven solutions can effectively bypass middlemen and empower farmers. Pakistan must now adopt similar approaches by scaling direct-to-consumer marketing channels, investing in digital platforms like the proposed "Kisan Dost" app, and enforcing cooperative legislation to enhance farmer bargaining power.

Complementing these reforms with targeted investments in cold storage, transportation, and formal agricultural credit will help dismantle the exploitative stronghold of middlemen. A more equitable and efficient agricultural marketing system is essential, not only to uplift farmer incomes but also to ensure price stability, food security, and inclusive rural development.

References: FAO; IFPRI; World Bank; Punjab Agriculture Department; State Bank of Pakistan; Economic Survey of Pakistan; PARC; USAID; WFP; Govt. of Punjab; UNDP

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Public-Private Partnerships in Agricultural Transformation

Explore how public-private partnerships (PPPs) are essential for agricultural transformation in Pakistan and other developing nations. These partnerships enhance productivity, inclusivity, and climate resilience, addressing challenges like food security and climate change effectively.

Ajwa Fatima

8/18/2025

Agriculture remains the backbone of many economies, particularly in developing nations where it not only ensures food security but also provides livelihoods for millions. In Pakistan, the sector contributes 22.7% to GDP and employs 37.4% of the labor force (Economic Survey of Pakistan 2023–24). Despite this central role, the country's agriculture faces persistent challenges: low productivity, fragmented landholdings, water scarcity, limited mechanization, and the mounting impacts of climate change. Traditional farming methods, while deeply rooted in cultural practice, are no longer sufficient to meet the modern demands of food security, climate resilience, and sustainable economic growth.

In this context, public–private partnerships (PPPs) have emerged as a transformative force. By leveraging the strengths of both government and private actors, PPPs can bridge critical gaps in technology adoption, financing, and market access. Governments play a vital role in providing enabling policies, subsidies, and infrastructure, while private enterprises contribute innovation, investment capital, and efficiency (World Bank, 2023). These collaborations create synergies that accelerate agricultural modernization and make farming more inclusive and competitive.

Practical applications of PPPs are increasingly visible in mechanization services, digital agriculture platforms, and financial inclusion models. For instance, machinery rental services supported through PPP frameworks allow smallholder farmers who form the majority in Pakistan, to access modern equipment without heavy upfront costs. Similarly, digital platforms developed by agri-tech startups in partnership with state institutions provide real-time weather updates, market prices, and crop advisory services to rural communities. In addition, financial institutions collaborating with the government are expanding microcredit and crop insurance programs, enhancing resilience against climate shocks (Asian Development Bank, 2023). As Pakistan seeks to future-proof its agricultural sector, strengthening and scaling public–private partnerships will be pivotal in ensuring a more productive, sustainable, and climate-resilient farming economy.

The Need for Public-Private Collaboration in Agriculture

Agriculture lies at the heart of food security, economic growth, and rural livelihoods, yet it continues to face significant challenges across the developing world, including Pakistan. Governments alone cannot meet the rising demands of efficiency, innovation, and sustainability due to budgetary constraints, bureaucratic hurdles, and outdated extension services. Similarly, while private enterprises bring in technology, investment, and market-driven solutions, their success depends on policy stability, enabling infrastructure, and farmer trust. Public-private partnerships (PPPs) therefore provide the necessary bridge, mitigating risks, enhancing governance, and accelerating the pace of agricultural transformation (IFC, 2023).

Globally, PPPs have already demonstrated their impact. India's PM-KISAN scheme, combining public funding with private fintech platforms, has digitally disbursed $30 billion to farmers since 2019 (World Bank, 2024). In Kenya, the AgriFin Accelerator funded by USAID and private banks has expanded digital loans to over 2 million smallholders (AFDB, 2023). Brazil's EMBRAPA, which integrated public research with private seed companies, revolutionized soybean farming and boosted yields by 300% within three decades (OECD, 2023). These examples highlight that partnerships unlock transformative potential when both sectors leverage their comparative advantages.

In Pakistan, PPPs are already making inroads across several domains. Technology adoption is being accelerated through initiatives such as *AgriTech Punjab*, which provides AI-based crop advisory to over half a million farmers (FAO, 2024). Similarly, digital mechanization services like Nigeria's *Hello Tractor* offer a blueprint for IoT-enabled machinery sharing that Pakistan could adopt at scale. On the financial front, Pakistan's Credit Guarantee Scheme, developed in collaboration with banks, increased agricultural loans by 28% in 2023 (State Bank of Pakistan, 2024). Bangladesh's weather-indexed insurance model offers another example, covering over a million farmers against climate risks and underscoring the potential for climate-smart finance.

Strengthening extension services is another critical area where PPPs excel. With only 30% of Pakistani farmers accessing formal training (PARC, 2023), collaborations such as Telenor's *Khushal Zamindar* which reaches 8 million farmers with SMS and voice advisories demonstrate how digital platforms can close information gaps. Similarly, corporate demonstration farms, such as those operated by Engro in partnership with the Sindh Government, are training hundreds of

thousands of farmers annually in modern techniques.

Finally, PPPs are crucial for market development and climate-smart agriculture. Nestlé Pakistan's milk supply chain now connects 300,000 smallholders to formal markets, while solar-powered drip irrigation projects in Sindh delivered jointly by government and private firms are reducing water use by up to 40% (World Bank, 2023). Together, these examples show that PPPs are not just an option but a necessity for ensuring resilient, inclusive, and sustainable agricultural systems in Pakistan and beyond.

Challenges and Future Opportunities in Agricultural PPPs

While public-private partnerships (PPPs) have shown great promise in transforming agriculture, they continue to face critical challenges that limit their full potential. Policy instability is one of the biggest hurdles, as frequent changes in government priorities and regulations disrupt the continuity of long-term projects (OECD, 2024). Trust deficits also persist private firms often fear contract breaches and unpredictable policy enforcement, while smallholder farmers remain wary of corporate motives, fearing exploitation or unfavorable contract terms (ADB, 2023). Furthermore, inclusion remains limited: studies show that only 15% of PPPs in Africa effectively engage small farmers, reflecting the broader global challenge of ensuring equity in agricultural development (IFC, 2023). Corruption and bureaucratic inefficiencies further compound these issues, with nearly 30% of agricultural PPP funds in South Asia facing some degree of mismanagement or leakages (Transparency International, 2024).

To address these challenges, stronger governance and accountability mechanisms are essential. Independent PPP regulatory bodies, such as Pakistan's PPP Authority, can play a vital role in ensuring oversight and reducing political interference. Farmer cooperatives should be empowered to participate in contract negotiations, giving smallholders greater bargaining power. Meanwhile, the use of blockchain and digital tracking systems offers an innovative solution for transparent fund management and minimizing corruption risks.

Looking ahead, significant opportunities exist for agricultural PPPs. Women and youth engagement is one critical area: with women making up 60% of Africa's smallholder farmers (UN Women, 2024) and agri-tech incubators like Pakistan's NIC Agri-Tech attracting young entrepreneurs, gender- and youth-inclusive PPPs can unlock untapped potential. Digital agriculture and AI are another frontier, especially as global agri-tech investment reached $10 billion in 2023 (AgFunder, 2024). Climate finance mobilization and access to carbon markets represent additional opportunities, particularly given the $7 billion allocated to climate-smart agriculture in 2024 (Green Climate Fund, 2024). Finally, regional partnerships such as CPEC's planned agricultural zones can strengthen trade and value chain integration, positioning countries like Pakistan for greater export competitiveness.

Conclusion

Public–private partnerships (PPPs) represent a cornerstone of agricultural transformation, offering a pathway toward productivity, inclusivity, and climate resilience. As Pakistan and other developing nations grapple with mounting pressures ranging from food security to climate change traditional approaches alone cannot deliver the scale of solutions required. PPPs provide a vital bridge, enabling governments to overcome fiscal and institutional limitations while allowing the private sector to channel innovation, investment, and efficiency into agriculture.

The evidence, both global and local, underscores the transformative potential of these collaborations. From India's fintech-enabled farmer support schemes to Brazil's soybean revolution, PPPs have consistently demonstrated their ability to accelerate modernization when supported by strong governance and farmer-centered policies. In Pakistan, success stories in mechanization, digital extension services, and climate-smart irrigation systems prove that PPPs are already reshaping the agricultural landscape.

Yet, for these partnerships to reach their full potential, challenges such as policy instability, trust deficits, and exclusion of smallholders must be urgently addressed. Establishing robust governance frameworks, fostering farmer participation, and leveraging digital innovations are essential steps. By scaling inclusive and transparent PPPs, Pakistan can not only enhance food security and rural livelihoods but also position its agriculture at the forefront of sustainable, globally competitive farming systems.

References: ADB; FAO; IFC; Pakistan Economic Survey; World Bank; Asian Development Bank; IFC; AFDB; OECD; State Bank of Pakistan; PARC; Transparency International; ADB; UN Women; AgFunder

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Importance of Agricultural Insurance in Pakistan

Agricultural insurance in Pakistan is essential for protecting farmers and stabilizing markets. It mitigates climate shocks and supports formal credit pathways. Despite its benefits, gaps in awareness, affordability, and institutional trust continue to limit its reach.

Eman Fatima

8/26/2025

Agricultural insurance provides farmers with a crucial safety net against losses caused by uncontrollable perils such as floods, droughts, pests, and diseases. In a sector where a single climate shock can wipe out months of hard work and investment, insurance acts as a stabilizer that cushions farmers from devastating financial setbacks. Its core economic functions extend beyond compensation: it safeguards farm profits, sustains production cycles, and reduces the government's heavy fiscal burden of post-disaster relief and ad hoc subsidies. Instead of reactive spending after calamities, insurance allows risks to be shared more systematically across institutions and markets.

By redistributing resources, minimizing uncertainty, and providing timely payouts, agricultural insurance also unlocks access to formal credit. Financial institutions are more willing to extend loans to insured farmers, knowing their repayment capacity is less likely to collapse after a disaster. Stable revenues and the assurance of protection create incentives for farmers to invest in improved seeds, irrigation, and climate-smart technologies that raise productivity. In this way, insurance not only mitigates risks but also fosters long-term resilience and modernization in farming.

In Pakistan, the urgency of agricultural insurance cannot be overstated. With agriculture employing more than a third of the labor force and contributing nearly a quarter to GDP, climate-induced shocks translate directly into economic and social instability. The floods of 2022 alone destroyed vast tracts of farmland, displacing millions and pushing food inflation to record highs. Traditional relief measures were insufficient and fiscally draining, underscoring the need for institutionalized insurance mechanisms. Well-designed schemes, whether index-based, crop-specific, or livestock-focused, can provide scalable and transparent protection for smallholders who are most exposed. For Pakistan's food security and rural economy, expanding agricultural insurance is no longer optional; it is a strategic imperative for resilience and sustainable growth.

The Pakistani Context and Insurance Products

Agriculture in Pakistan operates under persistent uncertainty, with floods, droughts, pests, and market shocks regularly disrupting farm incomes. While insurance is one of the most effective tools to mitigate these risks, its penetration remains strikingly low. The federal government has introduced schemes like the Crop Loan Insurance Scheme (CLIS), which is often bundled with agricultural credit. Yet, awareness and trust remain limited. A study in Punjab revealed that only 61.3 percent of surveyed farmers knew about crop insurance, and many viewed it unfavorably due to high premiums and complicated procedures (Abid et al., 2021). Socioeconomic factors such as landholding size, literacy levels, and access to extension services strongly influence farmers' willingness to pay for coverage. For subsistence farmers, affordability remains the defining barrier, underscoring the need for sustained government subsidies and simplified processes.

Beyond crops, livestock insurance represents an equally urgent priority. Livestock contributes more than 60 percent to agricultural value-added and over 11 percent to Pakistan's GDP, yet small-scale pastoralists are left exposed to mounting risks. Climate change is intensifying heat stress, degrading rangelands, and accelerating the spread of animal diseases. Insurance products covering mortality from disease or extreme weather could provide critical protection for millions of rural households whose survival depends on cattle, goats, and buffaloes.

Weather-Based Index Insurance (WII) offers another pathway to expand coverage in a cost-effective manner. By linking payouts to measurable weather parameters such as rainfall deficiency, WII avoids costly and time-consuming farm-level loss assessments while minimizing moral hazard. Pilot projects in drought-prone areas like Tharparkar have already demonstrated the model's viability, delivering timely compensation to affected farmers (IFRC, 2022). Scaling such initiatives could revolutionize agricultural risk management in Pakistan, offering transparency, efficiency, and greater confidence among farming communities.

Economic Benefits, Challenges, and the Way Forward for Agricultural Insurance in Pakistan

Agricultural insurance offers a transformative pathway for stabilizing rural incomes and building resilience in Pakistan's volatile farming sector. Its first and most visible benefit lies in income stabilization. By providing a financial safety net, insurance shields farmers from catastrophic losses after droughts, floods, or pest attacks, reducing the likelihood of distress sales of land, livestock, or equipment. This stability also enhances confidence, allowing farmers to plan for the next season rather than being trapped in cycles of recovery. Beyond stability,

insurance directly enhances credit access. When farmers are insured, banks and microfinance institutions view them as lower-risk borrowers, which improves the flow of credit for quality inputs like seeds, fertilizers, and technology (World Bank, 2020). In a country where smallholders often rely on informal lenders, this shift toward formal credit can unlock higher productivity and modernization. Agricultural insurance also strengthens fiscal resilience by reducing the government's dependence on ad-hoc post-disaster relief, which is costly, politically driven, and often poorly targeted. Finally, by lowering the fear of total ruin, insurance encourages innovation. Farmers are more willing to adopt high-yield seeds, modern irrigation, or new cropping systems that carry higher risk but promise long-term gains.

Despite these advantages, implementing agricultural insurance faces formidable challenges in Pakistan. Affordability remains the most obvious barrier: smallholders often cannot afford the premiums, and government subsidies, while necessary, place a heavy fiscal burden. Awareness and trust are equally pressing issues. Many rural farmers have little understanding of how insurance works, and negative experiences with delayed claim settlements have reinforced skepticism. Classic problems of adverse selection and moral hazard also complicate product design, as riskier farmers are more likely to enroll, and insured farmers may take greater risks. High transaction costs are another structural barrier, with loss assessments and claims processing in remote areas proving both expensive and slow. Finally, the lack of reliable historical data on yields, weather, and losses makes accurate pricing nearly impossible, leading to premiums that often do not reflect actual risks.

Looking abroad provides valuable lessons. The United States' Federal Crop Insurance Program (FCIP) demonstrates the potential of public-private partnerships. With premium subsidies averaging over 60% and private companies managing policy delivery, the model balances fiscal support with market efficiency. One cautionary lesson, however, is the danger of inertia, where farmers stick to familiar plans despite better options, highlighting the need for continuous farmer education (USDA, 2023). Kenya's Index-Based Livestock Insurance (IBLI) offers another relevant case. Using satellite imagery to monitor vegetation and trigger payouts when forage scarcity is predicted, it has provided timely and transparent support to pastoralists (ILRI, 2021). With similar agro-ecological vulnerabilities, Pakistan could adapt such index-based approaches for both crops and livestock.

Technology will be central to the way forward. Remote sensing and GIS can cut costs by monitoring crop health and verifying weather indices without field visits. Big data and predictive analytics can improve risk models and allow more accurate pricing. Mobile technology can expand accessibility by enabling registration, premium payment, and claims processing through phones, while blockchain can enhance transparency by recording immutable transactions. To move ahead, Pakistan must invest in awareness campaigns that build trust, diversify insurance products with affordable index-based models, strengthen public-private partnerships, and expand digital finance integration. Most importantly, the government should prioritize building centralized data systems to underpin accurate product design. Agricultural insurance, if supported with the right mix of policy, technology, and farmer engagement, can evolve from a niche tool into a cornerstone of rural resilience.

Conclusion

Agricultural insurance in Pakistan stands at a decisive crossroads. The evidence shows that it is not merely a financial tool but a structural necessity for protecting farmers, stabilizing markets, and reducing the government's chronic fiscal exposure to disasters. By cushioning households against climate shocks and creating pathways to formal credit, insurance has the potential to transform subsistence farming into a more resilient and productive sector. Yet, the gaps in awareness, affordability, and institutional trust continue to limit its reach. Without targeted subsidies, clear communication, and streamlined claim processes, farmers will remain skeptical and underinsured.

The global examples of index-based schemes and technology-driven monitoring prove that innovation can reduce costs and build transparency. Pakistan's pilots in rainfall-index and livestock insurance are promising starts, but they require scale, consistency, and strong public–private collaboration to succeed. At the heart of the challenge lies data: reliable, centralized information on weather, yields, and losses must be built into the system to design fair premiums and ensure timely payouts.

Agricultural insurance cannot be treated as a short-term project. It must be institutionalized as a pillar of rural policy. For Pakistan's food security and rural stability, scaling up insurance is not optional, it is urgent.

References: Abid & Rahman; IFPRI; IFRC; ILRI; Government of Pakistan; USDA Risk Management Agency; World Bank

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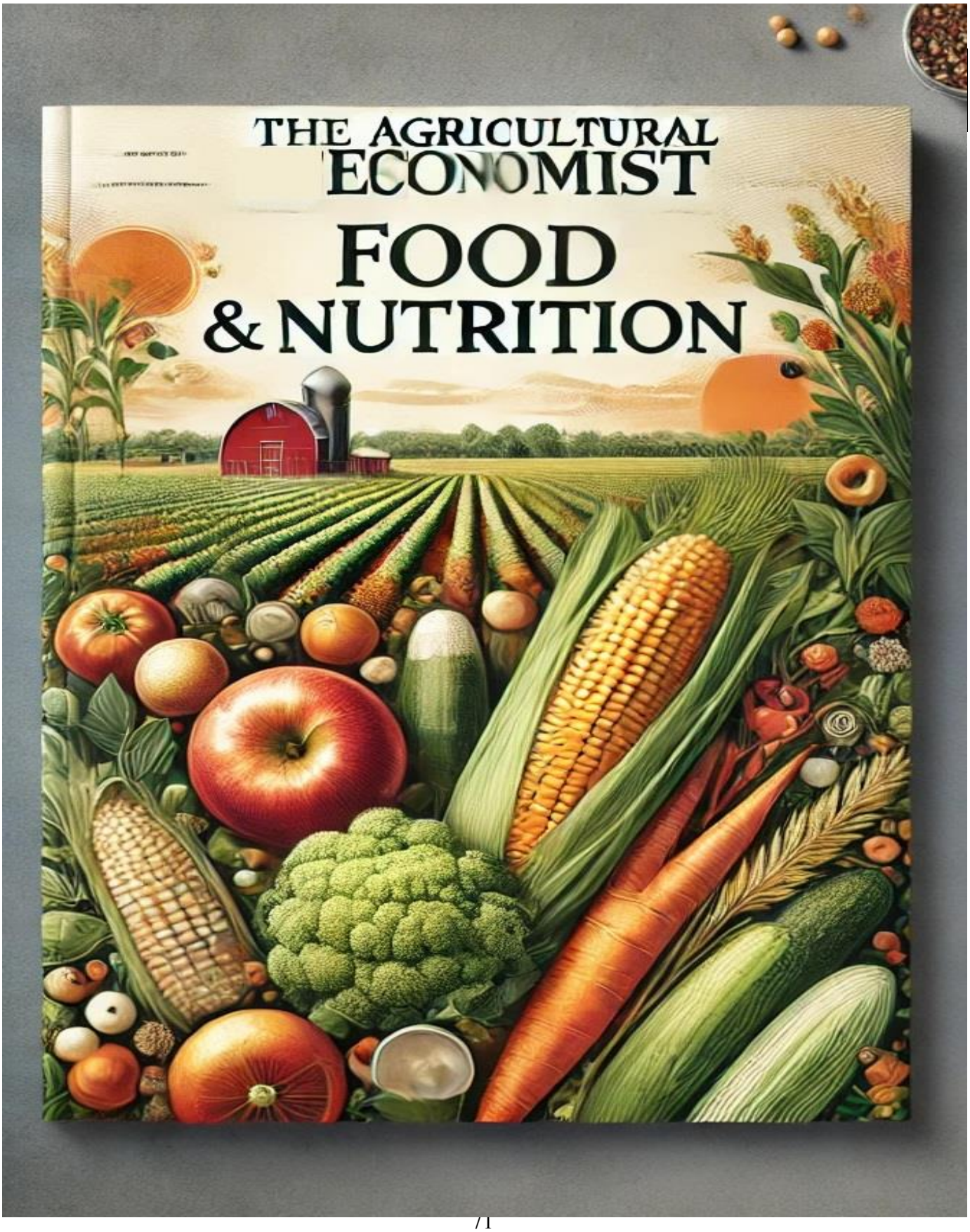

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Resource Scarcity and the Global Food System

Resource scarcity is reshaping the global food system due to climate change and population growth. It poses significant challenges to meet nutritional needs, raising food prices, and exacerbating hunger. Urgent intervention is needed to address these interconnected crises.

Tarim Nayyab

8/6/2025

Resource scarcity represents a critical imbalance between the planet's finite natural endowments, such as water, arable land, and energy, and the accelerating demands of a growing global population. With the world's population expected to reach 9.8 billion by 2050 (UN, 2022), the pressure on these resources is mounting at an unsustainable rate. Land degradation, for example, already affects 40% of the Earth's land area, undermining soil fertility, reducing agricultural productivity, and accelerating desertification (UNCCD, 2022). Water scarcity is equally alarming, with 2.3 billion people currently living in water-stressed countries (WHO, 2023). As agriculture accounts for nearly 70% of global freshwater withdrawals (FAO, 2023), competition between farming, industry, and urban consumption is escalating, posing serious risks to food production and rural livelihoods.

Energy demand further complicates the picture. While renewable energy is expanding, fossil fuel consumption still outpaces green alternatives, particularly in developing countries where energy access remains limited (IEA, 2023). Agriculture's dependence on energy-intensive inputs, such as irrigation systems, mechanization make chemical fertilizers, makes it vulnerable to both fuel price volatility and emissions regulations. Climate change compounds these stresses, disrupting weather patterns, increasing the frequency of extreme events, and reducing crop yields in already vulnerable regions.

The convergence of these resource pressures creates a profound challenge to global food security and sustainable development. Without urgent action to improve resource efficiency, shift toward climate-smart agriculture, and invest in renewable energy and sustainable land management practices, the gap between demand and supply will continue to widen. Addressing resource scarcity requires a coordinated global response, one that integrates technological innovation, policy reform, and behavioral change to ensure that food systems remain resilient, equitable, and capable of nourishing future generations within ecological limits.

Key Drivers of Resource Scarcity

Resource scarcity is driven by a complex interplay of demographic, environmental, and systemic factors that are intensifying stress on the planet's limited natural resources. A major contributor is rapid population growth and the corresponding surge in consumption. Each additional person requires significantly more water and energy to meet basic food needs, with estimates suggesting a 20% increase in water and 30% increase in energy demands per capita (World Resources Institute, 2023). As a result, global food demand is projected to rise by 50% by 2050 (FAO, 2022), placing immense pressure on land, water, and energy systems.

Climate change is another critical driver, disrupting weather patterns and reducing agricultural reliability. Rising global temperatures could slash crop yields by up to 30% in already vulnerable regions (IPCC, 2023), while the frequency and intensity of extreme events such as droughts and floods, now three times higher than in the 1980s, continue to damage farmland and infrastructure (WMO, 2023). Simultaneously, the overexploitation of natural resources is depleting ecological reserves. Nearly 90% of the world's fisheries are either fully exploited or overfished (UNEP, 2023), and deforestation is erasing 10 million hectares of forest each year, further reducing arable land (Global Forest Watch, 2023).

Pollution and soil degradation are compounding these issues. One-third of global soils are now degraded due to excessive erosion and chemical misuse (FAO, 2022), and microplastic contamination affects over 80% of agricultural soils, posing risks to food safety and soil health (Science Advances, 2023). Meanwhile, inefficiencies in resource management exacerbate scarcity. Between 30–40% of food is lost post-harvest due to inadequate storage and distribution, and outdated irrigation systems waste up to 60% of water used in agriculture (World Bank, 2023; IWMI, 2023). Addressing these interconnected drivers is essential to securing a sustainable resource future.

The Far-Reaching Effects of Resource Scarcity on Global Food Systems

Resource scarcity is rapidly undermining the resilience of global food systems, with water stress, land degradation, and rising input costs threatening the stability of food production. Currently, 4 billion people face severe water scarcity for at least one month each year (Mekonnen & Hoekstra, 2023), and prolonged droughts like those in the Horn of Africa between 2020 and 2023 caused widespread crop failures affecting 37 million people (UNOCHA, 2023). At the same time, the world is losing 24 billion tons of fertile soil annually (UNCCD, 2023), with Africa alone suffering $68 billion in losses each year due to soil degradation (AU, 2023). These environmental constraints have triggered a surge in production costs, contributing to a 23% global food price increase in 2022 (World Bank, 2023). The war in Ukraine further

intensified the crisis, with fertilizer prices tripling in some regions (IMF, 2023).

This scarcity has led many countries, particularly in Africa, to deepen their reliance on food imports. Today, 55% of African nations depend on imported food, while wheat imports to Sub-Saharan Africa have increased by 90% since 2000 (AfDB, 2023; OECD, 2023). These vulnerabilities have cascading effects on global food security. In 2022, 828 million people faced hunger, and 45 million children suffered from acute malnutrition (SOFI, 2023; UNICEF, 2023). Rising food costs and shortages also trigger social unrest, food riots erupted in over 30 countries during the 2022–2023 inflation crisis (ACLED, 2023).

Resource scarcity further deepens global inequality and exacerbates health disparities. Malnutrition-related causes claim the lives of 3.1 million children annually (WHO, 2023), while consumption patterns remain skewed, the richest 10% consume twenty times more resources than the poorest half of humanity (Oxfam, 2023). The global food system stands at a critical inflection point, urgently requiring more equitable, efficient, and sustainable solutions.

Advancing Sustainable Agriculture Through Innovation and Policy Action

Addressing the challenges of resource scarcity and global food insecurity demands a shift toward sustainable agricultural solutions supported by smart policy frameworks. Climate-Smart Agriculture (CSA) presents a promising approach, capable of increasing yields by up to 20% while simultaneously reducing greenhouse gas emissions (World Bank, 2023). Precision agriculture technologies, including satellite-guided irrigation and soil sensors, can further optimize resource use, cutting water consumption by 30–50% (MIT, 2023). In arid regions, efficient irrigation techniques such as drip systems can boost water efficiency by 90% (FAO, 2023), while countries like Israel set a global example by recycling 90% of their wastewater for agricultural reuse (OECD, 2023).

The integration of renewable energy into agriculture also offers transformative benefits. Solar-powered irrigation systems, for instance, have been shown to reduce fuel costs by 70% (IRENA, 2023), and in the EU, wind and biogas technologies have helped cut emissions from farms by 40% (EC, 2023). These energy transitions not only reduce operational costs for farmers but also contribute significantly to climate mitigation.

Policy support is equally essential. The European Union's Farm to Fork Strategy outlines a vision for a more resilient food system by aiming for 25% of agricultural land to be organically farmed by 2030 (EC, 2023). Similarly, the African Union's Comprehensive Africa Agriculture Development Progra (CAADP) targets 6% annual agricultural growth to ensure long-term food security and rural development (AU, 2023).

Food waste reduction is another critical avenue for sustainability. Halving global food waste could feed an additional one billion people (WRI, 2023), while digital innovations like blockchain are already helping reduce supply chain losses by 20% (WEF, 2023). Together, these solutions represent an integrated path forward, merging technological innovation with bold policy and collaborative action.

Conclusion

Resource scarcity is no longer a looming threat; it is a present reality that is reshaping the global food system in profound and unequal ways. As population growth, climate change, and unsustainable resource management converge, the world faces rising challenges in meeting the nutritional needs of billions. Water stress, land degradation, and energy dependence are not isolated problems but interconnected crises that undermine agricultural productivity, raise food prices, and deepen global hunger and malnutrition. Without urgent and sustained intervention, the gap between food demand and supply will widen, disproportionately affecting the most vulnerable populations and exacerbating social and economic instability.

However, this challenge also presents a vital opportunity for transformation. Solutions such as climate-smart agriculture, efficient irrigation, renewable energy, and food waste reduction offer scalable and impactful pathways to resilience. Backed by robust policy frameworks like the EU's Farm to Fork Strategy and the AU's CAADP, these innovations can enhance food security while preserving planetary health. Moving forward, global cooperation, inclusive investment, and behavioral change will be essential to align food production with ecological limits. Only by embracing integrated, forward-looking approaches can we build food systems that are not just productive, but sustainable, equitable, and future-ready for generations to come.

References: FAO; IPCC; World Bank; UNEP; WRI; UN; UNCCD; WHO; IEA; World Resources Institute; WMO; Global Forest Watch; Science Advances; IWMI; Mekonnen & Hoekstra; UNOCHA; AU; IMF; AfDB; OECD; UNICEF; SOFI; ACLED; Oxfam; MIT; IRENA

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Biofuels: Key to Decarbonization & Cleaner Energy

Explore the pivotal role of biofuels in the global decarbonization strategy, balancing cleaner energy opportunities with challenges in food security and sustainability. Learn about first, second, third, and fourth-generation biofuels and their impact on the future of energy.

Ariba Zahid

8/13/2025

Biofuels, produced from crops, algae, and waste biomass, are emerging as a cornerstone in the global effort to decarbonize transportation, especially in hard-to-abate sectors like aviation, where Sustainable Aviation Fuel (SAF) is gaining traction, and heavy freight, which relies on high-density energy sources. With oil prices fluctuating between $75 and $90 per barrel in 2024, biofuels present an opportunity for enhanced energy security by reducing dependence on fossil fuel imports. However, their adoption comes with critical challenges, including high production costs, competition for agricultural land, and varying greenhouse gas (GHG) reduction potential depending on feedstock and production methods.

Globally, biofuels accounted for 4.3% of transport fuel demand in 2023 (IEA, 2024), underpinned by strong policy mandates and technological advancements. Total production reached 186 billion liters, with ethanol, primarily from sugarcane and corn, representing 64%, and biodiesel largely from vegetable oils and waste fats making up 29% (REN21, 2024). Yet, the "food versus fuel" debate remains contentious, as 40% of U.S. corn and 50% of EU rapeseed oil are diverted to biofuel production (FAO, 2024), raising concerns about food price inflation and land-use pressures.

Advanced biofuels, derived from non-food feedstocks such as agricultural residues, municipal waste, and algae, offer a more sustainable pathway by reducing land competition. These second- and third-generation biofuels are expanding their market share but face high production costs estimated at $1.50–$3.00 per liter compared to conventional fossil fuels (IRENA, 2024).

Policy support is shaping the sector's trajectory. The EU's Renewable Energy Directive III (RED III) mandates a 29% share of renewables in transport by 2030, while the U.S. Inflation Reduction Act extends tax credits for low-carbon fuels. The interplay between policy incentives, technological breakthroughs, and sustainable resource management will determine whether biofuels can scale up without compromising global food security or environmental integrity.

Biofuel Generations: Technological and Economic Comparison

The evolution of biofuel technology can be categorized into four distinct generations, each representing a step forward in feedstock innovation, production efficiency, and environmental sustainability. First-generation biofuels, derived from food crops such as corn, sugarcane, and soy, are the most commercially mature and widely deployed. They benefit from established supply chains and lower production costs, typically between $0.50 and $0.80 per liter, making them competitive in many markets. However, their reliance on edible crops intensifies the "food versus fuel" debate, as they compete directly with food supply chains, potentially driving up food prices and straining agricultural resources.

Second-generation biofuels shift focus to non-food biomass, including agricultural residues, forestry waste, and dedicated energy crops like switchgrass. These feedstocks reduce direct competition with food systems and offer lower land-use impacts. Nonetheless, the complexity of breaking down lignocellulosic material into fermentable sugars results in higher production costs, averaging $1.20 to $2.00 per liter. While commercial plants exist, scaling remains limited due to capital-intensive processing technologies.

Third-generation biofuels, based on algae and cyanobacteria, hold the promise of exceptionally high yields per acre and can be cultivated on non-arable land using saline or wastewater, thereby avoiding agricultural land conflicts altogether. Despite these advantages, current production systems face technological and scaling challenges, particularly in harvesting and lipid extraction. These constraints push costs into the $2.50 to $5.00 per liter range, making them economically uncompetitive without significant subsidies or breakthroughs in bioprocessing efficiency.

Fourth-generation biofuels are still largely in the research and development phase. Using advanced synthetic biology and direct carbon capture technologies, these processes convert CO_2 into liquid fuels with the potential for carbon-negative emissions. While they represent the most sustainable long-term solution, current costs exceed $5.00 per liter, reflecting early-stage technology maturity and limited commercialization.

The economic and environmental trajectory of biofuels will depend on accelerating technological advancements, achieving economies of scale, and integrating supportive policies that can reduce production costs while ensuring sustainability. Ultimately, a diversified portfolio of biofuel generations may be necessary to meet global decarbonization goals without undermining food security or ecosystem health.

Economic Drivers of Biofuel Production

The economics of biofuel production are shaped by a combination of feedstock costs, processing expenses, logistical

challenges, and the strength of policy incentives. Feedstock prices remain a major determinant of overall competitiveness. In 2024, U.S. corn used for ethanol production averaged $210 per ton, with 40% of national corn output directed toward ethanol plants. Brazil's sugarcane, a far more efficient ethanol feedstock, cost just $45 per ton, with 60% of its harvest dedicated to ethanol. Algae, while offering high productivity and no competition with food crops, remains prohibitively expensive at $300–$1,000 per ton of biomass, making it viable only in niche or subsidized markets.

Processing and logistics costs add another significant layer. Cellulosic ethanol facilities, designed to handle lignocellulosic residues and dedicated energy crops, require capital investments between $200 million and $500 million. Transporting biodiesel is also more expensive than fossil diesel, 20–30% higher per unit, due to its lower energy density and specialized storage needs. These economic hurdles are partially offset by targeted policy incentives. The U.S. Renewable Fuel Standard (RFS), combined with Inflation Reduction Act tax credits, provides a $1 per gallon subsidy for sustainable aviation fuel (SAF). The EU's Renewable Energy Directive III mandates 29% renewable energy in transport by 2030 while banning palm oil-based biofuels, a move aimed at reducing deforestation. Brazil's RenovaBio program supports ethanol through carbon trading credits, and India's ambitious ethanol blending target of 20% by 2025 has spurred $6 billion in new biorefinery investments.

These economic drivers, however, have clear spillover effects on food systems. Rising biofuel demand has been linked to a 10–15% increase in global corn prices, and palm oil biodiesel expansion pushed cooking oil prices up 20% in 2023. Since 2020, over 5.7 million hectares have been diverted to biofuel crops, with Indonesia's palm oil sector alone contributing to 2.3 million hectares of deforestation since 2010. While by-products like distillers dried grains with solubles (DDGS) provide valuable animal feed, they cannot fully offset the resulting food security risks, especially in regions like Sub-Saharan Africa.

From an environmental perspective, biofuels vary in their climate benefits. Sugarcane ethanol achieves the highest lifecycle CO_2 reductions (70–90%), while corn ethanol averages 40–50%. Yet, water demands for biofuel production such as the 1,500 liters required for each liter of corn ethanol along with biodiversity losses from feedstock expansion highlight the delicate balance between economic viability, environmental sustainability, and global food security.

Future Outlook for Biofuels (2025–2030)

The next five years are set to be transformative for the biofuel sector, with a strong emphasis on technological innovation, sustainability, and market diversification. One of the most dynamic growth areas will be Sustainable Aviation Fuel (SAF), projected to expand tenfold by 2030 according to IATA (2024). This surge will be driven by binding decarbonization mandates in aviation, rising carbon prices, and increasing investment from both airlines and energy companies. Parallel to this, advancements in artificial intelligence for crop optimization are expected to reduce land requirements for biofuel feedstocks by as much as 20% (Nature Sustainability, 2024). Precision agriculture, predictive modeling, and real-time monitoring could enable higher yields without expanding agricultural land, thereby mitigating food-versus-fuel tensions.

On the technological frontier, 4th generation biofuels particularly e-fuels derived from captured CO_2 and renewable electricity may achieve production costs of around $2.50 per liter by 2030 (McKinsey, 2024), making them increasingly competitive with fossil-based aviation and marine fuels. However, scaling these technologies will require targeted policy support, infrastructure investment, and robust global supply chains.

To ensure that biofuel expansion aligns with climate and food security goals, several policy actions are recommended. Subsidies should be redirected toward 2nd and 3rd generation biofuels, which offer better land-use efficiency and lower lifecycle emissions. Governments must enforce strict land-use regulations to prevent deforestation and habitat loss linked to feedstock cultivation. Finally, the establishment of a global biofuel certification system, akin to the Forest Stewardship Council (FSC) in forestry, could standardize sustainability criteria, improve transparency, and enhance consumer trust in renewable fuels.

Conclusion

Biofuels remain a pivotal yet complex element in the global decarbonization strategy, balancing opportunities for cleaner energy with challenges to food security, environmental sustainability, and economic viability. First-generation biofuels have provided the necessary market entry but intensified the food-versus-fuel debate, while second- and third-generation alternatives promise greater sustainability at higher costs. Fourth-generation innovations, particularly e-fuels and CO_2-to-fuel technologies, offer long-term potential for carbon-negative energy systems but require significant investment and technological breakthroughs before widespread adoption.

The economic landscape, shaped by feedstock prices, production costs, logistics, and policy incentives, continues to evolve, with governments playing a decisive role in scaling sustainable pathways. Looking ahead to 2025–2030, the biofuel sector is poised for rapid growth, driven by Sustainable Aviation Fuel, AI-enabled crop optimization, and advances in next-generation biofuels. However, success will depend on aligning technological progress with robust policy frameworks that safeguard ecosystems, protect food systems, and incentivize low-carbon innovation.

A diversified biofuel portfolio, combined with strict land-use controls and a transparent global certification system,

can help ensure that biofuels contribute meaningfully to climate goals without exacerbating resource competition. The coming decade will be critical in determining whether biofuels evolve into a truly sustainable cornerstone of the global energy transition.

References: IEA; IRENA; FAO; IPCC; REN21; IATA; Nature Sustainability; McKinsey

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Tomatoes' Minimal Role in Türkiye's Inflation

This analysis reveals that tomatoes contribute only 0.87% to Türkiye's CPI basket, indicating their limited impact on food inflation. Key factors like rising energy costs, labor expenses, and market power in processed foods are the primary drivers of inflationary pressures.

Mithat Direk

8/15/2025

Tomatoes hold a symbolic place in Türkiye's food culture, yet their role in shaping national inflation is often overstated. According to TÜİK (2024), tomatoes account for just 0.87% of the Consumer Price Index (CPI) basket, a fraction too small to independently cause significant changes in the headline inflation rate. This means that while seasonal price spikes in tomatoes may draw public attention, their overall statistical effect is minimal. Consumer behavior also helps absorb these fluctuations. Data from the TURKSTAT Household Survey (2023) shows that when fresh tomato prices rise sharply, households readily substitute with other vegetables such as peppers or eggplants or shift to processed and canned tomato products. This substitution effect dampens the broader inflationary impact.

The real inflationary pressures in Türkiye stem from other sectors. Processed foods, which carry an 18.2% weight in the CPI basket, along with energy costs and fluctuations in the exchange rate, have a far greater influence on the overall inflation trajectory (CBRT, 2024). Exchange rate movements affect imported inputs such as fertilizers, seeds, and fuel, raising production costs across the agricultural sector.

Another often-overlooked factor is the farmer's share in the final retail price. For fresh tomatoes, producers receive only 15–20% of the price paid by consumers, compared to 50–60% for processed tomato-based products like paste and sauces (TARIM Dairesi, 2024). The remainder is absorbed by intermediaries, processors, distributors, and retailers, meaning that price volatility in fresh tomatoes has a diluted pass-through to the CPI.

In short, while tomato prices can spark public debate and seasonal concern, Türkiye's inflation dynamics are driven far more by structural factors in processed food markets, energy pricing, and currency trends than by the humble tomato.

The Tomato-Inflation Myth: Why the Narrative is Flawed

The idea that rising tomato prices significantly drive Türkiye's inflation is more myth than reality. According to TÜİK (2024), tomatoes represent just 0.87% of the Consumer Price Index (CPI) basket, tiny compared to staples like bread and cereals (7.5%), processed meats (4.3%), and oils and fats (3.1%). Even in the extreme case of a 50% price surge, tomatoes would contribute only about 0.43 percentage points to the overall inflation rate, far from being a primary driver.

Consumer behavior further dilutes this impact through the substitution effect. When fresh tomato prices jumped 112% year-on-year in June 2023, Ministry of Agriculture data shows pepper consumption rose 18% as households adjusted their purchasing habits. Türkiye's position as the world's 7th largest vegetable producer (FAO, 2024) ensures that a diverse range of alternatives such as eggplants, cucumbers, or canned tomato products remain readily available, cushioning price shocks.

The real drivers of food inflation lie elsewhere, particularly in processed food and input costs. Energy expenses, including electricity and fuel, have risen 32%, sharply increasing food processing costs (TOBB, 2024). Packaging materials have surged, glass by 45% and metal by 28% since 2022 (İSO, 2024), while labor costs have climbed 68% following minimum wage hikes (TÜRK-İŞ, 2024). In tomato paste production, for example, the raw tomatoes themselves account for only 20% of the final price, while energy, packaging, and logistics represent 65% (TARIM Dairesi, 2024).

In essence, while tomato prices may capture headlines and stir seasonal frustration, their actual weight in Türkiye's inflation story is small. The bigger forces shaping food prices are structural, rooted in energy, packaging, logistics, and labor costs, making the tomato a scapegoat in a far more complex inflation equation.

Why Farmers Are Unfairly Blamed

Public perception often places the blame for high food prices squarely on farmers, but the reality is far more nuanced. In Türkiye's tomato supply chain, most of the production destined for industrial use, around 85% is secured through contract farming agreements (Aegean Exporters' Association, 2024). These contracts lock in prices months before harvest, meaning seasonal market swings have minimal impact on the prices supermarkets pay. Major retailers such as Migros and BIM operate on stable cost structures, and their own breakdowns from 2023 show that retail price volatility is often disconnected from what farmers receive.

When prices do spike, climate change and speculation play far larger roles than farm-gate costs. The 2023 drought reduced tomato yields by about 12%, but wholesale prices climbed by 40% while retail prices soared by 90% (TZOB,

2024). Such disproportionate jumps point toward market manipulation and excessive intermediary margins rather than farmer profiteering. Data from TMMOB's 2023 report reveals that middlemen capture 60–70% of price increases between the farm and the store, capitalizing on climate-related supply concerns to justify outsized markups.

Addressing these distortions requires policy shifts that target structural inefficiencies rather than scapegoating farmers. Regulators must monitor concentrated market power in processed food industries, where just three firms control 72% of Türkiye's pasta market (Rekabet Kurumu, 2024). Energy costs, which heavily influence food processing expenses, could be capped following the EU's Food VAT Reduction model to prevent cost inflation from cascading into retail prices.

On the farmer side, direct support is key. Expanding electronic price transparency platforms, like the Turkish Grain Board's (TMO) live integration with Borsa İstanbul, would help align farm-gate prices with retail realities. Reducing the number of intermediary layers, an approach that proved effective in Antalya's 2023 citrus cooperative pilot, could also ensure a fairer distribution of value along the chain.

Finally, building climate resilience is essential. Drip irrigation subsidies currently reach only 23% of Türkiye's farmland (DSİ, 2024) and should be expanded. Investment in heat-resistant seed research, backed by TÜBİTAK's ₺850 million agri-tech budget for 2024, will help protect yields from increasingly erratic weather patterns. In short, farmers are not the cause of Türkiye's food price surgesth, they are often the first victims of systemic market flaws.

Conclusion

The evidence clearly shows that tomatoes are far from the main culprit behind Türkiye's inflationary pressures. Their tiny 0.87% weight in the CPI basket means that even dramatic price surges have only a marginal statistical effect on the headline inflation rate. Consumer substitution toward alternative vegetables or processed products further dampens their overall impact. Instead, structural factors, such as rising energy costs, packaging price hikes, labor expenses, and concentrated market power in processed food industries, play a far greater role in shaping food inflation.

Farmers, often portrayed as the source of price volatility, are in fact constrained by pre-agreed contract prices, climate-related yield losses, and market intermediaries who capture a disproportionate share of price increases.

The real challenge lies in addressing inefficiencies and speculative practices within the supply chain. Targeted policies that improve price transparency, strengthen cooperative marketing, cap critical input costs, and invest in climate-resilient farming technologies would do far more to stabilize food prices than focusing on seasonal fluctuations in tomato costs. By shifting the public debate away from simplistic scapegoats toward deeper structural reforms, Türkiye can build a more resilient, fair, and transparent food economy, one in which both consumers and farmers are protected from avoidable market distortions.

References: TÜİK; CBRT; TARIM Dairesi; Rekabet Kurumu; TURKSTAT Household Survey; TOBB; FAO; İSO; TÜRK-İŞ; Aegean Exporters' Association; TZOB; Rekabet Kurumu

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Food Security Challenges in Pakistan: Urgent Solutions

Explore the urgent food security challenges in Pakistan, where millions suffer from undernourishment despite agricultural potential. Learn about the impact of climate shocks, governance gaps, and the need for equitable food distribution and nutrition.

Hafiza Minahil Imran

8/27/2025

Food security is a foundational pillar for national development, encompassing economic stability, public health, and social cohesion. For Pakistan, a nation with a rapidly growing population exceeding 240 million people, achieving food security is not just an agricultural goal but an urgent economic and national security imperative (Pakistan Bureau of Statistics, 2023). Food security exists when all people always have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. This concept rests on four interconnected pillars: availability (domestic production, imports, aid), access (affordability and purchasing power), utilization (nutritional value and safety), and stability (consistency of the first three over time) (FAO, 2006).

In Pakistan, this multi-faceted challenge is exacerbated by climate change vulnerabilities, water scarcity, economic inflation, and rapid population growth. Erratic monsoon patterns, recurrent floods, and prolonged droughts reduce agricultural output, while shrinking water resources intensify competition between agricultural, industrial, and domestic use. Inflation compounds the problem by eroding household purchasing power, making even locally available food inaccessible to millions of families. At the same time, nutritional deficiencies persist, with high rates of child stunting and maternal malnutrition, underscoring that food security is not only about quantity but also quality.

The economics of food security highlights the delicate balance between production incentives, trade policies, and household welfare. Price support mechanisms, input subsidies, and targeted social safety nets can help safeguard vulnerable populations, but they must be carefully aligned with long-term sustainability. Investments in climate-resilient farming, water management, and storage infrastructure are equally vital to stabilize supply and reduce post-harvest losses. Ultimately, ensuring food security in Pakistan demands a holistic policy framework that integrates agriculture, trade, health, and environmental strategies, anchoring both human well-being and national stability.

The State of Food Security in Pakistan: Current Statistics

Despite being an agricultural economy, Pakistan faces severe food security challenges that reveal deep structural flaws in the country's food system. The most recent figures are sobering. As of 2023, 36.9% of the population experiences moderate or severe food insecurity (FAO, IFAD, UNICEF, WFP & WHO, 2024). Child nutrition remains an even more alarming indicator, with 40.2% of children under five stunted, a sign of long-term deprivation, and 17.7% wasted, reflecting acute malnutrition (National Nutrition Survey, 2018). These figures highlight how persistent poverty and inadequate diets undermining the country's human capital.

Economic access is another critical barrier. In 2023, food price inflation averaged above 38%, eroding household purchasing power and pushing nutritious diets further out of reach for millions (State Bank of Pakistan, 2023). This has intensified reliance on cheaper, calorie-dense foods that fill stomachs but do little to meet nutritional requirements. The paradox of an agrarian nation grappling with widespread hunger underscores that food insecurity in Pakistan is not only about low production but also unequal distribution, lack of affordability, and poor dietary diversity.

Pakistan does maintain self-sufficiency in staples like wheat and rice, yet these gains are fragile. Climate-induced shocks such as the devastating 2022 floods, which wiped out $3.7 billion in agricultural output (World Bank, 2022), reveal how vulnerable the system remains. Smallholder farmers face yield gaps due to outdated practices, lack of modern inputs, and poor access to credit. Even when food is available, utilization suffers because of dietary monotony, weak food safety standards, and sanitation challenges that impair nutrient absorption. Stability of supplies is further compromised by political volatility, global price swings, and climate risks. Taken together, these dynamics show that food security in Pakistan is a multidimensional crisis requiring more than just higher crop yields ,it demands systemic reforms that address access, nutrition, and resilience.

Key Government Policies and Programs

Pakistan has introduced a range of policies and programs to tackle food insecurity, combining agricultural development with social protection measures. The National Food Security Policy of 2018 serves as the overarching framework, setting out goals of sustainable agricultural growth, improved access to safe and nutritious food, and nutrition-specific interventions. It emphasizes modernizing farming practices, better water management, and strengthening the value chain to reduce post-harvest losses. While progressive in design, the policy's implementation has struggled with weak institutional coordination and limited resources.

On the social safety net front, the Benazir Income Support Program (BISP) stands as one of the country's largest poverty alleviation tools. By providing unconditional cash transfers to millions of poor women, it directly boosts household purchasing power, ensuring families can afford at least a minimum level of food consumption. However, the rising cost of living often outpaces the benefit, limiting its effectiveness in guaranteeing nutritional adequacy.

To enhance agricultural productivity, the government launched the Prime Minister's National Program for Agricultural Emergency, channeling subsidies and technical support to farmers producing key crops like wheat, rice, and sugarcane. The initiative aims to close yield gaps and strengthen food availability, but progress has been uneven due to outdated farming methods, input shortages, and climate shocks.

At the retail level, the Utility Stores Corporation (USC) provides essential commodities such as wheat flour, sugar, and ghee at subsidized rates nationwide. While this reduces pressure on vulnerable households, problems of mismanagement, leakages, and limited coverage reduce its reach.

Taken together, these initiatives show that Pakistan has laid an institutional foundation for tackling food insecurity. Yet, persistent challenges, implementation gaps, fiscal constraints, and weak monitoring, continue to limit their impact. Strengthening governance and ensuring better targeting will be critical to translating policy into real improvements in food security.

Global Lessons and Comparative Policy Analysis

Food security is a universal challenge, and Pakistan can benefit greatly from studying how other nations have approached it. India's National Food Security Act (2013) provides a rights-based framework, ensuring subsidized food grains for nearly three-quarters of the rural population and half of the urban population. By enshrining food access into law, India transformed food security into a justiciable right rather than a policy aspiration, a lesson Pakistan could adapt to strengthen the social contract with its citizens.

Brazil's Fome Zero (Zero Hunger) offers another valuable model. Rather than relying solely on cash transfers or subsidies, Brazil integrated multiple approaches, combining direct support to poor families with measures to strengthen family agriculture and local food systems. By linking social protection with agricultural development, Brazil improved nutrition outcomes while simultaneously supporting rural economies. For Pakistan, where smallholder farmers dominate the landscape, such an approach could address both poverty and food insecurity.

The Comprehensive Africa Agriculture Development Program (CAADP) highlights the role of political will and regional cooperation. Its commitment to allocate at least 10% of national budgets to agriculture and achieve 6% annual growth provides a benchmark for resource prioritization. Pakistan, which currently invests far less in agriculture as a share of GDP, could draw inspiration from this framework to ensure more consistent and adequate public investment in the sector.

Applying these lessons, Pakistan must adopt a holistic strategy that emphasizes climate-smart agriculture, expanded social protection, reduced post-harvest losses, improved dietary diversity, and real-time monitoring systems. Global evidence is clear: food security cannot be achieved through production alone. It requires integrated policies that combine agricultural innovation, equitable economic access, and institutional accountability. By adapting successful international models, Pakistan can move closer to building a resilient, inclusive, and food-secure future.

Conclusion

Food security in Pakistan is both an urgent challenge and a critical opportunity. Despite being an agricultural country, millions remain undernourished because production gains are offset by weak access, poor dietary diversity, and systemic inefficiencies. Climate shocks, water scarcity, and inflation deepen these vulnerabilities, while governance gaps limit the impact of existing policies. At its core, the crisis is not just about growing more food but ensuring equitable distribution, affordability, and nutrition.

The experience of other countries shows that progress is possible when policies are bold, integrated, and backed by political will. India's rights-based model, Brazil's linkage of social protection with local agriculture, and Africa's commitment to budgetary prioritization all demonstrate practical pathways Pakistan can adapt to its own context. What is needed is a long-term national food security strategy that combines climate-resilient farming, targeted social protection, efficient storage and distribution, and investments in human nutrition.

Ultimately, food security is inseparable from economic stability, health, and national security. If Pakistan succeeds in creating a food system that is productive, inclusive, and resilient, it will not only nourish its people but also strengthen the foundations of sustainable growth and social harmony for generations to come.

References: FAO; IFAD; UNICEF; WFP; WHO; Government of Pakistan; Ministry of National Health Services; Lipper et al.; Ministry of Planning, Development & Special Initiatives; PBS; State Bank of Pakistan; World Bank; National Nutrition Survey

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