

From Fields to Future: Digitizing Agricultural Systems

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Backbone of Pakistan's economy

Agriculture is the backbone of Pakistan's economy as it plays a pivotal role in the provision of food security, economic growth and providing livelihood to many. With 47% of its land devoted to agriculture¹, Pakistan's fields hold the promise of feeding millions—yet, outdated practices threaten this critical lifeline. In addition, the Economic Survey of Pakistan 2024 highlights the contribution of the agriculture sector worth 24% to the Gross Domestic Product (GDP) and also generates 37.4% of employment opportunities in the country. Therefore, the sector's significance and contributions cannot be overlooked or understated. This white paper explores the challenges faced by Pakistan's agricultural sector and outlines how digitization can unlock its full potential to ensure food security and economic resilience.

Globally, 34% of agricultural land is degraded, worsening food security challenges for future food, fiber, and feed production. In Pakistan, an agrarian economy, low crop yields, climate change, stagnant productivity, limited R&D investment, and slow technological adoption hinder sustainable growth. Embracing technological advancements, Artificial Intelligence (AI), and digital innovation can boost productivity, ensure food security, and build resilience against future uncertainties.

Challenges in the Agricultural Sector in Pakistan

To delve further in the topic, it is imperative to have an in-depth analysis of the challenges faced by the agricultural sector in Pakistan. The agriculture sector in Pakistan is being operated on conventional techniques from the 19th Century. Despite having similar land and water resources as neighboring countries, Pakistan's agricultural productivity lags behind significantly due to its reliance on outdated practices. This is primarily because of the fact that many countries choose to adopt technologies, including artificial intelligence that can support and revolutionize agricultural output based on research, use of weather sensors, data-based algorithms and GPS about crops and its types. These advanced tools leverage weather sensors, data-based algorithms, and real-time analysis to boost efficiency. Pakistan must embrace such innovation to remain competitive.

In addition, lack of irrigation facilities, exhaustion of soil, unavailability of electricity, and limited economic resources are posing great challenges to the quality of crop and volume of trade as well.

Waara Bandi System: Challenges in Water Allocation

The Waara Bandi system is a significant challenge to the agricultural sector. Water being a scarce resource, disrupts the Waara Bandi schedule, resulting in inequitable distribution, with downstream farmers receiving insufficient water. The outdated system fails to account for the needs of diverse crops or changing weather conditions, leading to inefficiencies and water wastage. Furthermore, weak enforcement mechanisms enable manipulation and favoritism by influential landowners, exacerbating inequalities.

These inefficiencies directly affect agricultural productivity, with crop yields significantly lagging behind global averages—wheat yields, for instance, are 30% lower than the global average (World Bank, 2020).



Lack of irrigation facilities

Unpredictable and uneven rainfall creates uncertainty for farmers, while insufficient irrigation reduces crop yields. Pakistan's acute water scarcity, driven by overexploitation and mismanagement, worsens during summer, impacting both households and agriculture. Limited water availability intensifies competition between agricultural, industrial, and domestic needs, further straining the agriculture sector and its role in the economy and food security.

Exhaustion of Soil

The exhaustion of soil poses a significant threat to Pakistan's agriculture sector by reducing its productivity and long-term sustainability. Over-cultivation of land, particularly in densely populated regions like Punjab and Sindh, depletes essential nutrients in the soil such as Nitrogen potassium, calcium, magnesium and more. Over 6.3 million hectares of land in Pakistan are affected by salinity and waterlogging due to improper irrigation practices. This has resulted in annual productivity losses of \$1.5 billion (World Bank, 2019)⁵. In addition, the overuse of chemical fertilizers to counteract declining soil fertility disrupts the natural nutrient cycle and degrades soil quality over

credit further hampers modernization efforts, leaving 45% of smallholder farmers dependent on exploitative informal lending systems. Public investment in agricultural research and infrastructure remains insufficient, limiting the adoption of advanced techniques and mechanization.

Addressing these financial and energy constraints is critical to ensuring the long-term viability of the agricultural sector.

Limited economic resources

Limited economic resources threaten Pakistan's agriculture sector, reducing productivity and efficiency. Around 90% of farmers, operating on small landholdings under 5 hectares, lack funds for quality seeds, fertilizers, and machinery (Bureau of Statistics, 2022). Only 45% access formal credit, with many relying on exploitative informal lending (State Bank of Pakistan, 2021). Insufficient public investment in research, infrastructure, and extension services hampers modern farming adoption and global competitiveness. These challenges also limit farmers' capacity to address climate change, jeopardizing food security and rural livelihoods in a sector contributing 19% to GDP and 38% to the workforce.



Digitizing the Agricultural Systems

In the 21st Century, it is necessary to bid farewell to conventional and redundant ideas for using the lens to understand and resolve the issues. Instead, it is about time that in order to address Pakistan's agricultural challenges, digitization can revolutionize farming by leveraging modern technologies like AI, precision agriculture, and data-driven strategies. This transformation can enhance resource efficiency, optimize yields, and ensure sustainability.

time. Reports from the National Fertilizer Development Centre indicate a 54% increase in fertilizer consumption over the last two decades, contributing to soil acidification and reduced microbial activity (NFDC, 2023).

Climate change further amplifies soil exhaustion, with rising temperatures and erratic rainfall patterns accelerating erosion and depleting organic matter. Global Climate Risk Index ranks Pakistan as one of the most vulnerable nations to climate change (Eckstein et al., 2021). Addressing these challenges requires immediate attention to sustainable farming practices, efficient irrigation, and soil conservation measures to safeguard the nation's agricultural productivity.

Limited Access to Agricultural Markets

Limited access to agricultural markets in Pakistan is a significant challenge, particularly for smallholder farmers, who constitute 89% of all farm owners and manage 48% of the national farm area.

The agricultural sector's fragmentation aggravates difficulties in transporting produce to markets due to inadequate infrastructure and high transportation costs. Moreover, farmers often lack access to real-time pricing information and alternative buyers, making them reliant on intermediaries who frequently offer unfavorable terms. These challenges also contribute to post-harvest losses, reducing farmers' incomes and economic stability.

Energy Crises

The energy crises pose a significant threat to Pakistan's agriculture sector by disrupting essential processes like irrigation, storage, and mechanization, leading to reduced productivity and economic losses. Over 60% of Pakistan's farmland relies on tube wells for irrigation, most of which are powered by electricity. Frequent power outages force farmers to depend on costly diesel-powered alternatives, increasing production costs and reducing profitability (Pakistan Economic Survey, 2022). Additionally, unreliable power supplies hampers the operation of cold storage facilities, leading to post-harvest losses estimated at 30-40% annually, particularly for perishable crops like fruits and vegetables (FAO, 2021)¹⁰. The lack of mechanization due to electricity shortages further slows agricultural processes, limiting efficiency and scalability. Rural areas, where agriculture is the primary livelihood, face the brunt of these challenges, as over 50% of villages remain off the national power grid (World Bank, 2020)¹¹. Addressing this energy gap is crucial to modernizing Pakistan's agriculture, enhancing food security, and ensuring sustainable rural development. Additionally, limited access to affordable

AI-Powered Farming Systems

AI technologies can mitigate water scarcity by enabling smart irrigation systems that uses weather and soil data in the real time to optimize water usage. This technology can also assist in predicting rainfall patterns, helping farmers plan more effectively and reducing dependency on an unpredictable rainfall patterns. In addition, research from the World Bank (2021) also highlights that AI-driven irrigation management can cut water usage by up to 30%, a critical improvement for water-scarce regions like Pakistan

Data-Driven Decision Making

According to McKinsey (2023), farmers using data-driven techniques reported a 40% reduction in post-harvest losses, which is critical for a country where up to 40% of perishable produce is wasted annually. Use of data analytics platforms can empower farmers with actionable insights into market trends, weather conditions, and crop performance. For example, predictive analytics can guide farmers on the optimal timing for sowing and harvesting crops.

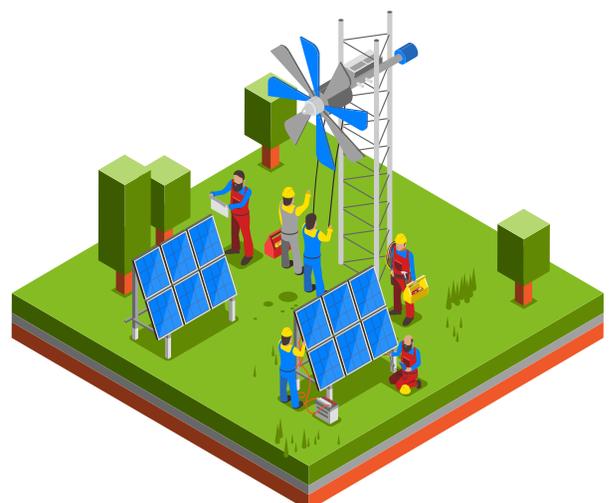
Resource Optimization Methods

Digitization enables resource optimization through technologies like solar-powered irrigation pumps and smart energy grids to address electricity shortages. Solar-powered tube wells could reduce reliance on costly diesel alternatives, cutting irrigation costs by 50% (Pakistan Economic Survey, 2022). Additionally, automated cold storage facilities powered by renewable energy can prevent significant post-harvest losses of fruits and vegetables.



AI-Enabled Credit Scoring

To overcome limited economic resources, AI-based credit scoring systems can expand access to formal credit by assessing farmers' creditworthiness based on alternative data like crop yields and market history. According to the State Bank of Pakistan (2023), fintech solutions have the potential to increase access to agricultural loans by 60%, enabling smallholders to invest in modern inputs and technology.



Innovative solutions with the country's current technological landscape and socio-economic conditions

Technology Partnerships

Collaboration with technologically advanced agricultural nations such as the Netherlands and China can facilitate knowledge exchange and the transfer of AI-driven farming technologies. For example, Pakistan can establish joint research and development (R&D) initiatives focused on precision agriculture and resource optimization. Cross-border technology transfer programs like China-Pakistan Economic Corridor (CPEC) can serve as a platform for introducing digital tools in irrigation and crop monitoring systems. The World Bank (2021) suggests that technology partnerships increase agricultural productivity by 30% in low-resource countries.

Market Integration

Pakistan's agricultural sector can enter into international markets by engaging in agricultural trade networks and participation in global value chains. Digitizing supply chain management, can play a major role in helping Pakistan meet international standards for traceability and food safety, expanding its access to premium markets. According to the FAO (2023), countries that adopt blockchain-based supply chain solutions see a 15% increase in agricultural exports due to improved transparency and trust. Pakistan's inclusion in platforms like the International Agri-Food Network could accelerate such initiatives.

Human Capital Development

Building the capacity of farmers and agricultural stakeholders is essential to ensure the successful adoption of digital tools. A report by the Asian Development Bank (2022) found that capacity-building programs improve farmers' income by 20-25% when paired with digital interventions. International programs, such as those supported by the UN's Food and Agriculture Organization (FAO) and Japan International Cooperation Agency (JICA), can train Pakistani farmers in data-driven decision-making and AI-enabled farming practices. The Punjab Agriculture Department has already piloted e-learning initiatives, and scaling these programs could address the skill gap.

Conclusion

unlock the full potential of Pakistan's agricultural sector, ensuring a prosperous and resilient future for the country.

To conclude, it is important to be cautious about the challenges faced by Pakistan's agricultural sector, including unreliable irrigation systems, soil exhaustion, limited access to electricity, and inadequate economic resources. The persistence of these issues hinder productivity, reduce agricultural output, and exacerbate food security concerns. However, embracing digitization offers a promising solution to address these challenges. Digitizing agriculture will not only enhance Pakistan's food security but also enable farmers to adapt to climate change and compete in global markets. With proper investment in technology and infrastructure, Pakistan can overcome the current limitations and unlock the full potential of its agricultural sector, ensuring a prosperous and resilient future for the country.



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