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DISCOURSE

MODERNIZING PAKISTAN'S AGRICULTURAL ECONOMY

PIDE
Pakistan Institute of Development Economics

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The agriculture sector is unquestionably the backbone of Pakistan's economy, as it plays a critical role in contributing meaningfully to economic growth, creating a large number of employment opportunities, and backing considerable exports. On the other hand, regardless of its prominence, the sector faces several challenges that emasculate its productivity, profitability, and sustainable growth. Therefore, it is crucial to address these issues to unlock the full potential of Pakistan's agricultural economy, ensure food security, and improve its contribution to the national economy.

This issue of Discourse is envisioned to nurture a knowledgeable debate on how Pakistan's agricultural sector can grow and thrive. Therefore this special issue spans over 4 different sections. Each of the sections focuses on critical aspects related to modernization in the agricultural sector and economy. These sections comprise the persistent challenges in agriculture and suggest practical elucidations and ways forward, exploring the transformative role of Artificial Intelligence (AI) in advancing farming practices, evaluating the opportunities and constraints related to the use of drone technology, and discussing the potential of the Gene Revolution in reforming Pakistan's agricultural landscape.

We hope this issue provides treasured insights and stimulates constructive discussions that contribute to a more prosperous and sustainable agricultural future for Pakistan.

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THE AGRICULTURE SECTOR IN PAKISTAN

The agriculture sector is a cornerstone of Pakistan's economy, yet it faces challenges that hinder its productivity, profitability, sustainable growth, and contribution to food security. Despite being among the top ten global producers of several agricultural commodities, Pakistan's per-acre yield remains significantly below international averages. Numerous initiatives and reforms have yet to align Pakistan's agricultural output with global standards. Consequently, it is crucial to first identify the key issues, policies, and practices impeding agricultural potential in Pakistan. In the second stage, targeted reforms are needed to promote economic transformation and unlock productivity and profitability.

Addressing these challenges requires a comprehensive and integrated strategy. The Pakistan Institute of Development Economics (PIDE) has taken on the task of documenting critical issues in the agricultural sector. These challenges include low productivity, poorly targeted subsidies, monopolistic market practices, excessive regulation, resource deterioration, and environmental degradation. PIDE's evidence-based research proposes economically viable solutions to improve efficiency across agricultural markets by optimizing resource use management (e.g., land and water), enhancing input markets (e.g., seeds and fertilizers), and streamlining output markets for key crops such as wheat, fruits, and vegetables.

PIDE has shared its research findings through reports, knowledge briefs, newspaper articles, blogs, and policy papers. These publications emphasize the urgent need for reforms to create more competitive input-output markets by reducing bureaucratic barriers, deregulating input markets, eliminating price-setting interventions, and addressing monopolistic practices. This document summarizes PIDE's holistic approach to transforming Pakistan's agriculture through liberalizing input-output markets. The current document builds on PIDE's research over the past five years and provides recommendations to enhance efficiency and competitiveness across the agricultural sector.

AGRICULTURAL INPUT MARKET

1. Liberalizing the Seed Industry

High-quality, genetically pure seeds are essential for achieving higher productivity in agriculture. However, complex regulatory procedures involving multiple government departments have stunted the growth and potential benefits of the seed sector. Private investors are reluctant to invest in seed research and development due to over-regulation because seed certification from Federal Seed Certification and Registration Department (FSC&RD) is extremely hectic and this certification has no value in the market. The private sector believes that maintaining the brand reputation by supplying high-quality seed is more valuable than seeking approval from the (FSC&RD). However, the government is spending about Rs. 800 million annually on FSC&RD while it fails to bring any revolutionary change to enhance agricultural productivity.

Hence, PIDE recommends several measures to liberalize the seed sector[1&2&3]

- Abolish the stringent process of seed certification to attract private sector investment and to create space for its growth. Currently, a poorly regulated seed market promotes low-quality seeds, affecting agricultural productivity adversely
- The transition from a centrally controlled approval system to a free-market mechanism allowing unrestricted entry and exit.
- Withdraw the public sector from seed production and price regulation.
- Ensure intellectual property rights (IPRs) are transparent and justified, with private sector involvement.
- Establish specialized courts for biosafety and IPR-related issues or seek technical expertise from relevant experts within existing courts.

2. ABOLISHING FERTILIZER SUBSIDIES

Fertilizer subsidies have proven ineffective in reducing retail prices for consumers. For instance, An average family of 5 persons that consumes 15 maunds of wheat, 2 maunds of rice, and 30 kg of sugar in a year will get a monetary benefit of Rs.893 per annum (Rs.74/month) in terms of low prices against the subsidy of Rs.200 billion on fertilizer (Abedullah, 2021)[4].The subsidy does not justify its cost, and alternative measures to improve poor farmers' affordability should be explored.

3. IMPLEMENTING ECONOMIC WATER PRICING

Irrigation water is heavily subsidized, yet this policy fails to promote productivity or sustainable water use. Low water prices disincentivize investment in water-saving technologies like drip and sprinkler irrigation, exacerbating Pakistan's water crisis. Economic water pricing reforms, such as restructuring Abiana charges or introducing marginal pricing, would encourage efficient water use. Current water subsidy policies cost the government an estimated 677.56 to 899.05 billion PKR annually, or 0.81% to 1.07% of GDP (Abedullah and Ali, 2024)[5] .

4. FORMALIZING AND IMPROVING CREDIT MARKETS

The informal credit market, represented by "arthies," provides essential financial support for small farmers, offering flexible repayment terms. However, arthies charge high interest rates, which can be burdensome. PIDE suggests that formal financial institutions adopt elements of the arthi model to improve access to agricultural credit with more farmer-friendly terms[6].

5. PROMOTING AGRICULTURAL LAND CONSOLIDATION

Pakistan's agricultural landscape is marked by fragmented, small landholdings that hinder modernization and efficient resource management. Agricultural Land Consolidation (ALC) offers a solution by restructuring and redistributing land into larger, more logical plots. This could reduce production costs, enhance profitability, and lay a foundation for sustainable agricultural growth, ultimately boosting food security and rural development[7&8]

6. REVITALIZING THE AGRICULTURAL LAND MARKET

Land transactions in Pakistan are slow, corruption-prone, and governed by outdated regulations. To make the land market more dynamic and efficient, PIDE suggests[9]:

- Updating land transfer regulations to reflect current market needs.
- Revising land transfer fees, ideally eliminating the DC rate system or adjusting it to reflect actual market rates.
- Digitizing land records to reduce corruption and streamline transactions.

[1]https://pide.org.pk/research/revitalising-the-seed-industry-in-pakistan
[2]https://pide.org.pk/research/evaluation-of-seed-industry-way-forward/
[3]https://pide.org.pk/research/rethinking-the-seed-industry-in-pakistan/
[4]https://pide.org.pk/research/fertiliser-subsidy-an-ineffective-policy-tool-to-offer-low-prices-of-basic-food-commodities/
[5]https://pide.org.pk/research/the-cost-of-government-interference-in-agricultural-markets/
[6]https://pide.org.pk/research/the-role-of-arthi-in-agriculture-marketing-an-exploiter-or-facilitator-of-farmers/
[7]https://pide.org.pk/research/agricultural-land-consolidation/
[8]https://pide.org.pk/research/land-reforms-through-agricultural-land-consolidation/
[9]https://pide.org.pk/research/the-neglected-tale-of-agricultural-land-markets/

AGRICULTURAL OUTPUT MARKETS

1. ELIMINATING SUPPORT PRICES AND SUBSIDIES

Government support prices for crops have lowered agricultural market efficiency and placed a significant fiscal burden on the state, particularly in times of budget deficits. Additionally, places a substantial financial burden on the government, making it unsustainable in the long term, particularly given the budget deficits. PIDE is continuously advocating to end the support prices for the crops as these policies have failed to achieve their intended outcomes of offering low prices to consumers. Rather, fixing MSP has led to transfer taxpayers' money to flour mills and the middlemen without creating any benefit to producers or consumers (Jalil et al., 202010, Abedullah 2020[11], Rose and Abedullah 2023[12]& 2024[13], Rose and Ali 2024[14]). The implementation of the Minimum Support Price (MSP) has placed a significant financial burden on the government, primarily through the procurement process, which is funded via bank loans, institutional involvement, and specific budget allocations. Additionally, there is a forego loss due to reduced acreage allocation to competing crops, which are more profitable than wheat. In 2023, the procurement process alone resulted in a cost of approximately Rs. 168 billion, with institutional budgets amounting to Rs. 260 billion, and lost benefits from reduced acreage allocation under competing crops reaching around Rs. 11 billion. The cumulative burden, exacerbated by circular debt has reached to Rs. 907 billion, implying that the current MSP implementation is not sustainable. (Abedullah and Ali, 2024)[15] .

2. DEREGULATING THE SUGAR MARKET

Pakistan ranks as a major global sugar producer and exporter, yet the sector faces regulatory and market inefficiencies. PIDE's analysis suggests that the government should[16] :

- Deregulate the sugar industry to reduce entry barriers for new mills.
- There is a misconception that sugarcane is replacing cotton but our empirical findings reveal that other crops, such as maize and rice, have expanded more at the expense of cotton due to higher profitability and productivity of these crops.
- Remove import tariffs to promote competition.
- End export subsidies that contribute to higher domestic sugar prices and have destabilized the market in the past.

3. ABOLISHING DCO PRICE CONTROLS FOR FRUITS AND VEGETABLES

The Deputy Commissioner's Office (DCO) sets prices for fruits, vegetables, and grains, but these prices do not account for actual costs like transportation and spoilage, making them impractical. PIDE recommends discontinuing this intervention to let the market forces work to determine the market prices, which is more sustainable and economically sound[17] .

[10]https://pide.org.pk/research/wheat-support-price-a-note-for-policy-makers/
[11]https://pide.org.pk/research/does-free-market-mechanism-offer-a-win-win-situation-to-wheat-consumers-and-the-government/
[12]https://pide.org.pk/research/wheat-import-doors-not-closed-yet/
[13]https://pide.org.pk/research/subsidies-vs-market-forces/
[14]https://pide.org.pk/research/revitalising-agriculture-road-to-green-revolution/
[15]https://pide.org.pk/research/the-cost-of-government-interference-in-agricultural-markets/
[16]https://pide.org.pk/research/the-sugar-industry-of-pakistan-understanding-structural-and-regulatory-underpinnings-of-the-current-sugar-crisis-3/

4. ENHANCING STORAGE FACILITIES AND ENCOURAGING PRIVATE PROCUREMENT

Pakistan's storage facilities for grains and cold storage for perishable goods are inadequate, particularly in KPK and Baluchistan, with capacity falling short by three times. Poor storage conditions lead to significant post-harvest losses, costing the agriculture sector around Rs. 315.41 billion annually. PIDE recommends that the government may encourage private investment in modern, well-equipped storage infrastructure to reduce post-harvest losses and improve product quality[18] without her direct engagement.

RESEARCH AND DEVELOPMENT INVESTMENT

Redirecting funds from subsidies and support prices toward sustainable research and development (R&D) could significantly boost productivity. If Pakistan were to raise average production levels to match those of progressive farmers, it could add approximately Rs. 1,722 billion to the economy. A restructured seed market and targeted R&D investments along with private sector partnership are vital steps toward achieving this (Abedullah and Ali, 2024)[19].

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[17]https://www.aciar.gov.au/sites/default/files/2024-05/adp-2017-024-final-report.pdf
[18]https://pide.org.pk/research/the-cost-of-government-interference-in-agricultural-markets/
[19]https://pide.org.pk/research/evaluation-of-seed-industry-way-forward/

THE PHENOMENON OF DEREGULATION OF THE SUGAR SECTOR CRITICAL TO PROMOTE EFFICIENCY

Zartasha Inayat & Tuaha Adil

The sugar sector has been susceptible to trade restrictions and domestic regulations by the government of Pakistan. These regulatory measures create distortions in the sugar industry, thus disrupting the whole supply chain. Placing the sector under Schedule I of the Export Policy Order, 2020, the government restricts the private sector from exporting sugar to meet the domestic demand for sugar. In cases when there is excess sugar supply, quotas are assigned to the private sector by the federal government to export the determined amount of sugar. Recently, the Economic Coordination Committee (ECC) allowed the producers to export 0.10 million tons (MT) of sugar, following 0.15 MT of exports in June 2024. The restrictions exist on the import side of the trade as well, where the import of sugar by the government has been restricted or hampered through high tariffs and embargoes. Given the shortage of sugar in the market, import is allowed under the special regulatory order (SRO), to avert any market failure. However, the import ban is only lifted once the shortage of sugar has been realized, creating chaos in the market.

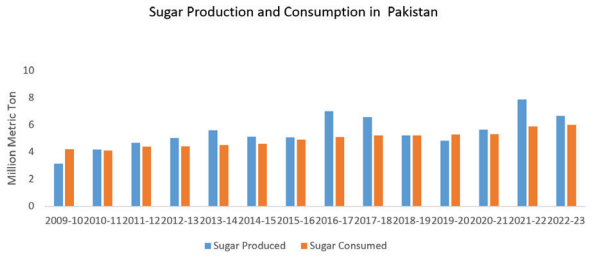
The sugar sector is highly regulated with a significant government footprint, where approval from relevant government officials is required at every step of the supply chain. The sugar industry faces price controls by the federal government of Pakistan under the act under Article 6-I of the Sugar and Sugar Products Control Order, 1948. Due to these price controls, the artificial shortage of sugar in the market is created, causing a rise in high prices, as per the law of demand.

Policy Research Institute of Market Economy (PRIME) evaluated the policies and regulations governing the entire supply chain of the sugar sector in Pakistan. The report also presented an analysis of the stock position of sugar and domestic requirements and recommended the opening up of exports. The government allowed the exports resulting in $270 million foreign exchange earnings in 2023.

The sugar industry is one of the important industries in Pakistan, contributing substantially to agricultural output and providing employment to many in Pakistan. Ranking among the top ten producers globally, most of the sugar is produced in Punjab and Sindh. The importance of sugar industry could be

derived from the fact that it is providing direct employment to around 1.5 million people in Pakistan[20]. Furthermore, contributing 20.5% to important crops of the country and 0.8% to the country's GDP during the fiscal year 2022, Pakistan's production of sugar stood at 7.9 MT[21].

However, the production of sugar declined by 1.25% in FY23, where it reached a total of 6.65MT, as shown in the graph below.



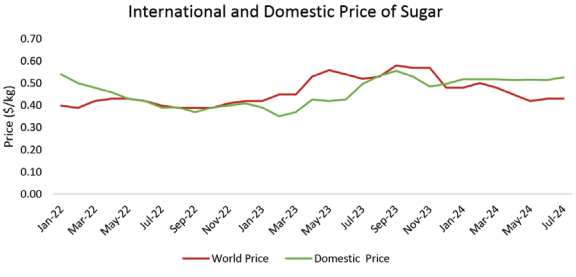
Data Source: Pakistan Sugar Mills Association (PSMA)

The country's sugar policy to date revolves around four objectives: ensuring self-sufficiency, affordability of sugar for consumers, protection of farmers, and profits for mills. To achieve self-sufficiency, the government has maintained support prices of sugarcane and protected the native sugar industry by imposing restrictions and tariffs. Moreover, the government has administered the marketing of white sugar including its rationing at fixed prices to maintain its prices low for consumers. The consequences of current policies are the volatile domestic price of sugar compared to the international price, the burden on the government in the form of export subsidies, seasonal shortages at home, price hikes, exploitation of farmers, and abnormal profits for sugar manufacturers.

A policy is only effective if it encompasses local dynamics and is implemented to the fullest; however, the existential sugar policy has failed to reap its objectives because of the government's inability to bring efficiency into the sector. Paradoxically, a highly regulated market has given rise to market failures that are beyond the government's control. To begin with, the benefits of the support price on sugarcane are not passed on to the farmers who are exploited by sugar factories to sell sugarcane at a price below the determined by the government.

In addition, the government controls licenses for the establishment of factories to provide protection to existing mills, ensure a significant supply of sugarcane to the mills, and meet self-sufficiency of sugar. Moreover, when the government determines the price of sugar not keeping in view the actual cost of production then it encourages sugar manufacturers to adopt other avenues for profit maximization like exploiting farmers, maneuvering accounts, artificially raising costs, and creating shortages, which raises the retail price of sugar.

The review of the domestic and international prices of sugar indicates that the domestic price has remained below the international price from July 2022 to December 2023. The government allowed the export of sugar in 2023 and the country earned more than $270 million. It is pertinent to highlight that the domestic price of sugar increased from January 2024 as compared to the international price. This increase can be attributed to lower productivity and higher cost of production. Furthermore, the sugar smuggling across the Afghanistan borders in 2024 led to a shortage of sugar in the market, thus causing a hike in sugar prices. The surge in sugar prices can also be attributed to an increased price cap by the government to stabilize the prices and limit the prices to increase post-ex-mill prices, thus preventing them from exceeding a certain point. Moreover, the increase in domestic price also results from the management of the exchange rate as the government-initiated crackdown in the foreign exchange market in September 2023 and the currency has remained stable since then. However, there are several markets like the USA where the price of sugar is significantly higher and Pakistan has the potential to export surplus sugar and earn foreign exchange.



Data Source: World Bank and Pakistan Bureau of Statistics

[20]Sugar Sector Report September 2023
[21]Sugar Sector Study by The Pakistan Credit Rating Agency Limited August 2023

CURRENT CHALLENGES FACED BY THE SUGAR INDUSTRY IN PAKISTAN

Despite the availability of sugar and surplus stocks for local consumption, the government remains reluctant to allow the export of sugar. The rationale behind restricting the trade of sugar is to ensure the sugar availability for domestic consumers. However, imposing trade restrictions often leads to disincentivizing producers, leading to the stagnancy of the sector. Similarly, the embargoes and high tariffs on the import of sugar can also hurt the sugar market, where if the domestic supply of sugar is not sufficient, it can lead to higher sugar prices for consumers.

In addition to the trade restrictions, the government also controls prices of the sugar to prevent them from exceeding a certain limit. However, these price controls often lead to volatile domestic prices of sugar, due to disruption in the supply chain of the sugar. The domestic prices can be higher than the international prices, making the sugar industry inefficient and unproductive. Similarly, the existing policies of price control create a burden on the government in the form of export subsidies, seasonal shortages of sugar domestically, and exploitation of farmers.

Sugarcane is known for its extreme water requirement, where it needs around 1500-to-2500-millimeter water over the growing period, depending on the climate situation. Pakistan being a water-scarce country, directs a significant portion of water towards the sugarcane crop, which has lower economic gains because of a nonexistent pricing mechanism, which makes the sugar more expensive than the sugar we can import.

In the context of crop productivity, farmers lack access to formal capital and have to resort to informal sources of capital that make it impossible for farmers to adopt modern farming techniques and use better quality seeds.

RECOMMENDATIONS

To address the challenges in the sugar industry and improve the productivity of the sector, the following recommendations are in order:

1. There should be no trade restrictions and the export of sugar should be allowed at all times to incentivize the producers due to high international demand. Furthermore, lifting trade restrictions can prevent price fluctuations and loss of $1 billion of foreign exchange annually.
2. The government should refrain from regulating the prices of sugar through price controls and let the forces of supply and demand determine the prices.
3. The government may not restrict the free movement of sugar across the provinces, thereby creating price differences across the provinces.
4. The impact of support price should be assessed as it removes incentives for farmers to improve crop yield because of guaranteed returns, increases the input cost of mills, and encourages farmers to cultivate sugarcane, which is a water-intensive crop with low economic returns and substitutes cultivation of crops with better returns.
5. Pakistan is a water-scarce country and there is no mechanism to ensure conservation and efficient utilization. As a result, water is being used to cultivate crops with low economic returns. An efficient water pricing mechanism should be devised and implemented in the country.

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REFORMING AGRICULTURAL LAND MARKETS IN PAKISTAN: OVERCOMING STRUCTURAL INEQUITIES

Sobia Rose

THE HISTORICAL ROOTS OF INEQUITABLE LAND OWNERSHIP

Social and political hierarchies are shaped by land ownership historically. Land ownership appears as a powerful force defining social and political structures in the society. This pattern is clearly noticeable in south Asia and particularly in Pakistan, where control over land has severely impacted political dynamics. According to Beg (2014), political candidates who own land are more likely to secure votes than those without landholdings. Therefore, most of national and provincial assemblies' representation consist of members who are landlords or those who have the feudal backgrounds, across party lines. Hence, political power in the region often favors those with landholdings, creating a landscape dominated by landlords. This pattern has led to argue that Pakistan's history is largely defined by feudalism, except for periods like General Ayub's rule and the PMLN's focus on industrialization in the 1990s. Nevertheless, large landowners have dominated local politics, accentuating the association between land control and political power. Further, The legacy of the colonial era and the introduction of the 1901 Land Alienation Act have fostered this inequitable land ownership, shaping political and economic power to the present day.

THE FLIMSY ARRANGEMENT OF AGRICULTURAL LAND MARKETS IN PAKISTAN

The basic pillar of Agricultural Land Market (ALM) is the transfer of agricultural land from one hand to another. Whenever the factors that influence agricultural production are evaluated, regardless of its significance, the disquiets connected to weak ALM are overlooked usually. Generally, ALMs in Pakistan are plagued by bureaucratic delays, frequent corruptions, and complex transactional procedures. The process of transferring land is consist of various intermediaries which takes up usually three to four months to

complete a transaction. This procedure is coupled with various instances of corruption, another significant element causing delays. A big disparity between the officially recorded value of land and the prevailing market prices is another important aspect which severally impacts the farmers' particularly small farmers. Therefore it is nearly impossible to realize a cost-free and hassle-free land transaction. These are primary factors which prevents the formation of a fair and efficient ALM in Pakistan.

THE SWAY OF FEUDALISM AND ALM STAGNATION

Land is a production factor just like labor and capital but land is immobile and further the potential for expansion is limited which usually drive up land prices with increasing demand whereas supply remains fixed (Hirashima, 2008)[22]. Furthermore, the agricultural land is seen as source of power and status which makes the land prices inelastic. For all political elites and feudal lords, land ownership is central to influence and control that is the core reason behind all the resistance against the land reforms we usually observe.

In land transactions, parties frequently manipulate reported values to avoid the high 8 percent transfer fee on the total property value. Both buyers and sellers commonly understate the land's value to align with the official Deputy Commissioner (DC) rate, concealing the actual market rate. This exercise perpetuates entrenched corruption in land transfers, habitually benefiting large landowners and feudal elites who exploit these undervalued transactions to maintain lower tax liabilities. As a result, feudal elites influence these arrangements to preserve power, relying on their dominance in local constituencies to secure votes. On other hand, during this process small farmers are becoming marginalized more and more.

CHALLENGES FACING SMALL FARMERS AND FRAGMENTED LAND HOLDINGS

The agricultural landscape in Pakistan is dominated by small and fragmented landholdings. Nearly 89% of farmers operate on farms less than 12.5 acres, with 64% holding less than 5 acres. When transferring land, these small farmers have to face dogged snags. Further they have a very limited access to the facilities of formal financing. They have to encounter frequent displacements too due to unresolved land disputes. Their economic potential is further stalled due to an inefficient administrative structure and the outdated land records.

These small farmers can be empowered by establishing efficient ALMs with clear property rights and ownership. But, this prospective is importunately resisted by those who capitalized in maintaining the status quo. The influence of local landlords is further reinforced by the local land politics, extending their power onto the national political stage.

OUTMODED LAND LEGISLATION: AN OBSTRUCTION TO MODERNIZATION

The legal structure governing ALM is outmoded, such as the Land Revenue Act of 1967. There are several regulations which remained unchanged since pre-partition times, forming substantial blockades to modernization. Even though land records were last updated in 2016, provincial Revenue Departments have not effectively leveraged this data. Numerous sections of the Land Revenue Act of 1967 require revision. For example, a Revenue officer is allowed to establish estate boundaries and to put boundary markers under the section 117. As an alternative, modern methods can be used to define estate boundaries such as digitized land records and satellite-based demarcation could define land parcels more accurately.

Further, the *patwari* system eliminated a decade ago, was later reinstated with expanded powers, giving the patwari a central role in issuing the fard for land mutation. This practice often favors large landlords, sidelining small farmers and landowners in the process.

For a more transparent and efficient ALM in Pakistan, digital tools like satellite mapping can be leveraged. Further laws related to ALM can be streamlined with the assistance of digital tools.

[22]Hirashima, S. (2008). The land market in development: a case study of Punjab in Pakistan and India. Economic and Political weekly, 41-47.

PROPOSED REFORMS FOR A TRANSPARENT AND EFFICIENT ALMS

For increased agricultural productivity and equitable economics growth in the country modernization of ALM is fundamental. Which can be leveraged by addressing structural inequities, modernizing land laws, and implementing transparent processes. For this following reform recommendations are imperative:

- Keeping in view the current structure, there is prerequisite to revamp the laws related to mutation and registry. For this purpose, technology can be acquired to simplify and automate land transfers.
- The valuation method, generally the DC rate system is archaic. Further, DC rate system is not the true representative of land value. Land valuation should be dynamic by considering the key features of land, such as location, amenities, and market demand.
- Land transfer fee is also high providing incentives for undervaluation. Therefore, to ensure transparency in transactions and land valuations, land transfer fee should be reduced. This will absolutely reduce the incentives for misevaluations.
- To reduce bureaucratic delays and minimize procedural costs, there is need to introduce a one-window solution
- To ensure comprehensive land management strategies and efficient dispute resolution, cross department collaboration need to enhanced and strengthened especially between Agriculture and Revenue department.

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DECODING THE DYNAMICS OF PRICING IN THE FRUIT AND VEGETABLE MARKET: Highlighting the Government Imperfections

Muhammad Asad ur Rehman Naseer

The fruit and vegetable (F&V) market in Punjab, Pakistan, is a critical component of the region's agricultural economy, yet it remains plagued by volatile prices that affect both consumers and producers. Despite the government's regulatory efforts like Punjab Agricultural Produce Markets (PAPM) Ordinance, 1978 and Rules framed there under 1979, and recent Government intervention, i.e., the establishment of the Punjab Agriculture Marketing Regulatory Authority (PAMRA), price stabilization remains elusive. This persistent instability not only strains household budgets but also undermines the financial viability of producers. The underlying reasons for this inefficiency are multifaceted, ranging from supply chain disruptions to inadequacies in regulatory enforcement, raising important questions about the effectiveness of current government interventions.

Now, the question arises, Who sets the prices – farmers, markets, commission agents, retailers, management, transporters, or cold storage owners? The answer is none of them. While all these players are integral parts of the supply chain, prices are determined purely by the dynamics of demand and supply.

The production costs borne by farmers for fruits and vegetables include expenses for seeds, fertilizers, pesticides, diesel/electricity, labor, and other inputs. Although these costs significantly influence prices, they do not determine the market price of fruits and vegetables. For instance, farmers sometimes sell potatoes at prices lower than their production costs. One farmer, for example, brought a trolley of cauliflower to the market only to find the market rate so low that it didn't even cover the transportation fare, prompting him to discard the produce. Conversely, an efficient farmer might sometimes earn more than double the profit due to a shortage of a specific commodity in the market. This highlights the inherent uncertainty and volatility in the price mechanisms.

When a farmer brings produce to the market, they must contact a middleman (commission agent) who has to take a license to sell their agricultural produce from the local Market Committee of the notified area that is governed by the PAMRA at the provincial level. In this system, farmers cannot sell directly to consumers within the premises of public Fruit and Vegetable Markets in the province. The middleman conducts an auction in the presence of Market Committee officials. Any customer can give a bid but in most cases wholesalers (Pharria) and large retailers place bids based on the quality, demand, and availability of the produce.

For example, high-quality potatoes will fetch a good price, but if many farmers bring potatoes, the excess supply will drive prices down due to competition. Similarly, if there is low demand for potatoes, prices will fall regardless of supply levels. The middleman retains a commission, and the farmer receives the auction bid amount. Pharria then sells the produce to retailers at a profit, setting the auction price for fruits and vegetables. The Market Committee issues a rate list based on the retailer's profit margin at this auction price, updated daily to prevent abnormal profits. The following are the two main reasons for market inefficiency in local fruit and vegetable markets.

1. DEPENDENCE OF THE FRUIT AND VEGETABLE SUPPLY CHAIN ON PHARRIA

Most fruits and vegetables brought to markets by farmers or intermediaries (beopari) are non-graded and not packed to meet customer needs. Here, Pharria plays a crucial role in the fruit and vegetable supply chain by providing essential services such as grading and sorting and facilitating bulk breaking. Pharria charges for these services and incurs several associated/hidden costs. Notably, there is no proper dedicated space for Pharria in fruit and vegetable markets. Furthermore, under the new PAMRA system, an annual registration fee for Pharria has also been introduced by the respective Market Committees of the notified area. This PAMRA regulation adds further costs, which are ultimately passed on to consumers.

In my opinion, the services provided by Pharria are often neglected in the markets of Punjab, Pakistan, causing discrepancies between the retail rate lists and prevailing market rates. This neglect underscores the inefficiencies within the supply chain and the need for systemic reforms to support Pharria's role and reduce costs for consumers. The only way to minimize the role of Pharria is to improve post-harvest practices at the farm level, such as sorting, grading, waxing/washing, and packing.

2. IMPACT OF POST-HARVEST LOSSES

Post-harvest losses not only reduce the overall supply but also lower the quality of fruits and vegetables. For example, if 100 tons of potatoes are produced in Sahiwal, poor post-harvest handling might leave only 70 tons of good-quality potatoes, with 30 tons deteriorating due to mishandling during digging, packaging, and transportation. Consequently, the overall price decreases because the market includes lower-quality products, leading farmers to feel they do not receive fair compensation. Meanwhile, the supply of high-quality potatoes diminishes, driving up their price and causing consumers to perceive prices as higher than expected.

To mitigate post-harvest losses, it is imperative to adopt better handling practices, improve storage facilities, and invest in technologies that enhance the longevity and quality of produce. By addressing these issues, the supply chain can become more efficient, ensuring better prices for farmers and more reasonable prices for consumers.

CURRENT SYSTEM PERFORMANCE

Controlling prices within this system necessitates maintaining a delicate balance between supply and demand to prevent abnormal profits. Achieving this balance is a complex task that requires coordinated efforts across various levels of the supply chain. There are following key measures to enhance current system performance in the short run.

- Facilitating Pharria to reduce costs by providing dedicated spaces and minimizing additional fees imposed by Market Committees.
- Minimizing the role of Government in fruit and vegetable markets. All types of registration fees (commission agent, Pharia, broker) may be avoided to minimize the gap between the producer's price and the consumer's price.
- Ensuring accurate crop reporting or statistics to estimate seasonal demand and production accurately.
- Allocating cultivation areas and production targets to farmers based on demand analysis.
- Arranging imports ahead of time if local demand for a vegetable cannot be met to prevent shortages and price spikes.

POLICY LEVEL INTERVENTIONS

To further improve the system in the long run, several policy-level interventions can be implemented:

Maintain a Comprehensive Dataset: Develop a rich and accurate dataset of farmers by commodity. Crop reporting should provide real-time data on acreage within districts and across provinces, leveraging satellite imagery (SUPARCO) instead of manual surveys. This will help in making informed decisions and planning better.

Utilize Climate Data: Use climate data from the Pakistan Meteorological Department (PMD), Islamabad, for accurate climate projections. This information is crucial for anticipating and mitigating the impacts of climate change on agricultural yields.

Model Yield Estimates: Engage agricultural economists and researchers to model yield estimates considering all factors, including climate change. By understanding the expected yield, it is possible to identify the gap between estimated supply and demand before each season, guiding import and export policies.

Adopt Advanced Technologies: Embrace the latest technologies to minimize post-harvest losses and deterioration of fruit and vegetable quality. This includes investing in better storage facilities, transportation, and handling practices.

These measures will enhance market efficiency, stabilize prices, and ensure fair compensation for farmers while maintaining reasonable prices for consumers. By addressing both the supply chain inefficiencies and the broader systemic issues, the fruit and vegetable market can achieve a more sustainable and equitable balance, benefiting all stakeholders involved.

THE ROLE OF GOVERNMENT POLICY IN SUPPORTING THE FRUIT AND VEGETABLE MARKETS

Government policy plays a crucial role in stabilizing the fruit and vegetable market. Effective policies can help manage supply and demand, regulate pricing, and ensure fair practices throughout the supply chain. The following policy recommendations aim to enhance the efficiency and fairness of the market:

Keeping Prices Open/Free: The fruit and vegetable market in Punjab serves as a quintessential example of pure competition, characterized by the presence of a vast number of buyers and sellers. In such a highly competitive environment, no single buyer or seller has the power to influence market prices, as the forces of supply and demand naturally determine them. Given this extensive participation, the necessity for external price notifications or regulations by the Market Committee or District Government significantly diminished market efficiency. The market's inherent dynamics ensure that prices remain fair and reflective of current conditions, making additional interventions largely redundant.

Farmer Registration and Data Management: Establish a comprehensive registration system for all farmers. This database should be integrated with real-time crop reporting and statistics to monitor production levels, predict market trends, and manage supply more effectively.

Accurate Demand Forecasting: Invest in advanced analytics and data modeling to predict seasonal demand accurately. This involves collaboration with meteorological departments, agricultural economists, and research institutions to develop reliable yield estimates and demand forecasts.

Regulated Import Policies: Develop flexible import policies that can be adjusted based on real-time supply and demand analysis. This will help prevent shortages and surpluses, stabilizing prices and ensuring a steady supply of essential commodities.

Support for Pharria and Market Infrastructure: Provide dedicated spaces for Pharria within markets and reduce unnecessary fees. Improving market infrastructure, including storage and transportation facilities, will help reduce costs and enhance the efficiency of the supply chain.

Technological Advancements: Promote the adoption of modern technologies in post-harvest handling, storage, and transportation. This includes investing in cold storage facilities, efficient packaging solutions, and advanced logistics to minimize losses and maintain product quality.

By implementing these policy recommendations, the government can create a more resilient and efficient fruit and vegetable market. This will benefit farmers by ensuring fair compensation, protecting consumers by stabilizing prices and enhancing the overall sustainability of the agricultural sector.

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SUPARCO INTERVENTIONS FOR GEOSPATIAL MONITORING OF AGRICULTURAL CROPS

Ibrar ul Hassan Akhtar

Agriculture has been a pivotal sector in Pakistan's economy since its independence. It has played a crucial role in providing employment, ensuring food security, contributing to GDP and exports. At independence, Pakistan inherited an agrarian economy with a limited industrial base. The sustainable agriculture sector demands agricultural research, which is crucial for the development and sustainability of the agricultural economy. In Pakistan, where agriculture sector plays a vital role in the livelihoods of millions and contributes significantly to the GDP, investing in agricultural research can lead to substantial economic upliftment. Some of the key elements to be explored through the lens of research and development in the agriculture sector are (i) Enhancing crops' productivity, (ii) Sustainable agricultural practices, (iii) Addressing climate change (iv) Improved Market access and Value addition and (v) Socio-Economic Impacts.

Some of the latest and emerging technologies that can significantly address the challenges of the Pakistani agriculture system are nano-technology, biotechnology, Artificial Intelligence, Precision technology, and Space Technology. Space technology has led to the evolution of Geospatial technologies, which include Geographic Information Systems (GIS), Remote Sensing (RS), and Global Positioning Systems (GPS), which have the potential to revolutionize agriculture in Pakistan. These technologies provide detailed spatial information that can help farmers make informed decisions, optimize resource use, and increase productivity.

If we go into history of satellite technology applications in agriculture sector in Pakistan, two attempts were recorded. In 1970s, crop statistics on cropped area, yield, and production were based on opinions and local market trends. There were no institutional infrastructure working on scientific principles as well as pragmatic system for data collection, analysis and generation of crops statistics to be used by government for policy and decision making to ensure food security, uplift agroeconomics and promote research.

Initially, The Village Master Sampling (VMS) System, implemented by the Central Statistical Organization (CSO) of Pakistan in 1970. It was developed under the guidance of the Federal Bureau of Statistics (FBS) now that is Pakistan Bureau of Statistics (PBS) to enhance agricultural statistics and rural data collection in the country. This system was particularly crucial for creating reliable datasets necessary for formulating agricultural policies and development plans.

The Village Master Sampling System was introduced as part of broader efforts to modernize statistical methodologies in Pakistan. The system involved selecting

a representative sample of villages from revenue records across the country to gather detailed information on various aspects of rural life and agricultural practices. This sampling method was aimed to provide a more accurate picture of rural conditions than previous approaches, which often relied on less systematic data collection techniques. Despite its successes, the VMS system faced challenges such as logistical difficulties in accessing remote villages, ensuring the accuracy of data collection, and maintaining consistency over time. These challenges prompted continuous improvements and adaptations in the system.

Most recent geospatial intervention by National Space Agency of Pakistan i.e., Pakistan Space and Upper Atmosphere Research Commission (SUPARCO) is playing significant role in the development of satellite technology based agricultural crops monitoring system, started in 2005. Initially, the government of Pakistan funded a PSDP pilot project to demonstrate the effectiveness of high-resolution satellite images in major crop-type mapping and monitoring in three districts of Bahawalpur, Rahim Yar Khan, and Ghotki. Technology base was provided by the French satellites of 2.5m to 10m spatial resolution along with collaborative technology incubation with French counterparts. Initially, wheat, cotton and sugarcane crops were assessed in cultivated area and crop yield forecasting along with ground truth surveys was performed. The results were found very promising in term of timeliness in generating spatial statistics, accuracies, for the better decision-making.

Later, this ambitious research project was funded by the Government of Pakistan to expand to the national level major crops monitoring system to generate scientific crop statistics with the collaboration of Food and Agriculture Organization (FAO) of the United Nations and international consultants from various advanced countries. This first phase of the project was a success story in the history of Pakistan by developing scientific method for crop area estimation, yield and production forecasting of wheat, cotton, rice and sugarcane during 2005-2009. Major stakeholders in the pilot project were the Provincial Crop Reporting Services (CRS), the Pakistan Bureau of Statistics, the Ministry of Food and Agriculture, Pakistan Meteorological Department, and others. Two major scientific breakthroughs were achieved: (i) Crop area estimation based on ground surveys data integrated Satellite data processing and development of satellite-based crop area sampling frame for nine different cropping zones across irrigated areas and (ii) development of crop yields and production forecasting/estimation models using FAO-UN philosophy.

These nine cropping zones include four form Punjab (North East, Potohar, Central and South zones), Sindh (Left Indus and Right Indus zone), Khyber Pakhtunkhwa (Peshawar Valley and South zone), and Balochistan Irrigated zone. While, the FAO-UN crop yield foresting philosophy was based on the integration of agro-meteorological conditions with crop inputs applied, irrigation water use, fertilizer applications, and satellite-based vegetation indices like Normalized Difference Vegetation Index (NDVI) from SPOT Vegetation sensor data of one km resolution. International consultants carried out the technology audit to ensure the quality of crop statistics generated through use of satellite technology. In general, SUPARCO developed crops monitoring system was found way ahead in comparison to conventional system adopted by the provincial CRS.

Later, SUPARCO took initiative for further improvements in developed geospatial technology for crops monitoring, sharing of technologies with agricultural departments across the country, building dedicated labs and execution of capacity building programs during 2009-2017. Under the project, three dedicated information systems were developed i.e., (i) Crops Information Portal hosting all spatial and non-spatial data related to crops, agro-met, irrigation, fertilizer and NDVI for near real-time data reporting and charting[23] (ii) Pakistan Global Agricultural Area Monitoring (GLAM-Pakistan) based on Terra/AQUA satellite MODIS sensor data for change detection in crop conditions[24] and (iii) Smartphone application for ground survey data collection with real time transmission of data from field to Labs during 2012-2016. Further, dedicated Geospatial Labs were established in Provincial HQs of all four provinces along with at University of Agriculture Faisalabad and University of Agriculture Tandojam. Extensive capacity building program was run to ensure adoption of technologies by stakeholders up to gross root level.

Additionally, two more satellite data-based products were generated during the course of the project execution. Firstly, high resolution land use land cover (LULC) mapping and Atlases for Punjab and Sindh later expanded to Khyber Pakhtunkhwa, Balochistan and Gilgit Pakistan.[25] This LULC is globally accepted valuable geospatial products used in disaster

[23]https://openknowledge.fao.org/server/api/core/bitstreams/592ecbd0-7cda-43f3-bfe7-f9d1f59eb2b7/content
[24]https://glam.nasaharvest.org/explore
[25]https://www.fao.org/geospatial/resources/detail/en/c/1024589/

management, procurement of land for building infrastructures, land use policy optimization and others. Secondly, crops field digital layer extraction (crop mask or crop data layers) products were generated for wheat, rice, cotton, maize and sugarcane crops.[26] Best case use of crops field data was demonstrated for Punjab Kissan Package 2015 when farmers of cotton and rice growers were given subsidies. These crops digital fields were used to verify farmer claim of crop cultivation and ensured transparency in subsidy distribution.

In recent years with evolution of artificial intelligence, Internet of Things (IoT), drone technologies, SUPARCO is researching on integrated used of satellites, aerial and ground-based sensors technologies not only to provide spatial statistical information on crops but to promote adoption of precision farming system to enhance the crops productivity with sustainable agriculture. A PSDP project is under execution in collaboration with PMAS arid agricultural university since 2020 to demonstrate the precision agriculture benefits and integration with satellite technology for better decision support system at field/local scale.

The agriculture sector in Pakistan has made significant advances since independence, transitioning from traditional practices to modern techniques. Despite facing numerous challenges, it continues to be a cornerstone of the economy and a crucial source of livelihood for millions. Addressing current challenges through sustainable practices, technological innovation, and effective policies is key to ensuring the sector's continued economic growth and development. Further, agricultural research holds the key to transforming Pakistan's agricultural economy. By focusing on enhancing productivity, promoting sustainability, addressing climate change, improving market access, and supporting socio-economic development, research will drive significant improvements in the agricultural sector. Investments in research and development, coupled with effective policy implementation, will be crucial in realizing the full potential of Pakistan's agriculture.

SUPARCO's use of satellite technologies in agricultural crop monitoring has provided significant benefits for Pakistan's agriculture sector. By offering timely and accurate information, supporting resource management, and aiding in policy planning, SUPARCO has enhanced the efficiency and sustainability of agricultural practices. Addressing the challenges of data accessibility and capacity building will further strengthen the impact of these technologies, ensuring a more resilient and productive agricultural economy in Pakistan. In conclusion, National space agency of Pakistan has significantly contributed towards better agricultural economy.

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VALUING ENERGY EFFICIENCY POTENTIAL IN THE AGRICULTURE SECTOR

Anjeela Khurram & Muhammad Faisal Ali

The energy crisis in Pakistan has extended the need for investments and improvements in energy efficiency to make the present energy consumption more efficient. This article focuses on energy efficiency within the agriculture sector by examining the current state of energy consumption, and the potential of energy efficiency in the agriculture sector.

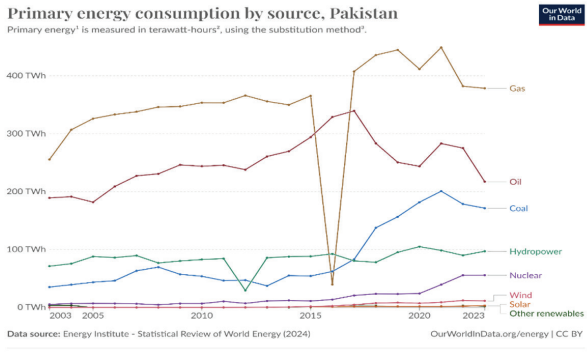
Pakistan is primarily an agricultural country, and its agricultural sector is a significant consumer of energy resources. Energy sources are used in various ways in the agriculture sector, having major applications encompassing mechanization, irrigation, and transportation. This energy consumption predominantly takes the form of electricity (90%) and High-Speed Diesel (HSD) (10%)[27]. Mechanization involves the use of tractors, harvesters, transplanters, and other seasonal machinery, spanning tasks from land management to harvesting and the subsequent transportation of agricultural produce to markets. Another critical area of energy consumption lies in irrigation, where a substantial amount of energy is required to operate tube wells. Tube wells are powered by both electricity and diesel to ensure efficient irrigation processes.

The energy consumption trends worldwide reveal that energy consumption in developing countries, including Pakistan, is increasing. However, in the case of Pakistan, this heightened energy demand has led to an energy crisis. This underscores the necessity for alternative energy sources, such as solar power, or to promote the more efficient use of energy to address and manage this crisis effectively.

PAKISTAN ENERGY SITUATION

The diversification that has occurred over time in Pakistan's energy sector is shown in (Figure 1). The per capita energy consumption has increased significantly, which has surged to 937 terawatt-hours (TWh) in 2023[28]. The primary source of energy comes from gas (8.44 TWh), followed by oil (217 TWh), coal (171 TWh) and from renewables (16 TWh).

Figure 1: Diversification in Energy Sector



To strengthen its national economy, Pakistan should consider investing in enhancing energy efficiency. An ADB Report (2009) highlights that Pakistan has the potential to save 11.09 MTOE through improvements in energy intensity without compromising GDP growth, which is approximately 18 percent of its primary energy consumption. In terms of the net oil imports, this translates to a 51 percent reduction, considering that the cost of importing oil amounted to $12 billion in FY 2008. Well-planned energy efficiency initiatives could also lead to savings in gas and electricity, effectively adding 6,770 MW of generation capacity.

ENERGY CONSUMPTION IN THE AGRICULTURE SECTOR

The agriculture sector plays a pivotal role in the country's economy, contributing 24 percent to the GDP and employing approximately 37.4 percent of the workforce.[29] Furthermore, it serves as a vital source of raw materials for industries, making its expansion intricately linked to the overall economic health.

From the perspective of rural development and food security, sustainable growth in this sector is of paramount importance. The post-COVID-19 period has realized a sharp increase in the prices of various commodities, further highlighting the significance of this sector. However, it is worth mentioning that the advancements in agriculture production systems also come with significant energy consumption.

Improving energy efficiency is vital to sustainable agriculture growth. Pakistan being one of the economies with the lowest agricultural energy efficiency can achieve a competitive edge by reducing production costs, by adopting energy-efficient measures.

The traditional agricultural methods rely on internal combustion engines using petroleum products like HSD and Light Diesel Oil, primarily supporting mechanization and irrigation that are employed in tasks ranging from land preparation to harvesting and the subsequent transportation of agricultural produce to markets. However, over the last three and a half decades, there has been a gradual decline in oil consumption in the agricultural sector, with a corresponding shift towards increased electricity consumption. A significant uptick in electricity usage in the agriculture sector has been observed due to various government-sponsored initiatives, like providing subsidized electric motors, pumps, and other equipment to encourage farmers to adopt modern farming practices. Concurrently, the introduction of electricity-based agricultural machinery and rural electrification projects further contributed to this trend. As a result, electricity has gradually replaced a substantial portion of petroleum consumption within the agriculture sector. This trend seems to persist during the current decade as well .[30] Another prospect is that farmers may tend toward solar tube wells to meet their future demands and to avoid bills and uninterrupted supply for smooth operation. However, this may lead to the over-extraction of groundwater in the country.

[27]https://neeca.gov.pk/SiteImage/Downloads/DRAFTpercent 20NEECpercent 20ACTIONpercent 20PLANpercent 202023-2030.pdf
[28]https://ourworldindata.org/energy-production-consumption
[29]https://finance.gov.pk/survey/chapter_24/2_agriculture.pdf
[30]https://www.pc.gov.pk/uploads/report/IEP_Outlook_Final.pdf

THE POTENTIAL ENERGY EFFICIENCY IN LAND MANAGEMENT:

The energy demand for land management, particularly for soil preparation can largely be attributed to the rising level of mechanization, leading to a greater number of tractors used in agriculture. Currently, there are approximately 692,626 operational tractors in the country, providing an availability of around 0.9 horsepower (HP) per acre. However, the recommended power requirement is 1.4 HP per acre[31]. This shortfall suggests that there is still a gap to be bridged, and the growing number of tractors will result in even greater energy consumption to meet the required power levels. Nevertheless, the pivotal issue now is the inefficiency of nearly 60 percent of the total tractors, which are approximately 0.41 million out of a total of 0.692 million. This inefficiency significantly contributes to energy loss due to the increased consumption of HSD. It is worth noting that inefficient tractors usually consume 4 liters per acre more than efficient tune-up tractors. Alternatively, we can say that a properly tuned-up tractor can conserve 4 liters of energy per acre.

To estimate the total burden of the inefficient tractors, the extra energy used is multiplied by the area under cultivation. The total cultivated land area in the country amounts to 59.65 million acres, where tractors are employed to cultivate 35.79 million acres, representing 60 percent of the total cultivated area as reported by NARC (Table 1). Consequently, the estimated annual energy savings from utilizing well-maintained tractors is 143.154 million liters. This translates to a significant value of PKR 38.18 billion.

Table 1: Estimated Energy Savings from Improved Tractor Efficiency	
GCV of HSD	37.5 MJ/L
Total No. of Tractors in Pakistan (Nos.)	6,92,626
Inefficient Tractors, Kissan Board (Nos.)	415576 (60 %)
Total Area Cultivated in Pakistan	59647500 (Acres)
Area cultivated by Tractors	35788500 (60 %)
Saving Potential of HSD by Tune-up	4 L/acre
Total Energy Saved (Liters/year)	143154000
Total Energy Saved (MJ/year)	5368275000 (37.5 MJ/L)
Total Value of Saved Energy	**PKR 38.18 billion** (HSD @266.70/liter, Aug 2024)

Source: Authors estimates based on data from multiple sources

THE POTENTIAL ENERGY EFFICIENCY IN IRRIGATION (TUBE-WELLS)

Irrigation is another source of energy consumption in the agricultural sector, with a substantial amount of energy required to operate tube wells. However, irrigation through diesel and electric-powered pumps is highly inefficient. Inefficient irrigation techniques and practices, like flood irrigation, the excessive extraction of groundwater, and limited storage capacity, have all played a role in the loss of both water quantity and quality, along with a high level of energy consumption. The running cost of electricity diesel pumps is lower, making them more cost-effective than diesel pumps. Approximately 90 percent of the energy consumed comes from electricity, while 10 percent from HSD. Many conventional tube wells operate with an operational efficiency of 30 percent or even less in some cases[32]. Inefficient use of energy in these pumps often stems from issues such as oversized pumps and improper selection, a lack of proper maintenance, and the use of high-friction piping networks. Implementing effective energy efficiency measures like MEPS (Minimum Energy Performance Standards) for motors besides process optimization techniques can provide farmers with several benefits, including energy savings and reduced production costs.

The energy efficiency and conservation techniques in the agriculture sector can save up to almost 6.69 billion PKR (Table 2). The saving potential in diesel and electric tube wells is 0.5 percent and 15 percent respectively (NEECA, 2023).

[31]https://www.finance.gov.pk/survey/chapters_23/02_Agriculture.pdf

[32]https://www.undp.org/sites/g/files/zskgke326/files/migration/pk/National-Action-Plan---Final-28th-Nov-2019.pdf

Table 2: Energy Efficiency Potential in Tubewells	
Saving Potential in Diesel Tubewells	
GCV of HSD	37.5 MJ/L
Total No. of Tube wells	1,425,225
Total Diesel Operated Tubewells	962,502
Inefficient Diesel Tube Wells	4813
Consumption of inefficient Diesel Engine	2.5 L/Hr
Consumption of Efficient Diesel Engine	2 L/Hr
Average Daily Usage	6 Hrs
Average no. of Days (annually)	180 days
Annual Fuel Saving (annually)	540 L
Total Saved Fuel	259,875,5.4L
Total Cost Saved (annually) (HSD @266.70/L, Aug 2024)	0.69 billion PKR
Saving Potential in Electric Tube wells	
Total Electric Tube wells	407,626[33]
Average Daily Usage (Electricity)	7 KW
Daily Average usage	6 Hrs/Day
Average Daily Consumption of Electricity	42 KW/Day
Total Daily Consumption in Pakistan	17120.3 MWh/Day
Average no. of Days	180 Days
Annual Electricity Consumption	3,081,654 MWh
Annual Electricity Consumption (Efficient scenario @15%)	2,619,406 MWh
Annual Saving through EE measures (annually) @ 15%	462,248 MWh
Total Cost Saved (annually) @ PKR13/kWh[34]	6 billion PKR

Source: Authors estimates based on data from multiple sources

[33]https://mnfsr.gov.pk/SiteImage/Publication/mnfsrpublication.pdf
[34]https://www.brecorder.com/news/40211690

CONCLUSION

This article concludes that there is a sizeable potential for energy efficiency within the agriculture sector by using efficient tractors for land management practices and employing more efficient pumping motors of tube wells for irrigation. The estimated annual energy savings through utilization of well-maintained tractors amount to a substantial 1.43 billion liters of HSD, equivalent to a significant value of PKR 38.18 billion PKR. Whereas, the energy saved in irrigation through efficient tube wells, both electric and HSD, can save up to almost 6.69 billion PKR. Enhancing energy efficiency in the agriculture sector underscores a substantial opportunity to alleviate a significant cost, estimated at nearly PKR 44.87 billion.

WAY FORWARD

- This objective of energy efficiency can be achieved through planned awareness campaigns, especially during the cultivation and harvesting season. Implementing an awareness campaign for energy efficiency in the agricultural sector would primarily involve engaging two key stakeholders, the agricultural department's extension wing and NEECA.
- Energy efficiency can be realized by restructuring the incentive framework within the agricultural sector to prioritize energy efficiency. These incentives could specifically target the replacement of older tube wells with more energy-efficient pumping systems.
- Solarization presents a viable means to reduce energy consumption, but it must come with economic water pricing and metering mechanisms to prevent excessive depletion of already scarce resources like water.
- NEECA has undertaken a task to replace a maximum number of tube well pumps to enhance energy efficiency. However, there exists an opportunity to expand the scope of these programs further.

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REVOLUTIONIZING THE AGRICULTURAL SECTOR OF PAKISTAN – SIFC'S TOP PRIORITY

Rizwan Mir, TI(M)

NECESSITY AND VISION BEHIND THE CREATION OF SIFC

There is no denying the fact that Pakistan is a country that is replete with untapped resources and treasures. But due to lack of capacity and incompetence, not only we have been unable to tap them appropriately, but we also have given them away to the international hawk-eyed investors and agencies at practically no cost. It is nevertheless our good luck that we finally woke up to the realities of the present day and have started creeping towards improving the situation by focusing on two core issues - capacity and competence.

In the year 2023, a need was felt by the government to embark upon a journey to take Pakistan out of the economic turmoil and steer it out of disaster towards prosperity and development. A whole of the government approach was adopted and the civil and military officials joined hands in support of political leadership to create a council that comprises of civil and military leadership - the Special Investment Facilitation Council (SIFC). The purpose of creating SIFC was to help tap the economic potentials of Pakistan in the sectors we call the low-hanging fruits, bring Foreign Direct Investment (FDI) into the country, create a business-friendly environment in the country, and carry out changes in the policy by removing bureaucratic hurdles from the system and making the system more efficient and effective.

Considering the agriculture sector as the top priority of Government of Pakistan and ultimately of SIFC, the GPI was undertaken with LIMS-COE spearheading the initiative through incorporating modern technology and consolidation of existing data into the agriculture sector. As a result of a survey, more than four million acres of land were identified throughout the country, which could be brought under cultivation over four to five years thus adding to the existing 75.4 million acres of land already under cultivation. Coupled with a reduction in cost through economizing the use of fertilizers, water resources, and pesticides, and increasing the yield, it means a lot for Pakistan.

CONFIGURATION AND FUNCTIONING OF GPI AND LIMS

Green Pakistan Initiative (GPI) being the flagship project of SIFC has taken giant strides towards improvement in the agriculture sector in the past year. Based on the need analysis, GPI Headquarters was established in Rawalpindi under which the Laboratory Information Management Systems (LIMS) initiative was undertaken and a newly formed company under the aegis of Fauji Foundation - FonGrow - volunteered to serve as a model to be followed by the agriculture sector. GPI, capitalizing on the expertise of agriculturists, consolidating the survey data available with public and private sectors, and using the team of IT experts, launched the LIMS, which started revolutionizing agriculture from the very moment of its inception.

A question arises: In the wake of already existing projects in the field of agriculture, how do GPI and LIMS stand out? There are numerous reasons to be cited in the context, but to quote just a few:

- They have started working systematically, by first hiring experts in the field, collaborating with renowned national and international companies, and adopting the best practices worldwide.
- With the teams of dedicated workers in hand, and potential investors in the pipeline, GPI embarked upon the acquisition of arable land in the agricultural areas as well as the areas in deserts where no cultivation was done ever before.
- In different regions, GPI went on to establish model farms which, through the use of the latest technology, would serve as samples to be followed by the common farmers. They have shown improved yields with reduced costs and have inspired farmers all over the country to follow in their footsteps.
- Consolidating the agricultural data of the whole country in one place, integrating it with the latest satellite data available, and interfacing it all in their website, have made GPI and LIMS a state-of-the-art organization that has no rival in the country. This model is being studied by other countries as well, who want to acquire it for their use.

MAIN CONCEPT - REVOLUTIONIZING AGRICULTURE IN PAKISTAN UNDER SIFC

The measures taken by GPI and LIMS under the umbrella of SIFC include:

- Digitization of land data of the whole country
- Provision of real-time satellite imagery of land and linking it with the soil testing reports compiled by the government departments
- Introduction of corporate farming techniques by consolidating the land and procurement of the latest machinery to help in the cultivation of large chunks of land with minimum wastage
- Identifying new stretches of land to be added to the agriculture sector
- Ensuring the conservation of resources - water, fertilizer, pesticides, etc. to reduce the cost
- Ensuring the production of high-quality seeds that are more resistant and have a high survival rate
- Taking policy measures to ensure the effectiveness of the system
- Zoning of the whole country for crops most suitable for the type of soil, atmospheric conditions, sub-soil ingredients, and climatic conditions
- Reviving aquaculture of the country which possesses some unique species and breeds of marine and freshwater animals
- Reclaiming the original breeds of cattle of the country - once known in the whole world for their quality of output, meat, and milk - which had lost their pedigree over time owing to cross-breeding and lack of measures to protect the species.
- Reviving the cotton zones of the country which have relatively less requirement of water and other resources and give yields that are known in the whole world for their quality, but unfortunately were sacrificed to water-heavy sugarcane crops owing to vested interests of a few sugar producers
- Repair and de-silting of more than 55,000 canal miles of canals in Punjab to ensure the provision of water to the extreme canal terminals for better irrigation
- Reclaiming reserve forests and enhancing tree plantation by incorporating the society in government projects
- An extensive movement to reduce pollution, clean river waters, and hence improve the local environment
- Taking measures to improve tourism in the country by establishing a Green Tourism Company and developing tourist sites and resorts to attract local and international tourists
- Bringing more than fifty thousand acres of land under cultivation and allotting more than two hundred and fifty thousand acres of land to local and foreign investors for agriculture and related developments

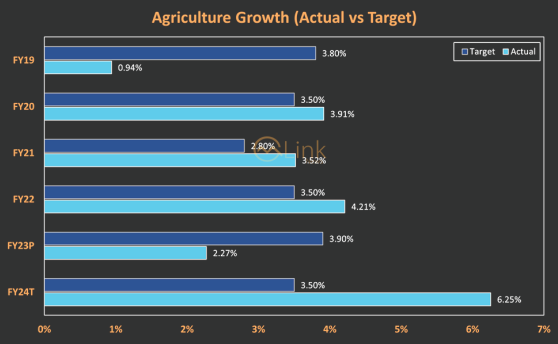
All these steps have brought about a revolution in the field of agriculture in the country. The first result of hard efforts of the complete year was seen in the form of bumper crops of wheat, barley, maize, and several vegetables. Ironically, when on the one hand the GPI was boasting of exporting the surplus yields to countries like GCC, China, and Europe, we nevertheless ended up in importing wheat in millions of tonnes, thus resulting in creation of a wheat crisis. The main lagging in our country that I mentioned earlier - capacity and competence - came in play and resulted in a crisis situation for crop growers. We are probably the only people who can create a crisis over abundance as well.

With an infrastructure developed, a team in place with a will to work and do something for the country, and the model enterprise to serve as an example for the farmers to follow, Pakistan is fully equipped to bring revolutionary changes in the agriculture sector and embark upon a spree to put Pakistan on the road to economic prosperity and development and take the country out of crisis.

The steps being undertaken in the GPI will have manifold advantages: giving opportunities to investors (both local and foreign) to invest in agriculture sector, whether it be crops, livestock or for that matter fisheries and blue investment; the local farmers will have direct benefit through reduction in cost, and enhancement in yield, the general population will be beneficiary in terms of reduction in price due to increase in production. In short, we can easily call it a win-win situation for all tiers of national power.

As a result of the efforts of SIFC and - under its aegis - the GPI and LIMS, there was marked improvement in the economy of Pakistan by the close of the financial year 2023-24. A few glimpses of the improvement as seen in the governmental statistics are appended below: -

- The Pakistan Economic Survey 2023-24[35] [36] report an expansion of 6.25% in agriculture sector, which helped in driving the GDP growth by 2.38% in FY 2024. The overall fiscal deficit was overturned only due to improvement in agricultural produce.
- The Trade Development Authority of Pakistan (TDAP) [37] highlighted that there was an increase of 37 % in agriculture exports, which reached $8bn in the financial year 2023-24. The increase was due mainly to an increase in exports of rice, maize, sesame, onion, and meat.
- This year, with further streamlining of the procedures, restoration of confidence of farmers, increased consideration of the investors to consider investing in Pakistan, and inclusion of new arable land in the agriculture sector of Pakistan, there are all the chances that these statistics will further improve.
- The establishment of SIFC is another such factor that gives indications towards this end because the main factor of its establishment was to keep it safe from political situations.



WAY FORWARD

Since the establishment of SIFC, I have always called it a 'National Effort' that can only achieve success when every element of society realizes the need for measures being undertaken and joins hands with the government to bring about positive changes in the country. Side by side, the government will have to enhance its capacity and competence to match the need of the hour.

We don't have any time to lose. It is written on the wall that the current century is the century of Asia - a quarter of which has already passed. If we do not wake up to the realities of life, if we do not welcome the opportunities that are banging (not knocking) on our doors, if we keep playing the blame game and maintaining a stagnant position through self-created conflicts and disagreements, we will be left behind in the race to development. The time is not far when - if we maintained the same state of procrastination - we will be looking at our neighbors growing head and shoulders above us and making us feel ashamed of ourselves.

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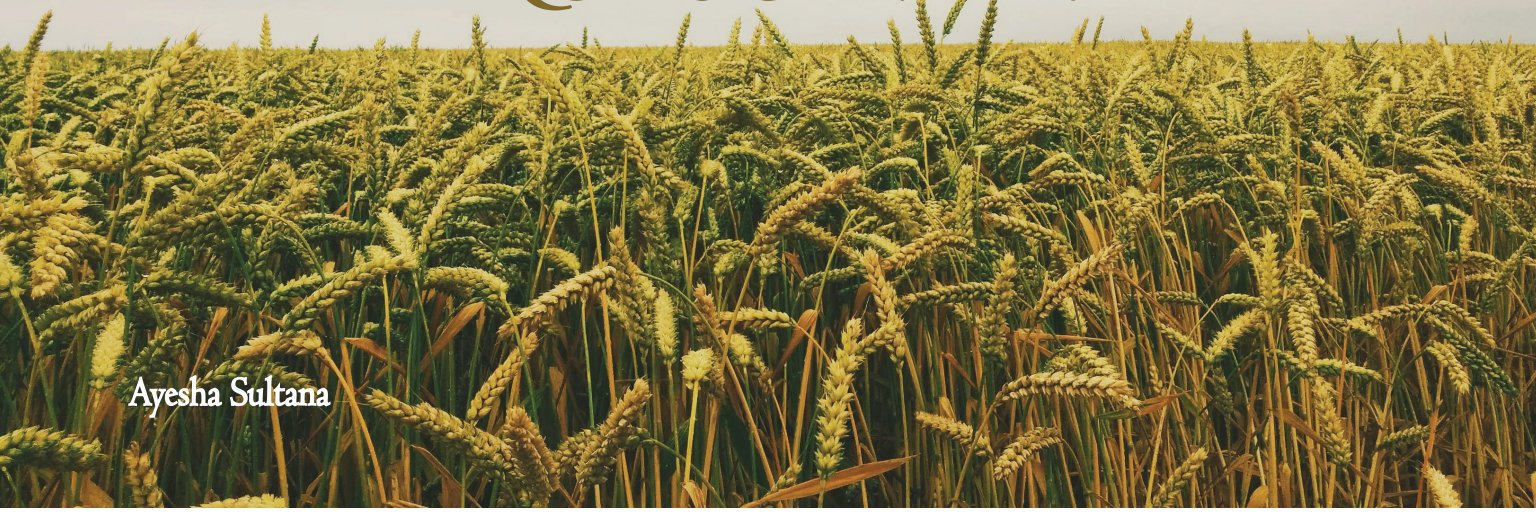
[35]https://mettisglobal.news/agriculture-sector-in-pakistan-records-6-25-growth-in-fy2024-exceeding-target/
[36]Economic Survey of Pakistan 2023-24, Economic Adviser's Wing, Finance Divie=sion, Government of Pakistan, Islamabad.
[37]Monthly Trade Report June 2024, Trade Development Authority of Pakistan, Ministry of Commerce.

WHY INVESTMENT IN R&D HAS NOT IMPROVED AGRICULTURE PRODUCTIVITY?



Ayesha Sultana

It has always been stated that agriculture is the backbone of Pakistan's economy. But unfortunately, this backbone is weakening with the growing age. A snapshot since the 1960s, when agriculture was contributing more than 43 percent of GDP, surviving through the lowest of 18 percent and currently standing at 22.3 percent, tells us the story of asymmetrical performance and neglected potential of the sector. Looking down for the reasons, one may easily find many, but a lack of research and failure to deliver development (R&D) is common in every model for Pakistan.

One cannot deny the role of R&D in the development of any sector. Globally, R&D has historically been a cornerstone of innovation and economic growth, particularly in technology, healthcare, and agriculture sectors. Global R&D investment has seen a substantial increase over the decades. Adjusted for inflation, global R&D investment has tripled over the past 30 years, growing from $672 billion in 1992 to over $2.2 trillion by 2021. Even in our region, China is leading the game. In 2001, China's R&D budget was 0.94 percent, R&D expenditure to GDP ratio, then after a decade was almost doubled (1.78 percent) and now after two decades, this ratio has increased to 2.43 percent. After looking at these numbers, no wonder why China has taken the place of the world's second-largest economy.

When it comes to Pakistan, it has always been portrayed that investment in R&D in agriculture has not yielded any increase in productivity. But what is that investment actually? According to the World Bank's latest update, R&D expenditure as a percentage of GDP in Pakistan was 0.164 percent in 2021. Whereas India has a 0.8 percent R&D expenditure to GDP ratio for the same year. In this 0.164 percent, how much could have been spent on agriculture R&D of Pakistan? Definitely very little.

Besides the low investment, one must also look for other factors that explain why it is not improving agricultural productivity in a multiplier effect. Firstly, it's the organizational complexity. In Pakistan, there are always long, complex, and inefficient procedures to do anything. Even the cumbersome documentation time in collaboration between public and private sector or research organizations frustrates the researchers.

Secondly, most of the R&D institutes/organizations are funded by the government, and lack of commitment is a norm therein. However, inefficient human

resources is another offshoot of this norm. Therefore, the R&D workforce lacks the basic commitment and devotion to serve their purpose.

Thirdly, multi-dimensional stratification within research-related organizations is weakening the growth impact. There is also a culture of seniority in almost every such organization in Pakistan. Employees or researchers are not characterized by their grades, degrees, and knowledge; instead, they are only seniors and juniors. In my own experience, juniors are not allowed to do anything in their way. In a government setup, one has to follow what is already routine. Especially in labs, there are equipment which are accessible to some particular people, and juniors are not allowed to even touch them.

Fourthly, Pakistan also lacks competent researchers for one reason or another, like a huge brain drain. The developed countries attract competent researchers all around the world through their specially designed brain pool programs. The young people of the country, even in the government sector, want to go abroad to have a better life, make contributions, and seek opportunities for advanced-level research.

Even after the existence of the above weaknesses, if success/innovation happens, there is another list of issues regarding the implementation of the agriculture sector. Almost every government project in the agriculture sector accompanies research-based innovation or public-sector innovation. But again, the cycle begins with complex procedures, time lags, lack of commitment, and organizational culture. Finally, it goes into the implementation phase through different wings or directorates of the agriculture department.

In the next phase, when it arrives at the district level and then to farmers, no one cares about the output, productivity, and benefits of the agriculture sector and the economy. The basic staff of the agriculture department only cares about the targets of the projects that are assigned to them. The staff goes to the big farmers of the area and requests them to register their names. Usually, landlords having large land holdings are generous enough to use their name for projects and schemes. And most of the time, these landlords take huge benefits from government schemes, especially subsidy schemes. In this whole practice, a real farmer, i.e., a small farmer, remains excluded from the scheme/projects, who is supposed to be the target beneficiary of the project or innovation. Even if these small farmers are approached, they are never ready to listen and do not have any interest in adopting something new due to stressed economic conditions.

I remember a project implemented in the province of Punjab named Extension 2.O, in which agriculture department staff had to take soil samples from farmers' land, then district soil labs of the area analyzed those samples and made soil health cards. That soil health card carried information regarding soil and its health and the recommended dose of fertilizers. It was something very useful and cost effective for farmers and farmers did not need to make any efforts. Sadly, farmers were not even interested in this. And the farmers who received those soil health cards did not bother to read them; following those recommendations is a far story. The big reason behind farmers' attitude is their illiteracy. So, they did not take any interest in soil health cards. More than half of the farming community cannot read and write. The only thing in which they are keenly interested is the cost-benefit ratio of their crops.

Apart from R&D, the agricultural productivity of Pakistan is not improving due to other certain reasons. The cost-benefit ratio is taking the lead. Inputs prices surging day by day. On the other hand, farmers are not getting fair benefits from their crops. Uncertain market prices of their produce are making the situation worse for them. A recent example is the wheat price of 2024. Before sowing, the market price of wheat was around Rs. 5000 to 5500 per 40kg, but when the crop was harvested, no one was buying it even at the support price of Rs. 3900 per 40 kg.

Keeping all these reasons aside, if we take a step back and look at the larger picture, maybe it is the economy that is transforming. The statistics tell us the share of the Services sector is growing (52.19% of the current share in GDP), followed by the industrial sector. Maybe it is high time to accept the reality and need to move the direction of resources from subsistence agriculture to manufacturing or services. Many developed countries have opted for other sectors over agriculture; South Korea is an example. Pakistan assisted South Korea with $378,000 and plenty of wheat during their war from 1950-53. It was the third-biggest financial contribution that South Korea received. After its separation from North Korea, South Korea was also an agriculture-based economy, but then it moved to manufacturing. This shift made S. Korea one of the leading economies of Asia.

However, every country has its unique circumstances. If we have to stick to agriculture, we need a clear and strategic plan. First, the government should significantly boost its investment in agriculture and encourage private companies by offering tax breaks and grants. Simplifying the processes within research

organizations and holding them accountable will make them more efficient. At the same time, we should invest in the people who work in agriculture by offering specialized training programs for ground-level staff. And there is a need to provide competitive incentives to keep talented individuals from leaving the country or brain drain. Furthermore, aligning R&D efforts with the needs of farmers, especially smallholders, is crucial. This can be done by involving farmers in the research process and improving extension services with modern digital tools to ensure new technologies reach the farmers who need them most.

We also need to improve market access by developing better infrastructure and offering financial incentives, so farmers can easily adopt new innovations. Building strong partnerships between the government and private sector is essential for driving agricultural innovation, whether through joint ventures or creating hubs where different stakeholders can collaborate. These approaches will lead us to have more fruitful R&D in agriculture sector.

Policy changes that support sustainable farming practices, backed by regulations and incentives, will ensure long-term productivity and protect the environment. Lastly, setting up a strong monitoring and evaluation system, with continuous feedback from those involved, will help us adapt and refine our strategies over time. This approach will lead to a more resilient, innovative, and sustainable agricultural sector, helping Pakistan grow economically and ensuring food security for its people.

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UNPACKING PAKISTAN's WHEAT CRISIS: RISKS AND REALITIES FOR FUTURE FOOD SECURITY

Abedullah and Muhammad Faisal Ali

The wheat market in Pakistan has long been a topic of debate and scrutiny, especially when substantial taxpayer money is being spent on procuring wheat at the Minimum Support Price (MSP). This policy was designed to stabilize prices and protect producers and consumers, but it has largely failed to achieve its objectives. Instead of benefiting small farmers and consumers, the primary beneficiaries have often been flour mill owners and middlemen. Beyond the circular debt, more than Rs. 168 billion of taxpayer money is consumed each year on wheat procurement and related activities. Yet, these funds rarely provide significant benefits to actual producers and end consumers. Consequently, fixing the MSP has led to unintended consequences, raising concerns about the policy's sustainability, market efficiency, and overall effectiveness.

Although, for years, the government's withdrawal from the wheat market has been suggested as a potential solution, but the Punjab government's abrupt exit from the market has led to substantial disruptions. This decision was poorly timed, as the government had imported 3.5 million tons of wheat from September 2023 to March 2024, just before the new harvest season. The large stockpiles held by the government discouraged middlemen from participating in wheat purchases, which suppressed farm-level wheat prices, implying that the government made the right decision but at the wrong time.

Over the previous four consecutive years, middlemen offered farmers prices higher than the government MSP, underscoring the government's inability to

protect farmers' interests. However, in the absence of middlemen this year, millers formed a cartel that severely exploited small farmers. While the decision to exit the wheat market was sound, its execution was poorly managed, especially considering the significant reserves held by the government, which discouraged middlemen from investing in wheat procurement from farmers.

Ideally, the government should have gradually scaled back procurement from small and medium farmers, who make up about 89% of the farming community. Unfortunately, the abrupt implementation of the decision left these farmers vulnerable to exploitation by the millers' cartel. Although small farmers have been affected but the impact is less severe than media portrayals suggest. This is because small farmers retain much of their produce for household use, share some with relatives, and reserve a portion for seed and animal feed, leaving a relatively small marketable surplus. Medium-sized farmers, who typically have a larger surplus to sell, have borne the greatest impact of the crisis.

The prices offered by millers barely covered the cost of production. Having secured the majority of the marketable surplus at low prices, millers are now lobbying to get government's permission to export wheat, which would drive up domestic prices and increase their profit margins. Wheat export at this stage may lead to a sharp price increase in the coming months, severely impacting low-income households. High prices shortly before the next harvest could prompt millers to urge the government to re-enter the wheat market, blaming price hikes on the government's exit. Thus, allowing wheat exports under current circumstances would be unwise.

The government's absence from the wheat market is being depicted as a precursor to a broader food crisis due to the expected decrease in wheat acreage in the upcoming planting season. Farmers often use the previous season's prices as a signal when deciding how much acreage to allocate to wheat. This year's unfavorable prices are likely to lead to reduced wheat cultivation next season, a predictable response from farmers. While this may necessitate wheat imports to balance supply and demand, it does not indicate an impending food crisis. Rather, it is part of a natural cycle: with less acreage devoted to wheat next year, prices are likely to increase in subsequent years, prompting farmers to return to wheat cultivation as supply-demand imbalances correct themselves.

Additionally, farmers may allocate less wheat acreage to higher-value crops such as sugarcane and edible oil crops. Shifting toward edible oil crops could reduce the government's import burden, which currently stands at around USD 4.5 billion. However, for this shift to be sustainable, the government must ensure fair pricing for edible oil crop growers by taxing the import of low-quality edible oil (such as palm oil), which is often not the case. Given that Pakistan imports low-quality palm oil, domestic high-quality mustard, and sunflower oils struggle to compete in terms of price. To make locally produced high-quality oils more competitive, the government could consider raising taxes on low-quality imported palm oil. This measure would protect local farmers and conserve foreign reserves, which could then be used to support wheat imports if needed.

The wheat crisis in Pakistan underscores the complexities and challenges of agricultural policy and market management. Despite portrayals by various market players, the government's withdrawal from the wheat market does not indicate an impending food crisis in Pakistan. Therefore, there is no need for the government to re-engage in comprehensive wheat marketing operations. If necessary, government involvement should be limited to supporting small growers to maintain strategic reserves for emergencies. Moreover, the government must act with greater responsibility and foresight in managing the wheat market.

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ARTIFICIAL INTELLIGENCE (AI) FOR AGRICULTURAL ADVANCEMENTS

USE OF ARTIFICIAL INTELLIGENCE IN THE AGRICULTURE SUPPLY CHAINS OF PAKISTAN

Sher Khan, Nauman Ejaz and Anwar Shah

The agriculture sector is considered the backbone of Pakistan's economy contributing 24% towards the country's GDP and employing 37.4% of the country's labour force, thus serving as a primary source of livelihood for millions.[38] It is also a potential source for earning foreign reserves, with key commodities such as rice, cotton, vegetables, and fruits impacting the balance of trade. In addition, the sector plays a crucial role in ensuring food security as it aims to achieve and sustain self-sufficiency in staple crops. Despite such an important role and share in the economy, Pakistan's agriculture sector remains vulnerable to pre- and post-harvest losses. These losses not only impact the farmers but also negatively impact consumers in terms of low-quality and less nutritional agricultural produce. Shortcomings at various stages in the agriculture supply chains such as inadequate storage facilities, lack of processing units, and poor infrastructure contribute to around 30% of fruit and vegetable losses in these chains.[39] The economic impact of these is about $4 billion, thereby reducing farmers' incomes and increasing food insecurity in the country. These

post-harvest losses are more common in perishables such as mangoes, tomatoes, and citrus, where poor handling and lack of cold chain lead to spoilage.

The agriculture supply chains of Pakistan are open to several issues and challenges such as lack of traceability and transparency which significantly contribute to food losses. Statistics reveal that a significant portion of agricultural produce is lost or wasted every year due to poor market information and inadequate tracking systems.[40]These issues hinder farmers and other supply chain stakeholders from making informed decisions regarding distribution and pricing. Challenges with transparency and traceability make it difficult to precisely identify critical loss points that contribute to food and economic losses. These loss points not only impact farmers' income and contribute to food insecurity but also lead to inflated prices and reduced availability of fresh produce in the market. Similarly, the lack of systematic tracking and monitoring systems reduces information penetration at almost every step in the supply chain, more so at the farm level, where the ability of farmers to make timely decisions is severely hampered. This has serious implications; one study shows that farmers with perfect market information have 4.3 times greater access to markets as compared to others.[41] It is no surprise that timely availability of information plays a key role in marketing agricultural produce more effectively.

The emergence of Artificial Intelligence (AI), specifically Blockchain Technology (BCT), was fast-tracked with the launch of bitcoin in 2009[42], which was designed as a decentralised digital currency. At first, BCT was mainly concentrated on cryptocurrencies, however its potential for safe and secure, transparent, and immutable record-keeping quickly received attention in different industries and sectors. Over the years, BCT has evolved beyond cryptocurrencies and enabled smart contract functionality in decentralized finance, voting systems, supply chain management, and digital identity. One significant advancement of BCT in this respect was the introduction of Ethereum in 2015, allowing for programmable smart contracts and expanding the use of BCT.[43]

The recent advances in BCT can assist in identifying critical loss points that negatively impact the agriculture sector of Pakistan and transform traditional supply chains into modern value chains by reducing traceability and transparency-induced losses. The technology can be used to store records of product movements and associated transactions in blocks, enabling customers and stakeholders to trace back the origin of food items from farm to fork. These prospects will provide real-time data on production, harvest, storage, handling, and transportation that can not only be used for monitoring and problem-identification but also to provide timely information for decision-making.

Efficient information flows are specifically important for fresh produce supply chains that are arguably the most affected by climate change; for instance, some estimates indicate a shortfall of 600,000 metric tonnes in Pakistan's mango export in 2024.[44] Farmers, although now increasingly aware of fluctuations in seasonal patterns and the implications in terms of extreme weather events and disease management, have been slow to respond, with many still unaware of the requisite practice changes. BCT can help speed up awareness, as well as, make information accessible for farmers to optimize their operations. Moreover, AI can help stakeholders predict market trends and consumer demands based on the vast amount of data stored through BCT. This will help in making informed decisions regarding crop production and marketing. A recent survey by PwC finds that 84% of supply chain leaders believe blockchain will become a permanent fixture in their organizations.[45]

In addition, the integration of BCT with Internet of Things (IoT) sensors and AI analytics can transform the agriculture sector by optimizing operational efficiency. As an example, IoT-based BCT can assist in monitoring environmental variables such as humidity, temperature, and exposure to toxins during the various stages of the supply chain, while enabling accurate tracking and monitoring of agricultural produce through the chain using timestamps. Such immutable records of the journey of fresh produce from source to destination will ensure the availability of high-quality produce and mitigate food losses. Additionally, AI analytics can process the vast amounts of data generated by IoT devices to identify patterns and predict potential risks and critical events, enabling proactive decision-making and policy responses.

[38]Raza, M. Y., Wu, R., & Lin, B. (2023). A decoupling process of Pakistan's agriculture sector: Insights from energy and economic perspectives. Energy, 263, 125658.
[39]Firdous, N. (2021). Post-harvest losses in different fresh produce and vegetables in Pakistan with a particular focus on tomatoes. Journal of Horticulture and Postharvest Research, 4(1), 71-86.
[40]https://www.dawn.com/news/1394618
[41]https://www.thejaps.org.pk/docs/v-26-03/29.pdf
[42]Mahankali, S. (2019). Blockchain: The Untold Story: From birth of Internet to future of Blockchain. BPB Publications.
[43]Ahmad, M. S., & Shah, S. M. (2021). Moving beyond the crypto-currency success of blockchain: A systematic survey. Scalable Computing: Practice and Experience, 22(3), 321-346.

[44]https://www.deccanherald.com/world/after-high-transportation-costs-pakistan-mangoes-suffer-losses-due-to-climate-change-3033496
[45]https://www.pwc.com/us/en/services/consulting/business-transformation/digital-supply-chain-survey/supply-chain-tech.html

Due to the traditionally informal nature of transactions, monetary fraud is one of the major issues in the agriculture sector. BCT can help in enhancing credibility and accountability among the stakeholders by providing a protected, decentralised ledger of events and transactions in the supply chain, significantly enhancing transactional efficiencies. Thus, by creating and maintaining a complete and authentic record of every transaction; from inputs' selection to the delivery of produce to consumers, BCT can reduce the risk of fraud and disputes, which are currently very common in the supply chains.

Similarly, the implementation of BCT can help streamline the process of conferral and verification of organic and fair-trade certifications, thus enabling farmers to demand premium prices for their certified products both in domestic and international markets. This is specifically important if the Pakistani growers want to keep up with the emerging trends in the fresh produce markets.

In summary, the adoption of BCT in Pakistan's agriculture sector exhibits a significant opportunity for stakeholders to achieve a traceable high-quality product that attracts premium pricing by creating a secure, complete, and transparent record of the entire supply chain, from cultivation to sale, that buyers can use to validate the origin and quality of their food. Research indicates that traceable produce commands price premiums of up to 20% in markets where consumers are increasingly concerned about food safety and quality[46].

Despite the prominent benefits of BCT in the agriculture supply chains, there exist several challenges in its adoption and implementation including

- A lack of awareness and understanding of BCT among farmers and supply chain actors. Most stakeholders are unfamiliar with the benefits and applications of this emerging technology.[47] Addressing this knowledge gap through targeted awareness campaigns and training programs is essential for adoption.
- Low investments in BCT infrastructure such as internet connectivity, computing hardware, and storage solutions. Many rural areas in Pakistan lack reliable access to internet and electricity, making it difficult to deploy blockchain-based systems.
- Significant resource requirements for training farmers and supply chain workers on how to use and maintain blockchain platforms. Given the budgetary constraints of the government sector and the potential positive externalities associated with BCT, it seems implausible that the public or corporate sector alone will be able to garner sufficient resources. Therefore, there is a need for public-private partnerships to train farmers and all other players in the supply chains to fully harness the benefits of BCT.
- Regulatory uncertainty around blockchain systems and digital transactions. Pakistan currently lacks clear guidelines and regulations for the use of blockchain in business applications. This uncertainty deters stakeholders from investing in and implementing the technology. Developing a supportive regulatory framework that provides clarity and safeguards for blockchain-based transactions is necessary to accelerate adoption in the agriculture sector.

Nonetheless, BCT holds significant promise for optimising Pakistan's agriculture supply chains, offering a robust pathway towards food loss minimization, which is crucial for enhancing farmer incomes and food security. To realise this potential, collaboration between the government, industry, and academia is essential. With the implementation of the right policies and incentives, blockchain can indeed revolutionise Pakistan's agribusinesses, fostering a more efficient, transparent, and sustainable ecosystem.

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[46]https://www.sciencedirect.com/science/article/pii/S2666833522001009
[47]https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3814912

HARNESSING AI FOR AGRICULTURAL TRANSFORMATION -A PROSPECT OF PAKISTAN

Mahwish Rose

"Pakistan is an agricultural country" is a phrase every Pakistani has frequently heard and read since the nation's independence in 1947. Further, the country's location in the fertile Indus plains, abundant arable land, and access to both ground and surface water have supported its growing demand for food. Pakistan is the 5th most populous country globally and ranks as the 41st largest economy. However, despite being an agricultural nation, a significant portion of the population still faces food security challenges.

Although Pakistan is among the top ten producers of crops like wheat, cotton, sugarcane, and rice, its per-acre yield lags behind competitors. For instance, China's wheat yield is 5.39 tons per hectare compared to Pakistan's 2.92 tons per hectare. The situation is worsened by the severe impacts of climate change, such as flooding, extreme weather conditions, and insufficient rainfall during critical crop growth periods. These factors, combined with existing challenges like poor crop management practices, inefficient use of fertilizers and pesticides, lack of storage facilities, and declining soil fertility, exacerbate the crisis. However, the impact of agricultural challenges can be significantly reduced with the use of technology, particularly AI.

The rapid growth of generative AI powered by large language models (LLMs) has demonstrated its potential across various fields, including production, manufacturing, and transportation. The agriculture sector now stands at a crucial point where deploying this technology is essential. AI can play a pivotal role in offering advisory services at different stages of crop production, predicting weather patterns and water availability both within and beyond farms, and optimizing value chains from farm to market. Government-led initiatives to incorporate AI into agriculture have been underway since 2018.

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AI is revolutionizing agriculture, with one of the key areas being predictive analytics. This technology enables farmers to forecast crop yields, adjust planting schedules, and anticipate market trends. By analyzing historical data on soil conditions and weather patterns, AI can predict potential issues in crop production, allowing farmers to prepare for variations and minimize losses through better planning for storage and marketing.

Crop monitoring has also been improved through AI technologies like drones and satellite imagery, providing real-time surveillance of crops. This allows for early detection of diseases, pest infestations, and nutrient deficiencies, enabling targeted treatments to control the spread of disease while addressing specific crop needs. Precision agriculture, supported by sensors and algorithms, can guide farmers on the optimal use of fertilizers by analyzing soil conditions, ensuring efficient and cost-effective crop management.

AI can analyze crop images and environmental data to manage pest outbreaks, suggesting appropriate pesticide dosages or using natural predators to protect crops. This approach reduces the need for broad-spectrum pesticides, saving both money and resources. Additionally, meteorological data analyzed by AI can help farmers plan planting and harvesting activities, especially as climate change causes unexpected weather events. Accurate predictions of rainfall, thunderstorms, and heatwaves enable proactive crop protection.

Irrigation management also benefits from AI, with systems providing data-driven recommendations on watering schedules based on weather forecasts, soil analysis, and crop water needs. AI-based applications can suggest crop varieties suited to specific weather patterns and soil conditions, increasing resilience and productivity. Sensors equipped with AI can analyze soil health, identifying nutrient deficiencies, PH levels, and moisture content, helping farmers implement targeted and cost-effective soil treatments.

Cloud computing can play a significant role in storing and analyzing vast amounts of agricultural data. AI platforms utilizing cloud technology can aggregate data from multiple farms, offering insights and strategies for better farm management. The agricultural supply chain can also be transformed through AI, improving market access for farmers and strengthening their connections with buyers. By predicting market trends based on historical data, AI can help farmers plan crop production more effectively and manage storage to secure better prices.

Deploying AI in Pakistan's agriculture sector requires a comprehensive approach. The first step is to set clear objectives and assess the areas where AI can have the greatest impact, such as crop monitoring and water management while identifying all relevant stakeholders from the public, corporate, and non-profit sectors. Defining the scope of the project and establishing a timeline for achieving these objectives is crucial for integrating AI into agriculture.

Building the necessary infrastructure is the next key step. This involves acquiring hardware such as sensors and drones, installing them, setting up cloud computing systems for data storage, and ensuring that these technologies can be seamlessly connected at the farm level. Continuous data transmission and real-time analysis are essential to fully leverage AI's potential.
Given Pakistan's diverse agricultural landscape, with varying crops, soils, climates, and resources, a one-size-fits-all approach is not feasible. A pilot phase under controlled conditions is advisable before any large-scale rollout. AI technologies for crop monitoring or precision agriculture should be tested in these pilot phases, with regular assessments and user feedback used to refine the system. This phased approach will help address challenges in data processing and ensure the system is functioning optimally before scaling up.

Comprehensive training programs are critical for successful adoption. Tailored programs in local languages for farmers, technicians, and other stake

holders should be developed. Interactive workshops and hands-on training sessions will help ensure that users fully understand AI technology and can use it effectively. Engaging educated youth through internships and fieldwork can also promote AI adoption.
Once training and capacity-building efforts are in place, full-scale implementation can begin, with customized software and hardware designed to meet local needs. Ongoing support is essential to ensure AI is smoothly integrated with existing agricultural practices. A continuous feedback mechanism, along with regular monitoring and evaluation, will help improve system efficiency over time.

Finally, conducting a cost-benefit analysis (CBA) is crucial to assess the overall impact of AI integration in agriculture. The costs of technology investment, training, pilot projects, human resources, maintenance, and scaling up should be weighed against the benefits, including increased productivity, cost savings, improved decision-making, and enhanced sustainability. Evaluating the return on investment (ROI) by comparing these benefits with the costs, and considering long-term gains such as improved food security and environmental sustainability, will provide a clearer picture of AI's significance in agriculture.

The challenges faced by Pakistani farmers can be effectively addressed through AI, potentially transforming the country's agricultural economy. By increasing per-acre productivity, optimizing resource use, and improving market insights, AI can enhance farmers' livelihoods and financial security.

Pakistan has long been struggling with economic instability, marked by inflation, rising taxes, shifting public sector policies, and uncertainties in imports and exports, all of which hamper economic growth and affect everyday life. While AI holds undeniable potential for agriculture, its integration presents significant challenges. These include the need for rapid infrastructure development, improved connectivity in remote areas, and tailored training programs for a largely less-educated farming community. Additionally, the high initial costs of implementing AI, coupled with the need for continuous government support, make this a complex endeavor.

To ensure success, AI applications must be customized for local needs. This involves adapting software to local languages, creating user-friendly interfaces, aligning with local resources and practices, and ensuring affordability for small and medium-sized farm owners when it comes to subscriptions and service fees.

A coordinated effort between the public and private sectors, academia, and research organizations is essential for the successful integration of AI in agriculture. Government policies should be clear, well-coordinated, and aligned with the interests of both investors and farmers. Public-private partnerships can be explored to make AI-based tools and services more user-friendly and affordable. The potential impact of such efforts would be significant, leading to increased food security and economic growth in Pakistan.

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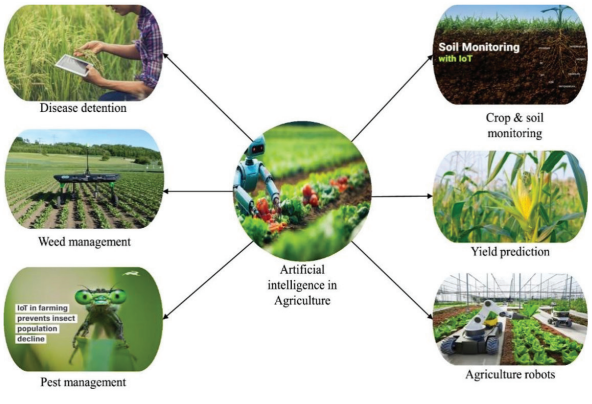
ARTIFICIAL INTELLIGENCE (AI) FOR AGRICULTURAL ADVANCEMENT

Shayan Malik

In today's world, Artificial Intelligence (AI) is changing how we farm. It's turning agriculture from an old-fashioned field into a high-tech industry. Farmers used to rely on hard work and good weather, but now they're using AI to boost their output and work smarter. This shift to AI in farming isn't just a cool new thing - it's become a must-have. It's changing the whole game, from how we deal with farming problems to how we spot new chances. AI has an impact on farming at its core leading to smarter and more effective ways of doing things. Experts think there will be about 10 billion people on Earth by 2050. This means we'll need to grow 50% more food than we did in 2013 even if the economy doesn't grow much. Right now, we use about 37.7% of the Earth's land to grow crops. Farming plays a big part in making rich countries richer and helps poorer countries' economies too. As farming has grown, country folk have seen their earnings go up a lot. So, it makes sense to focus more on farming.

The AI in agriculture market is expected to grow from USD 1.7 billion in 2023 to USD 4.7 billion by 2028, according to Markets and Markets.



The agricultural sector faces huge pressure to boost crop production and yields worldwide. Two main strategies have emerged to tackle potential food shortages: expanding farmland and adopting large-scale farming, or using new practices and tech to increase output on existing land. Many obstacles stand in the way of desired farm productivity, including small land holdings, worker shortages, changing climate environmental concerns, and declining soil health. These challenges are pushing modern farming to branch out in new directions. Farming has progressed a lot since the days of hand plows and horse-drawn tools. Each growing season brings new tech to boost efficiency and get more from the harvest. However, many farmers and big agri-companies often overlook the benefits AI can bring to their operations. Still, fresh ideas keep popping up in every field, and farming is no different. AI offers solutions to many problems and helps reduce the drawbacks of old-school farming methods.

DATA-BASED DECISIONS: PRECISION AND EFFICIENCY

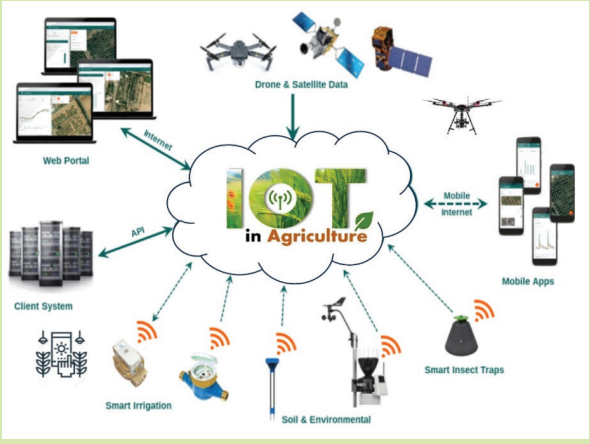
Data drives the modern world. Farms use data to gain deep insights into every farming step. They track each acre, watch the whole supply chain, and study how crops grow. AI prediction tools are changing agri-business. These tools use data from many sources, like space photos and ground sensors. AI then gives farmers detailed information about their fields. This data-based approach helps farmers use water, fertilizers, and bug sprays more. This knowledge helps farmers protect their harvests before problems start. AI lets farmers collect and process more data faster. It also looks at what people want to buy, predicts prices, and finds the best times to plant and pick crops.

PEST DETECTION AND CROP HEALTH MONITORING

Traditionally, pest control in agriculture has relied heavily on continuous pesticide applications. While this approach on the one hand is effective in combating pests, on the other hand, it often leads to overdose, posing a threat to environmental health and human safety solutions. AI in agriculture uses advanced techniques such as analysis of satellite-captured thermal imagery. This new method can quickly detect potential pest outbreaks or crop-affecting diseases. By analyzing subtle changes in temperature and other signals in these images, AI systems can pinpoint areas of concern long before visible signs of infection or disease appear. This ability to see quickly is critical; it empowers farmers to adopt a targeted approach in dealing with crop issues. Reduced chemical use means that less of the water flowing into adjacent water bodies is at less risk of affecting non-target species including beneficial insects and local fauna.

AUTOMATION IMPACT

Farming is hard, so labor shortages are nothing new. Thankfully, automation provides a solution that doesn't require hiring a lot of people. When the machine was emphasized and agricultural work was only a few hours away, the new wave of the digital wave materialized again, the driver, smart irrigation, Internet of Things (IoT), agricultural software, fruit Automated farm machinery such as greenhouse robots AI-powered harvesters are just some examples Compared to any human farmer for employees, AI-powered machines are far more efficient and accurate. Coupled with IoT sensors that monitor soil moisture levels and weather conditions, algorithms can decide how much water to supply crops in smart greenhouses in real-time AI automatically adjusts depending on temperature, humidity, and light levels real-time information to improve plant growth.



DETECTING LEAKS OR DAMAGE TO IRRIGATION SYSTEMS

AI plays an important role in detecting leaks in irrigation systems. By analyzing the data, algorithms can identify patterns and anomalies that indicate a possible leak. A Machine Learning (ML) model can be trained to recognize specific signals of leakage, such as changes in flow or pressure. Real-time monitoring and analysis provide early detection, preventing water wastage,

including potential crop failure. AI also incorporates weather data into crop water demands to pinpoint areas of overuse. By detecting leaks and providing alerts, AI technology increases water use efficiency to help farmers save resources.

CROP AND SOIL MONITORING

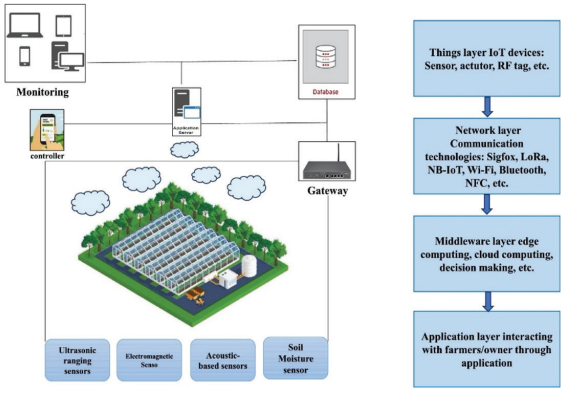
Soil nutrient balance can have a significant impact on the growth and quality of crops. AI helps farmers to identify these nutrients and their impact on crop production and make the necessary adjustments without any problem. Computer vision models can track soil conditions to gather the necessary data to prevent crop diseases and use plant information to determine crop health, flag specific cases, and make crop forecasts. Wheat growth and tomato ripening are just some of the things humans cannot do.

MONITORING LIVESTOCK HEALTH

Identifying health issues in animals may seem easier than detecting them in crops, but it's actually quite challenging. AI can be used for farming through the Cattle Eye application uses drones, cameras, and computer vision to remotely monitor livestock health, and find out what's going on with them, births, etc. Cattleeye analyzes feed additives for AI and ML solutions to get a better idea of the environmental impact. Farmers can use this knowledge to improve animal welfare and milk output.

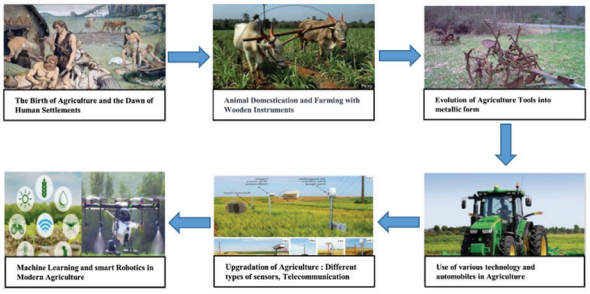
SURVEILLANCE

Farm management involves the maintenance of security. Burglars are a common sight on farms, it's impossible to watch every field. Animals can also be a threat like foxes in chicken coops or farmers' own livestock damaging crops or machinery. Computer vision machine learning video surveillance systems could detect security breaches in seconds. Some technology is mature enough to protect their staff from unlicensed visitors.



IMPACT ON SMALL-SCALE FARMERS AND LOCAL COMMUNITIES

AI provides a wealth of information and tools that help local farmers make informed decisions about farming practices. The focus is on selecting the most suitable time for planting, ensuring proper soil quality, utilizing appropriate water sources, and implementing pest management strategies. Farmers can optimize yield and resource utilization, and increase crop productivity and income by using data-driven AI tools. Hence, these developments are bringing about change, especially in areas where agriculture is the primary source of income and economy. Enhanced efficiency and productivity benefits for farmers not only improve their income but also contribute to economic growth and stability within their communities. Small farms can become more competitive in the open market by utilizing AI-equipped tools, breaking the cycle of dependence on outdated farming methods and limited resources. Agriculture is a whole lot more affluent, people are more empowered, and smart data-driven farming promotes fairness and success, not scale.



THE FUTURE OF AI FARMING IN PAKISTAN

Pakistan, a country with deep agricultural roots, relies heavily on farming. Agriculture makes up about 24% of the country's GDP, with Pakistan being a leading producer of wheat, cotton, sugarcane, mangoes, dates, rice, and oranges. As the world faces growing challenges in food production, technology-based farming techniques are emerging as a game-changer for Pakistan's agriculture, paving the way for more sustainable and resilient farming practices. Recognizing the potential of smart farming, Pakistan launched the Land Information and Management System (LIMS) under the Green Pakistan Initiative (GPI), a key project of the Special Investment Facilitation Council (SIFC). This system uses cutting-edge technology to promote precision agriculture, providing farmers with real-time data on climate, crop conditions, water management,

and fertilizer use. With this information, farmers can make smarter decisions, leading to better crop yields and more efficient use of resources.

Imagine a future where tractors drive themselves, planting, harvesting, and weeding with incredible precision, or where irrigation systems know exactly how much water your crops need and deliver it perfectly every time. This isn't just a dream—it's what the LIMS is working to make a reality. Currently, LIMS is in the Research and Development (R&D) phase, testing these smart agricultural practices on model farms in Punjab through the FonGrow initiative. But the innovation doesn't stop there. The GPI is also transforming livestock farming with the Green Corporate and Livestock Initiative (GCLI). By using AI-driven techniques like artificial insemination, the potential to increase livestock production is staggering from just 40-50 births per male animal each year to nearly 5,000. And the benefits of AI in agriculture are far-reaching. It's not just about improving efficiency. AI is helping to develop crop varieties that can endure extreme weather and resist diseases, significantly reducing the environmental impact of farming. Most importantly, it's playing a vital role in securing food supplies for future generations.

LIMS, by harnessing advanced technology, is not only boosting agricultural production but also helping Pakistan reduce its reliance on imports and increase its exports. And there are signs that these efforts are paying off. In 2023-24, Pakistan's agricultural exports reached $5.2 billion, a 13% increase from the previous year. This growth, driven by better productivity, prices, and global demand, includes major exports like rice, fruits, vegetables, cotton yarn, and fish. The shift from manual labor to planning and supervising AI-driven farming systems is not just a change in how farming is done—it's a transformation of the entire agricultural landscape. As AI technology continues to evolve, it holds the promise of turning agriculture into a more productive, sustainable, and equitable industry, meeting the challenges of the 21st century head-on.

CHALLENGES FOR AI AGRICULTURE IN PAKISTAN

AI is a concept that is only relevant to the digital world, with no connection to farming. Usually, it's because you don't know AI tools. AI in biotechnology is slow to be adopted in agriculture because there is no understanding in many areas, especially in nontechnical fields. The government must make significant efforts to help people understand the application of AI in agriculture. AI is a good investment for every farmer, it can help to sustain a farming industry. Still, some issues need to be addressed.

LARGE UPFRONT COSTS

AI solutions are relatively cheap in the medium to long term, but the initial investment is not without consequences. AI is not a viable option for the moment, especially for small farmers because of the financial difficulties of many farms and agri-businesses. AI farms cost less but technology improves it. Businesses can get government grants and private investment.

RELUCTANCE TO EMBRACE NEW TECHNOLOGIES AND PROCESSES

AI is a great way to help farmers, but people don't know how to embrace it. Resistance to innovation and a reluctance to risk new processes are the main obstacles to farming and its profitability. Farmers need to know that AI is just a refined version of simpler field data processing techniques. The public and private sectors must provide incentives, resources, and training to encourage agricultural workers to adopt AI. The governments must also create regulations to ensure that workers are exposed to the technology.

LENGTHY TECHNOLOGY ADOPTION PROCESS

Lack of infrastructure for AI is a common issue in the agricultural sector, along with a lack of knowledge and experience. Farms that have the technology already have the potential to make significant strides, but they may still face obstacles. Infrastructure challenges are also faced by agri-tech providers and software companies. A good way to do this is to approach farmers step by step, by using simple technology, like an agricultural trading platform. Once farmers get used to a simpler solution, providers can add additional tools and features to AI-based farms.

TECHNOLOGICAL LIMITATIONS

AI is still a concept, but it has limitations. Accurate models require diverse, high-quality data, which can be difficult to get in agriculture. Robots with sensors can help you to adjust to changing farming conditions. The challenge is to keep up with the research and data analysis. Farmers need to prioritize their decision-making over leaving it to AI. Early stages of AI adoption may benefit from manual monitoring.

However, Pakistan's journey toward AI-driven farming isn't without its challenges. For many farmers, who have relied on traditional methods for generations, embracing new technology can be daunting. Plus, small farmers often don't have the tools or resources needed to make the most of these advancements. To truly make this transition successful, both the government and private sector companies need to step up—offering loans, building infrastructure, and creating awareness programs that support farmers in adopting smart agriculture. By working together, we can help ensure that every farmer has the opportunity to thrive in this new era of farming.

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NEW DIRECTIONS IN PRECISION AGRICULTURE:

How the rise of 5G networks and the IoT can affect the national economy

Irfan Ali and Muhammad Sarwar Khan

RATIONALE

The use of modern IoT-related technologies including 5G and drones is becoming a center of hope against agricultural challenges such as low yield, high cost, and crop pests. Precision agriculture, facilitated by these technologies, enables the efficient utilization of resources resulting in increased crop productivity and minimized inefficiencies. The collection and analysis of data on the health of crops, soil, and patterns of weather, helped to make decisions, leading to improved allocation of resources and enhanced efficiency. Internationally, there is consensus on the increasing number of advantages of precision farming, which include notable enhancements in crop productivity, financial savings, and ecological sustainability.

The Pakistan Bureau of Statistics reports that key crops such as sugarcane, wheat, and rice have significantly lower yields per hectare compared to the world average. As an example, the world average for wheat production is approximately 3.5 tons per hectare, but in Pakistan, its closer to 2.8 tons per hectare (API, 2024).

The losses after harvesting always remained a matter of concern in Pakistan and in most cases, the emphasis remained on improving the storage and transportation facilities. According to reports, the average losses in fruits, grain, and vegetables are estimated between 15 to 40 percent (Firdous, 2021). The situation of food

security has become worse in the past few years due to high inflation rates and the income of the farmers is compromised.

Pakistan can leverage the convergence of Internet of Things (IoT) and 5G technology to address persistent obstacles in its agricultural industry. Pakistan can enhance its agricultural productivity by implementing modern farming practices.

To maintain economic growth, it is important to manage the essentials of life in the country. It is possible only by improving the lives in rural areas that contribute to nearly half of the population in Pakistan. Future success in Pakistan's agricultural sector and global leadership in sustainable agriculture hinge on the country's adoption of these technologies.

KEY FINDINGS

The area under automation is increasing around the world and after the incorporation of 5G, the scope is beyond expectations. This is the reason, that developing countries are investing more in the improvement of accuracy. For instance, in the US, the largest farmers are bringing more area under cultivation with the use of drone technology harboring remote sensors. As a result of implementing this strategy, the expenses associated with inputs have decreased substantially, the use of water has become more effective, and agricultural productivity has increased. Farmers can optimize productivity and minimize losses by making well-informed decisions using real-time data and promptly adjusting to dynamic conditions.

Another example is Australia which is one of the major exporters of agricultural goods and value additions. Even with the limited workforce, it is managing its global position by using smart agricultural techniques. These technological developments enable more accurate surveillance of animal movements, more effective control of feeding schedules, and improved monitoring of livestock health. As a result, there has been a rise in the output of meat and dairy products, even though there has been a significant decrease in labor expenses and an enhancement in the well-being of animals. The implementation of precision agriculture has yielded significant advantages for Japan's rice cultivation. The use of sensors has greatly improved the accuracy of applying pesticides and fertilizers. As a consequence, there has been a rise in more sustainable agricultural methods, leading to higher rice production and reduced reliance on chemical substances.

Source Credit: www.Precedenceresearch.com

China has become an important case study which is not only feeding the over a billion population but also became the center of the agricultural export market. China is expanding its market with CPEC and other initiatives. The combination of AI-powered analytics and unmanned aerial vehicles allows for very efficient control of agricultural processes. Agricultural output, resource usage, and expenditure have all seen significant improvements as a result. India, a nation that relies largely on agriculture, is using precision agricultural technologies to address inefficient use of resources.

ECONOMIC IMPACT

The national economy might have a transformational impact on the adoption of the above-discussed technologies. Currently, all the economically important crops, have average yields per hectare that are significantly lower than the world average right now. As an example, although the world average for wheat output is approximately 3.5 tons per hectare, Pakistan's average yield is closer to 2.8 tons. Pakistan may be able to raise its food products by approximately 20% or more by adopting and combining multiple modern practices. Not only would this raise food security, but it would also bring in billions of rupees more for farmers.

More importantly, the targets of substantial savings can be achieved with modernization. Depending on the crop and region, farmers can decrease input costs by 15-30% by optimizing and computational monitoring. Farm operations can be enhanced by the reinvestment of these savings, which in turn boosts profitability and productivity. Pakistan may enhance market efficiency and increase food supply by decreasing post-harvest losses, which presently constitute as much as 40% of certain crops.

These advancements could have a significant overall impact on Pakistan's economy. There would be more GDP growth, millions of farmers' livelihoods would improve, if agricultural productivity were to increase.

As a whole the global ranking of the Pakistan's agriculture can be improved. Reducing pesticide use and improving resource management would have environmental benefits as well, which would help Pakistan's agricultural industry last and continue to be an important part of the country's economy.

IMPORTANT CHALLENGES

After the emergence of pandemic, the evaluation of the different techniques applied in the smart agriculture remained in the critical evaluation and it is very important to understand them in context of Pakistani conditions for their implementation. Some of them are discussed here.

In less populated areas, the lack of basic infrastructure is much more of a problem for farmers. Although it is essential for 5G networks and IoT devices to have constant internet access, it is not always available. The data required for precision agriculture is too much for many rural locations to handle on 3G or 2G networks. Without substantial investment to enhance rural internet infrastructure, its implementation's fate would remain uncertain.

Pakistan is struggling to manage the energy crisis. The high cost of electricity and lack of policies for the sustainable energy is making the condition worsen that is disappointing the local and international investors. The precision agriculture technologies rely heavily on reliable power sources and the accessibility of resources through automated systems. Unfortunately, Pakistan experiences frequent power outages, particularly in rural areas, and many farmers simply cannot afford the exorbitant electricity bills. Issues with energy have a disproportionate impact on small-scale farmers, which is biggest hurdle in compelling them to adopt the technology. We must immediately begin investing in solar power and other renewable energy sources to help farmers overcome this challenge and have access to a reliable and affordable power source.

The high cost of precision agriculture technologies is another big obstacle. Important components of precision agriculture are out of reach for many Pakistani farmers, especially those operating on a smaller scale, due to a lack of finance. The lack of affordable financing options compounds this problem and prevents wider adoption. Lack of funding and interest from stakeholders is the main reason these technologies are out of reach for the farming community.

Training of the field worker is another big challenge. Workers who have stuck with the same methods for decades are understandably hesitant to adopt new technology. The majority of them have no idea what 5G and other forms of precision agriculture can do for their fields. In other words, having these tools available isn't going to cut it. Instead, it is critical to reach a consensus on the significance of precision agriculture. The influence of precision agriculture is limited and farmers are hesitant to engage in new technologies due to gaps in data availability. Farmers can avoid this issue by participating in extension and training programs that highlight the benefits of precision agriculture.
Pakistan is struggling to manage its finances. It is the reason that the government inspite of great desire, is unable to provide the subsidy to the farmers. Due to decrease in foreign reserve, the import processes are becoming complicated that is discouraging the investors to introduce new technologies. Investors also don't want to take these kinds of risks because the market is volatile, which makes long-term planning harder. For faster adaptation of technology, it is important to make sure that policies that support modernizing agriculture and making investments safe are stable and consistent.

It is very important to solve these problems right away if Pakistan wants to modernize its agricultural industry. This can be done by making the facilities better, lowering the cost of energy, helping people financially, and teaching people how to use the technology.

Pakistan's political and economic situation has never lived up to what people around the world thought it would be like, but the problem is very bad right now. The government is having a hard time running things and is under a lot of political pressure. Investing and farming have lost interest because policies change quickly and conditions are hard to predict. Investors also don't want to take these kinds of risks because the market is volatile, which makes long-term planning harder. For adaptation of IoT in agriculture, it is important to make sure that policies that support modernizing agriculture and making investments safe are stable and consistent.

To achieve the modernization of Pakistan's agricultural sector, it is imperative to promptly solve these challenges. Pakistan has the opportunity to fully harness the benefits of precision agriculture, which may significantly enhance production, sustainability, and economic growth. This can be achieved by improving infrastructure, reducing energy expenses, providing financial assistance, and offering training to users.

WAY FORWARD

In the light of above mentioned facts and discussion, the importance of the IoT is evident and there is an urgent need to allocate resources for its implementation. Intervention by the government to assist farmers in the adoption of technology should be the main goal of the Agriculture departments. This can be achieved by motivating international investors and companies to establish their model systems and provide interest-free loans to farmers having the intention of developing IoT infrastructure. The aforementioned obstacles can be surmounted by investing significantly and encouraging policies for the facilitation of the formation and use of renewable energy sources including solar energy. Currently, hundreds of Pakistani students are doing research in China on agricultural projects. Pakistan has a significant opportunity to re-design its research with Chinese universities collaboration. These graduates can become an important part of agricultural development through smart technologies. Collaborative research might further propel innovation in the field.

Programs for training are just as important. Farmers can be better prepared to make use of these technologies if agricultural training institutes are established with a focus on precision farming. In addition to increasing output, this will guarantee that monetary investments in technology produce the expected results.

There may be a sizable monetary effect from these upgrading initiatives. The efficiency of resource utilization might lead to a 30% decrease in input prices for Pakistan's agricultural sector if infrastructure and training were to be improved. The country's economy would get a huge boost if farmers could earn an extra billion rupees from a 20% rise in crop yields. These adjustments would boost food security and establish Pakistan as a strong contender in the international agricultural market, which would lead to sustainable economic growth in the long term.

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PAKISTAN's AGRICULTURAL PROBLEM AND ITS SOLUTIONS USING ARTIFICIAL INTELLIGENCE

Shain Taj Raisani

INTRODUCTION

"Pakistan is no longer an agricultural country". This is a controversial statement but if we consider the facts, we cannot deny the obvious. At the time of independence, the contribution of agriculture to the GDP amounted to 61% and today it contributes to 24%. The overall employment produced by agriculture is around 37.4% but it also includes low-skilled and least productive types of employment. Moreover, the three land reforms i.e. 1958, 1972, and 1977 have failed to include small farm owners and increase agricultural productivity. (Spielman, Malik, Dorosh, Ahmed,2016). Why Pakistan is no longer an agricultural country because the agriculture of Pakistan has been faced with multiple complex problems. These problems include:

LACK OF EFFICIENT UTILIZATION OF RESOURCES IN AGRICULTURE

The critical problem with agricultural resources is the precarious tradeoff between natural resources versus productivity. The relationship between land, water, and wastage has a huge impact on the overall growth of agriculture. As a result, since the 1980s the contribution of agricultural growth has stagnated to 2.5%. And it never crossed this threshold because the land and water along with climatic changes, need careful and balanced policy of resource utilization. For example, Spielmann, et. al, found that the increase in the total factor productivity for the years 1990 to 2012 in Pakistani agriculture is due to the incremental utilization of inputs rather than technological advancement. Similarly, the current irrigation system is highly inefficient with a water efficiency rate of 39%, because of failing infrastructure; along with 98% dependence on agriculture in the single Indus basin river system. Moreover, the general water productivity is quite low considering Pakistan ranked lowest among eight countries for water withdrawal (Maqbool, 2022).

MISGUIDED GOVERNMENT POLICIES:

The second issue is misguided government policies. To understand the policies of agriculture growth and trade needs context. For example, from 1950 to the 1960s the agriculture trade policy was highly biased because the ruling elite compromised agricultural growth against industrialization. (Zaidi, 2015). After the Green Revolution, agriculture fell into the web of

ineffective subsidies. The example of fertilizer-based subsidies that have reduced the cost of inputs in agriculture rather than output efficiency. Another example is the import policy of agriculture on account of food security that has historically damaged the prices for the poor framers in Pakistan. Lastly, substantial lack of research and development expenditure in agriculture since the 1980s (Spielmann. et, all. 2017).

INNATE INEQUALITY IN THE AGRICULTURE SECTOR

The third major problem is the persistent innate inequality in the agriculture sector. For example, the Green Revolution's success in impressive crop production is because of two reasons. First, tube wells, and second Tractorization. However, those who had large lands and spare capital were able to afford it. This led to the creation of landless peasants that were pushed into the tenant labor relationship. Moreover, the land assumption decreased the number of middle-class farmers that held the lands between 7.5 to 25 acres. As a result, those who have immense land and those who have not enough land increased significantly. As a result, the accumulated wealth increased disproportionality as well. (Hussain, 2012.) This phenomenon created inequal agriculture where the majority cannot afford investment in new technology. In addition to that the lack of credit availability for the small farmers is another reason that despite having re-distribution of land due to land reforms, the small farmers are unable to deploy high technology and increase productivity. (Zaidi, 2015).

LINEAR GROWTH MODEL OF THE AGRICULTURE OF PAKISTAN

The fourth problem is the linear growth model of production in agriculture. The linear model is defined as the utilization of inputs to generate the outputs for a single time only. The linear growth of agriculture is evident in the fact the increase in productivity is because of the increase in inputs. Moreover, there is no concept of regenerative agriculture or circular utilization of resources in the agricultural sector of Pakistan. (CITG, 2017).

HOW CAN AI HELP IN REDUCING THE KEY ISSUES OF AGRICULTURE IN PAKISTAN?

The concept of Artificial intelligence is still in its infancy. However, many scholars believe it to be a helping tool that will augment human skills and knowledge. Considering the multifaceted nature of Artificial intelligence, it is interesting to explore how it can help Pakistan solve its agricultural problems. The key solutions to help the agriculture sector in Pakistan are as follows:

CIRCULAR AGRICULTURAL ECONOMY MODEL

The circular model of agriculture deals with systematic change where the producer strategizes for the maximum utilization of the end products, along with the re-utilization of the end product as input for the new production. The aspect of artificial intelligence that can aid in the transformation is dependent on the development of circular economic systems. Currently, Pakistan produces 650 million tons of agricultural waste from just 04 major crops i.e. Rice, Wheat, Sugarcane, and Maize. Whereas, Pakistan has the potential to fulfill 30% of its electricity needs via thermal electricity by supplementing the oil with solid agricultural waste. Additionally, the biomass generated by using agricultural waste as a powerhouse can add 76% more electricity to the power grid (Saeed, et.al, 2015). Hence, agriculture in Pakistan seriously needs to be transformed into a circular economy where the agricultural waste can be reused, by the other industry as key inputs. Artificial intelligence accelerates this process by keeping track of the produced waste data, helps in running simulations to generate efficiency models, and much more.

REGENERATIVE AGRICULTURE AND AI

There are deliberate efforts to shift Pakistan's agriculture to organic agriculture. Currently, only 6% of the total agriculture is organic in Pakistan. Regenerative Production Landscape Collaborative Pakistan is the latest project initiated by the World Wildlife Fund in Punjab and Balochistan to shift agriculture towards regenerative agriculture. Hence there is substantial space for regenerative agriculture in Pakistan. Regenerative agriculture argues that the careful usage of soil, an understanding of biodiversity, and a sustainable ecosystem can add to the yield production. According to the estimate of FAO, three-fourths of the soil in Pakistan is degraded (Ebrahim & Bhardwaj, 2024). The utilization of Artificial intelligence by deploying farm sensory monitoring can directly decrease chemi-

cal utilization and increase soil's natural biodiversity.

PRECISE FARMING, AI, AND AGRICULTURE

The second solution of agriculture transformation in Pakistan deals with the adoption of precise farming using AI. The concept of precise farming is using inputs in agriculture exactly as needed. For example, if the farmers know how much fertilizer has been absorbed in the soil, they will not use more fertilizer based on intuition. Artificial intelligence added into the machinery to accurately measure the soil fertility, PH level, and weather conditions can help adopt precise framing. (Waqas, Wasim, Ashraf and Jatoi, 2023). Similarly, the research done by the authors Hossain and Majharul (2022) found that adopting AI in precise farming in Bangladesh increased crop yield by 22.5% more than that of imprecise farming. Hence, Pakistan can also increase its yield crop production by adopting Artificial intelligence, because the issues Bangladesh and Pakistan's agricultural issues are quite identical.

DATA-DRIVEN DECISION MAKING

The third way in which agriculture in Pakistan can be modernized with the help of AI is the integration of data-driven decision-making. It is profoundly important for agriculture as according to Talaviya et al.2024, the average farm will generate 4.1 million data points by adopting artificial intelligence methods by 2050. Data-driven decision-making via AI can benefit agriculture in two ways. Firstly, it will help in the successful utilization of Precision framing (Linaza, et, al., 2021). Secondly, it has immense potential to help the government to make effective policies. The three key areas where agriculture, artificial intelligence, and government policy overlap, are knowledge sharing with farmers, developing better supply chain mechanisms, and facilitation of credit and risk management of crops and livestock. (Beriya & Saroja, 2019). Moreover, data-driven decision-making will create more productive jobs as the data intermediaries will be required to connect farmers with the government. (Maru, et, al. 2018).

AGRO-CREDIT FACILITY USING AI SIMULATIONS

Another important solution to modernize the agriculture of Pakistan is to deal with inequality by extending the agro-credit facility to small and medium-level farmers. Artificial Intelligence can provide information on the crops' yield, water stress level, and possibility of drought or flood that can damage the crops. Such data helps the bankers understand the full extent of agriculture risk, optimize loan reimbursement, and ensure safer credit ratings for the farmers. A practical example is available in Bengal in India where such AI utilization is helping bankers and farming entrepreneurs facilitate agriculture finance. (Balaji,2020).

ECONOMIC IMPACT OF AI ON AGRICULTURE

AI can also have an immense economic impact as summarized, see table below.

Serial No.	Author Names	Key Research Findings	Economic Impact	Year
1	Saeed, et.al,	A circular economy can provide cheap inputs for other industries.	76% increase in the power grid using biomass in Pakistan.	2015
4	Maru, et. al.,	AI and data-driven decision-making in agriculture will lead to creating value-added jobs.	Development of jobs in the sector of Agriculture robotics, chatbots for farmers, and others.	2018
5.	Majid.	Climate change policy and usage of clean technology for agricultural production.	USD 47 Million pledged for adopting clean technology for climate-resilient agriculture in Pakistan.	2019
2	Hossain and Majharul.	Precise Farming and Agriculture in Bangladesh	A 22.5% increase in crop yield is realistically possible.	2022
3	Sharma & Sharma.	The Applications of Artificial intelligence can aid in agriculture in multiple ways such as intelligent sensing, forecasting, and effective monitoring	$9 billion addition in farm profits and 46% reduction in carbon foot printing in India	2023

CONCLUSION

The status of Pakistan as an agricultural country is precarious considering the multifaceted problems it has been currently facing. The lack of efficient utilization of water land and fertilizer inputs is affecting the TFP of the sector. Similarly, the misguided policies for agriculture by the government are generating a fiscal burden rather than improving the sector. Moreover, the innate functional inequality and linear model of growth have stunted the overall growth of the sector. Artificial intelligence might not be the silver bullet for all of the agriculture problems, but it is a good start. AI can help in the innovation of agriculture by aiding in circular economy transformation and the adoption of precise framing. Similarly, the data driven decision making using AI can be helpful not only in the adoption of agriculture but also for government decision-making. Besides the obstinate issue of inequality can be reduced using AI for farmer credit and effective risk assessment.

Artificial intelligence is the need of the hour as

Dr Kauser Abdulla Malik, emphasized that "Integration of Artificial intelligence in agriculture is not just an option but it is a strategic imperative to address these challenges head-on." Hence, modernization of agriculture of Pakistan with AI is not for the sake of introspection but for survival, if Pakistan wants to feed its population and earn economic value in the near future.

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HARNESSING TECHNOLOGY FOR A SUSTAINABLE AGRICULTURAL FUTURE

Maria Jawad Khan

INTRODUCTION

Despite the critical role of the agriculture sector in the economy and employment opportunities, it is plagued by inefficiencies and high production costs, hindering its potential for growth and development. Traditional farming practices, coupled with limited access to modern technology, exacerbate these challenges, leaving farmers vulnerable to economic pressures and environmental uncertainties.

In recent years, technological advancements have revolutionized various industries worldwide, including agriculture. The integration of cutting-edge technologies such as satellite imagery, drones, Internet of Things (IoT) sensors, and precision agriculture tools offers innovative solutions to age-old agricultural problems. These technologies enable farmers to monitor crops in real-time, manage resources more efficiently, and make data-driven decisions to enhance productivity and reduce costs.

This article explores whether the adoption of technology for crop monitoring and management can improve Pakistan's agriculture. By examining current agricultural practices, analyzing the impact of technological interventions, and identifying challenges and opportunities, we seek to understand the potential benefits and limitations of modernizing Pakistan's agricultural sector.

CHALLENGES FACED BY FARMERS IN PAKISTAN

Agriculture in Pakistan is deeply rooted in tradition, with many farmers still employing age-old techniques. This reliance on conventional methods often leads to inefficiencies. Mechanization is limited, and the use of advanced machinery is rare, making agricultural practices labor-intensive and less competitive on a global scale.

Water scarcity is another critical challenge. Issues such as water wastage, outdated irrigation practices, and over-reliance on groundwater resources exacerbate the problem. The impacts of climate change, including irregular rainfall and rising temperatures, further strain water availability, affecting crop yields and increasing the unpredictability of farming outcomes.

Soil health is also a concern. Intensive farming practices, including the continuous cultivation of the same crops, have led to the depletion of soil nutrients. The bulk of Pakistan's agricultural land is deficient in nutrients. Phosphorus deficiency affects 75–92% of total cultivated soil in Pakistan, whereas Potash deficiency affects 20–60% of total cultivated soil (Nasir et al., 2023). This monoculture practice not only reduces soil fertility but also makes crops more susceptible to pests and diseases, which in turn necessitates higher use of chemical fertilizers and pesticides, driving up costs (Zahid et al., 2020).

Furthermore, the **financial burden on farmers** is significant. High costs of inputs such as seeds, fertilizers, and pesticides, coupled with inefficient use due to lack of proper management practices, strain farmers' resources. Moreover, the limited access to credit and financial services makes it difficult for farmers to invest in necessary improvements or adopt new technologies.

Infrastructure inadequacies further impede agricultural efficiency. Poor storage facilities lead to substantial post-harvest losses, while inadequate transportation networks hinder the timely and cost-effective delivery of produce to markets. These factors collectively contribute to high production costs and reduced profitability for farmers.

ADVANCING PAKISTAN'S AGRICULTURAL POTENTIAL THROUGH TECHNOLOGY

Despite the above-mentioned challenges, there are pockets of progress. Some farmers have begun to adopt modern techniques and technologies, demonstrating significant improvements in efficiency and productivity. However, these instances are not yet widespread, and a comprehensive strategy is needed to address the systemic issues that plague the sector. To fully comprehend the impact of technological advancements in agriculture, it's essential to compare the current state of Pakistan's agricultural investments and outputs with the potential improvements that can be realized through the adoption of modern technologies.

Currently, Pakistan's agricultural sector heavily relies on traditional methods, leading to suboptimal yields and high production costs. Investments are primarily directed towards labor, conventional inputs like seeds, fertilizers, and pesticides, and outdated irrigation practices. Despite these investments, the sector's output has been disappointing. For instance, the average yield for major crops such as wheat, rice, and sugarcane remains significantly lower than global averages. In 2022, the average wheat yield in Pakistan was approximately 2.8 tons per hectare, compared to the global average of 3.5 tons per hectare (FAO, 2022). Similarly, the yield for rice was around 2.5 tons per hectare, below the global average of 4.6 tons per hectare (USDA, 2022). These figures highlight the inefficiency of traditional farming practices.

Technological advancements, such as **remote sensing**, have revolutionized the way farmers monitor their crops. Satellite imagery and drones provide detailed insights into crop health, soil conditions, and weather patterns. This technology enables farmers to make informed decisions, such as adjusting irrigation schedules or applying fertilizers precisely where needed, which ultimately leads to more efficient and productive farming practices (Samreen et al., 2023)

In Punjab, the use of drone technology has entered in crop management practices. **Drones** are employed to capture high-resolution images of crops, enabling farmers to monitor health, soil conditions, and identify issues such as nutrient deficiencies or pest infestations early. This led to a 30% reduction in pesticide use and a 15% increase in crop yields (The Nation, 2024).

Precision agriculture is another significant development, offering tools like GPS-guided machinery and variable rate technology. These innovations allow farmers to optimize the use of inputs, such as seeds and fertilizers, reducing waste and improving overall efficiency. In rice-growing areas, this technology has enabled more accurate fertilizer application, reducing costs by 20% and increasing yields by 10%-30% (World Bank, 2020). Automated irrigation systems further complement these technologies by ensuring that water is used judiciously, addressing both water scarcity and cost concerns.

The integration of **data analytics and artificial intelligence** into farming practices has also made a substantial impact. By analyzing data from various sources, AI systems can predict crop yields, identify potential pest infestations, and manage resources more effectively. Platforms like CropIn, which provide farmers with real-time data on weather, pest threats, and crop health,

have helped farmers increase yields by 15-20% (Ministry of Information and Broadcasting, 2023).

Mobile applications have emerged as valuable tools for farmers, offering real-time weather updates, pest detection, and expert advice. Apps such as "Kisan App" and "AgriSmart" deliver real-time weather updates, pest alerts, and expert advice. In Balochistan, where access to information can be limited, these apps have proven invaluable. Farmers using these tools have reported improved crop management and more informed decision-making. These apps bridge the information gap, providing farmers with timely support that can significantly influence crop management decisions.

The adoption of these technologies could potentially transform Pakistan's agricultural sector. By optimizing resource use and improving crop management, the sector could see a significant increase in crop yields. For example, if wheat yields in Pakistan were to increase by 20% through the adoption of precision agriculture, it would result in an additional 5.6 million tons of wheat annually, given the current production of approximately 28 million tons (PBS, 2023). This would not only enhance food security but also boost the agricultural economy.

BARRIERS TO ADOPTION OF TECHNOLOGICAL ADVANCEMENTS

While technological advancements offer significant potential for transforming agriculture in Pakistan, several challenges and barriers hinder their widespread adoption. One major obstacle is the **high initial cost** of advanced technologies such as drones and precision agriculture tools. Many small-scale farmers find these investments prohibitive, despite the long-term benefits they offer. This financial burden is often compounded by limited access to credit and financing options tailored to agricultural needs.

Moreover, the **technical knowledge** required to effectively use these technologies is another significant barrier. Many farmers lack the training necessary to operate sophisticated equipment or interpret complex data analytics. This knowledge gap prevents them from fully leveraging the potential of these innovations. Although some initiatives provide training, the reach and impact of these programs are often limited.

Infrastructure constraints also pose a considerable challenge. In many rural areas, inadequate internet connectivity and unreliable power supplies can hinder the effective use of digital tools and mobile applications. These infrastructure issues can significantly reduce the accessibility and efficiency of technology-based solutions, particularly in remote regions.

Additionally, there is **resistance to change** among some farmers who are accustomed to traditional farming practices. This cultural barrier can slow the adoption of new technologies, as farmers may be hesitant to shift from established methods to unfamiliar, high-tech solutions. Overcoming this resistance requires not only demonstrating the tangible benefits of technology but also providing consistent support and reassurance throughout the transition process.

Government policies and support systems also play a crucial role in technology adoption. While there are some initiatives aimed at promoting technological integration in agriculture, inconsistent policy implementation and lack of sustained support can impede progress. Ensuring that supportive policies are effectively executed and that there is ongoing assistance for farmers adopting new technologies is essential for overcoming these challenges.

POTENTIAL SOLUTIONS TO OVERCOME THE BARRIERS

Addressing the challenges to technology adoption in agriculture requires a multifaceted approach. A study by the World Bank suggests that Pakistan can increase its agricultural exports by up to 50% by 2025 through diversification and improved output quality, brought about by modernization. One of the primary recommendations is to enhance financial support for farmers. Government subsidies, low-interest loans, and grants specifically targeted at purchasing agricultural technology can make these innovations more accessible to small-scale farmers. Establishing more robust agricultural financing mechanisms will help reduce the financial barriers that currently limit technology adoption.

Investing in education and training programs is also essential. Providing farmers with the necessary technical knowledge and skills to operate advanced technologies will ensure they can fully utilize these tools. This can be achieved through partnerships between government agencies, educational institutions, and private sector companies. Regular workshops, demonstration projects, and hands-on training sessions can equip farmers with the expertise needed to integrate new technologies into their farming practices.

Improving infrastructure, particularly in rural areas, is another critical step. Ensuring reliable internet

connectivity and stable power supplies will enable farmers to effectively use digital tools and mobile applications for crop monitoring and management. Infrastructure development should be prioritized in agricultural policy planning to support the technological advancement of the sector.

To overcome resistance to change, it's important to engage with farmers and involve them in the process of technology adoption. Demonstrating the tangible benefits of these innovations through pilot projects and success stories can help build trust and acceptance. Creating farmer cooperatives or technology user groups can also facilitate knowledge sharing and collective learning, making the transition to new practices smoother and more collaborative.

Government policies must be consistent and supportive of technological integration in agriculture. This includes not only providing financial incentives but also ensuring that there are clear regulations and standards for the use of new technologies. Policy frameworks should encourage innovation while protecting farmers' interests and promoting sustainable practices.

CONCLUSION

Looking to the future, the prospects for technology in agriculture are promising. Advances in artificial intelligence, machine learning, and biotechnology hold the potential to revolutionize farming practices further. Precision farming techniques will continue to evolve, offering even more efficient and sustainable ways to manage crops. The development of affordable and user-friendly technology will likely increase, making it more accessible to a broader range of farmers.

While the current state of agriculture faces numerous challenges, including financial constraints, technical knowledge gaps, infrastructure deficiencies, and resistance to change, the integration of technology in crop monitoring and management presents a transformative opportunity for Pakistan's agricultural sector. The potential benefits of adopting modern technologies such as drones, GPS-guided machinery, data analytics, and mobile applications are immense. These innovations can significantly enhance productivity, cost-efficiency, and sustainability. To overcome the barriers to adoption, a multifaceted approach is required, involving financial support through subsidies and affordable financing, comprehensive education and training programs, and improved rural infrastructure.

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DRONE TECHNOLOGY AND AGRICULTURE SECTOR

BRING ON DRONE TECHNOLOGY IN PAKISTAN'S AGRICULTURE: REGULATORY CONSTRAINTS

Sadaf Safder

In the constantly evolving of modern agriculture, incorporating drone technology, also known as Unmanned Aerial Vehicles (UAVs) or Unmanned Aircraft Systems (UAS), presents a watershed moment with far-reaching consequences, and sustainability. Introducing drone technology is particularly important in Pakistan, a country whose agriculture is full of inefficiencies in input application due to skill deficits.

Pakistan's agriculture sector is vital to its economy, employing a large portion of the population and contributing substantially to GDP. The important crops include wheat, rice, sugarcane, and cotton, with rice and wheat being staple foods and major exports. Despite its economic importance, the sector struggles with outdated farming practices, water scarcity, and land degradation. Drones offer substantial advantages in the agricultural sector where accuracy and operational efficiency are essential. Drones equipped with advanced sensors and supported by artificial intelligence (AI) algorithms reduce the need for costly ground surveys and manual labor. They enable targeted treatment applications, minimizing pesticide and nutrient use, which reduces the total input, saves money, and lessens their impact on the environment by giving each plant only the necessary amount of fertilizer or pesticide. Additionally, the integration of machine and deep learning technologies has the potential to significantly revolutionize drone capabilities by allowing autonomous decision-making methods while in flight.

Drones have a variety of applications that promise to transform farming techniques. These applications include

- Accurate crop monitoring
- Real-time plant health evaluation
- Disease identification
- Abiotic and biotic stress detection
- Optimized input application (e.g., fertilizers and pesticides)
- Optimal irrigation system operation

The Pakistan Civil Aviation Authority (PCAA) is primarily in charge of monitoring the regulatory framework that governs drone activities in Pakistan. The Civil Unmanned Aircraft Rules, 2024, provide comprehensive and stringent guidelines for the import, use, licensing, and security clearances of UAVs. However, there are major challenges to the efficient application of these rules, which hinder the prompt deployment and successful operation of drones in agricultural contexts. The requirement of obtaining a No

Objection Certificate (NOC) from the Ministry of Defense before bringing drones into Pakistan is an important challenge. The procurement of vital equipment required for agricultural operations is sometimes delayed by this bureaucratic process, which might take several months.

Drones are used for scheduled tasks but also need to perform emergent operations owning to sudden pests' effects or other emerging input applications. The ongoing requirement for NOCs before every drone flight adds operational complexity. Furthermore, operational planning is made more difficult, and considerable collaboration with regulatory authorities is required due to the rigorous adherence to airspace laws, which include restrictions regarding proximity to airports and sensitive locations. All of these issues highlight the necessity of more efficient regulatory procedures and improved coordination systems to enable drone technology to be seamlessly incorporated into Pakistani agriculture.

Pakistan has to reevaluate its regulatory strategy to comply with international norms while taking into account regional differences in the face of these difficulties. The cooperation of key stakeholders, including technology providers, agricultural groups, and regulatory agencies, is necessary to improve operational flexibility, expedite the approval process, and create an environment that encourages innovation. Further, the introduction of a service provider model, attached with comprehensive training for drone operators and the establishment of pilot licensing is a crucial step toward efficient drone deployment.

Despite the drone technology has considerable potential, there are a lot of significant hurdles in Pakistan that prevent it from being widely used, especially convoluted regulation. Airspace management, safety procedures, data privacy, and licensing regulations are only a few of the factors that need to be taken into account while regulating UAVs and UAS; these factors also change among different regions and countries. Navigating these regulatory frameworks in Pakistan is particularly complex, involving clear regulations that maintain a balance between innovation and safety. Key challenges include:

Procurement: Procurement is a significant challenge due to the involvement of multiple organizations and a time-intensive process. For example, academic institutes or PSDP-funded projects like the National Center in Big Data and Cloud Computing (NCBC) initially submit the request to the Higher Education Commission (HEC). The HEC then forwards the request to the Ministry of Defense (MOD), which is responsible for further processing regarding NOC.
Flight operation NOC: Currently, it is mandatory to obtain permission prior to each aerial survey. However, in the domain of agricultural research, particularly when monitoring specific crops, it is essential to conduct observations at least once per week, and in many cases, twice weekly. This frequency is crucial for tracking crop growth, detecting nutrient deficiencies, identifying pest infestations, assessing drought stress, and evaluating lodging resulting from wind or other weather-related phenomena.

Professional Drone Certification: Imported drones currently lack registration and certification, leading to unauthorized use and unmonitored operations. Establishing certification requirements is essential to ensure operational standards are met.

Pilot License Certification: Drone pilots often lack professional competence in critical areas such as aviation regulations, human performance limitations, operational procedures, and technical and operational mitigations for ground and aerial risk management. Their knowledge is also lacking in pre-flight, in-flight, and post-flight procedural protocols. A dedicated training center is needed to provide comprehensive instruction and certification.

To solve these problems the solution and future policy are to implement a unified framework to issue general permissions for agricultural drones to government bodies, academic institutions, and reputable companies registered with the Securities and Exchange Commission of Pakistan (SECP). Rather than mandating separate NOCs for each procedural stage, a single NOC could be issued to a designated department to oversee UAVs for both research, development (R&D), and commercial purposes. This approach aims to streamline procurement procedures and reduce bureaucratic delays. Develop a web portal for organizations to allow organizations and academic institutions to apply for and secure the necessary permissions for each flight. To streamline the process and ensure compliance with regulations, certain guidelines could be established, such as restricting flight altitudes to a maximum of 80 to 100 feet and prohibiting flights over sensitive areas. Furthermore, it would be beneficial to require companies to submit post-flight logs, thereby enhancing transparency and accountability in the monitoring process, such as CAAC providing the regulation and policy based on a person's ID number, passport number, or mobile number. Introduce certification based on drone size and weight. For example, the French government[48] designates any drone weighing over 800 grams as a professional drone. All such

All such drones are registered with the AlphaTango portal, which assigns them an identification number valid for five years. This registration process ensures that the drone meets the necessary operational standards and is authorized for flight. Establish a training center to provide comprehensive instruction encompassing all essential aspects of drone operation and safety. Upon successful completion of the rigorous training program, pilots would be awarded a certification validating their proficiency and adherence to professional standards for drone flight, such as the FAA provides certificates to individuals based on the oral and practical pilot tests.

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[48]https://drone-geofencing.com/drone-regulations-certification-and-constraints/

REGULATORY CONSTRAINTS IN USING DRONE TECHNOLOGY

Hafsa Sarfraz

Drone technology has seen significant growth in the past decade, particularly in agriculture. The integration of drone technology in agriculture marks a significant advancement, promising enhanced efficiency, precision, and sustainability in farming practices. Unlike larger manned aircraft, drones, also known as Unmanned Aerial Vehicles (UAVs) or Remotely Piloted Aircraft Systems (RPAS), offer a safer and more cost-effective means to survey agricultural land. They provide real-time imagery and sensor data from fields that are inaccessible by foot or vehicle. This capability aids in crop health monitoring, and integrated GIS mapping, and reduces the need for physical presence in the field, thereby enhancing decision-making processes and management efficiency, leading to increased yields and cost savings. Moreover, drones have applications beyond agriculture, including monitoring rugged terrains, surveillance for illegal activities, and observing natural disasters like forest fires. Their versatility has also encouraged young professionals to enter agricultural service sectors, creating job opportunities and improving returns on investment for farmers.

Despite these advantages, the rise in drone operations has raised concerns over safety and privacy. UAVs represent new airspace entities that pose potential risks to other airspace users and individuals on the ground. Consequently, many countries are implementing regulations to mitigate these risks and protect safety and privacy. However, the widespread adoption of drones in agriculture faces challenges, particularly navigating the intricate web of regulatory constraints imposed by governments worldwide. Understanding these constraints enables stakeholders to effectively navigate legal requirements, optimize operational strategies, and fully leverage drones' potential in modern agriculture.

REGULATORY FRAMEWORKS: A GLOBAL PERSPECTIVE

The regulatory environment surrounding drone technology in agriculture varies significantly among countries. While some nations have embraced drones

with relatively open regulatory frameworks, others have adopted stringent rules addressing safety, privacy, and operational concerns. Adopting regulatory strategies makes safer the use of drone technology.

United States: The Federal Aviation Administration (FAA) regulates drones under Part 107 of the Federal Aviation Regulations (FAR). Operators must obtain a Remote Pilot Certificate and adhere to rules including altitude restrictions, visual line-of-sight requirements, and prohibitions on flights over people and nighttime operations.

- **European Union:** The European Union Aviation Safety Agency (EASA) oversees drone regulations through the EU Drone Regulation, effective from 2021. This regulation categorizes drones by risk and imposes operational limitations, registration requirements, and competency standards for operators.
- **China:** The Civil Aviation Administration of China (CAAC) regulates drones with rules covering registration, flight altitude limits, and restrictions around airports and sensitive areas.
- **Australia:** The Civil Aviation Safety Authority (CASA) mandates drone operators to obtain certification, follow operational rules, and seek approval for specific drone operations, including agricultural applications.
- **India:** The Directorate General of Civil Aviation (DGCA) regulates drone operations under the Civil Aviation Requirements (CAR), encompassing registration, licensing, and operational restrictions.

PRIMARY REGULATORY CONCERNS

Regulatory constraints on drone use in agriculture stem from several key concerns addressed through legislation and enforcement measures:

- **Safety:** Ensuring safe drone integration into shared airspace with manned aircraft is paramount. Regulations typically include rules on flight altitude, airspace restrictions, and operational limits to mitigate collision risks and ensure public safety.
- **Privacy:** Drones equipped with cameras and sensors raise privacy concerns, particularly regarding flights over private property or capturing images without consent. Regulations often mandate compliance with data protection laws, limits on surveillance capabilities, and guidelines for data collection and storage.
- **Security:** Misuse of drones for unauthorized surveillance or interference with critical infrastructure is a significant concern. Regulatory frameworks may include provisions for security clearances, encryption standards, and restrictions on drone capabilities to mitigate security risks.
- **Environmental Impact:** Drones can cause noise pollution, disturb wildlife, and affect sensitive ecosystems. Regulations may impose operational restrictions, especially in protected areas or during critical periods like nesting seasons, to minimize environmental harm.
- **Operational Standards:** To ensure reliable and efficient drone operations, regulations often specify technical standards, pilot training requirements, maintenance protocols, and operational procedures. These standards aim to enhance operational proficiency, mitigate risks, and promote responsible drone use.

CURRENT REGULATORY SETUP REGARDING DRONE TECHNOLOGY IN PAKISTAN

As of 2024, drone technology in Pakistan is regulated by the Pakistan Civil Aviation Authority (PCAA), which has established guidelines to ensure safety, security, and privacy while supporting the use of drones for various activities, including commercial, recreational, and governmental purposes.

REGISTRATION AND LICENSING

- All drones, irrespective of their size, must be registered with the PCAA.
- Operators of drones exceeding a specified weight limit need to obtain a Remote Pilot License (RPL).
- Commercial drone operators must secure specific permissions and adhere to additional licensing requirements.

1. Operational Guidelines

- Drones should be operated within the operator's visual line of sight (VLOS).
- Flying drones in restricted areas, such as near airports, military zones, and sensitive infrastructure, is prohibited.
- Night-time operations require special authorization.

2. Security and Privacy

- Drones with cameras or surveillance tools must adhere to strict privacy regulations, and any operation near critical infrastructure or large public gatherings requires special approval from authorities.

3. Commercial Use

- Operators using drones for commercial purposes, such as aerial photography, agriculture, or delivery services, must obtain special permissions and comply with additional safety regulations.
- Companies engaged in commercial drone activities must ensure that their pilots are adequately trained and certified.

4. Law Enforcement and Government Use

- Government bodies, including law enforcement and emergency services, have provisions for using drones in surveillance, search and rescue, and other public safety missions.

5. Penalties and Enforcement

- Non-compliance with drone regulations may result in fines, confiscation of equipment, and, in severe cases, legal action.
- The PCAA, in coordination with local law enforcement, is responsible for enforcing these regulations.

IMPLICATIONS FOR STAKEHOLDERS

Regulatory constraints surrounding drone technology in agriculture have significant implications for various stakeholders:

- **Farmers:** While drones offer tools to monitor crop health, optimize irrigation, and assess field conditions, compliance with regulatory requirements adds complexity. It may necessitate investments in training, equipment, and legal counsel to navigate regulations effectively.
- **Drone Operators:** UAV operators must understand and comply with regulatory obligations to operate legally and safely. This includes obtaining certifications, adhering to operational restrictions, maintaining equipment standards, and ensuring compliance with data privacy laws.
- **Policymakers:** Governments play a pivotal role in shaping regulatory frameworks that balance innovation with safety, privacy, and environmental concerns. Policymakers must consider stakeholder input, technological advancements, and international standards to develop adaptive regulations that foster innovation while ensuring safety and compliance.

TECHNOLOGICAL ADVANCEMENTS AND REGULATORY EVOLUTION

The rapid evolution of drone technology presents both opportunities and challenges for regulatory frameworks:

- **Beyond Visual Line of Sight (BVLOS) Operations:** Regulatory bodies are exploring rules to facilitate BVLOS operations, enabling drones to cover larger agricultural areas efficiently. BVLOS regulations require robust safety measures, technological standards, and operational protocols to manage risks effectively.
- **Autonomous Drones:** Advances in AI and automation drive the development of autonomous drones capable of complex tasks without human intervention. Regulatory frameworks must adapt to address safety, liability, and ethical considerations associated with autonomous systems.
- **Data Management and Privacy:** Drones collect extensive data on crops, soil, and farm operations. Regulations must ensure secure data transmission, storage, and usage, complying with data protection laws, consent requirements, and data anonymization practices.

The adoption of drone technology in Pakistan's agriculture sector faces several challenges that limit its effectiveness and widespread use. These challenges are diverse, involving regulatory, technical, economic, and social factors.

CONSTRAINTS REGARDING DRONE TECHNOLOGY IN PAKISTAN

1. Regulatory Challenges

- **Complex Approval Processes:** Farmers face burdensome regulatory requirements, including registration, licensing, and obtaining permissions, which can be time-consuming, particularly for small-scale farmers.

- **Lack of Specific Guidelines:** The general drone regulations provided by the Pakistan Civil Aviation Authority (PCAA) often lack clear guidance for agricultural applications, creating uncertainty and discouraging investment.

2. Technical Constraints

- **Inadequate Infrastructure:** Rural areas often lack the necessary infrastructure, such as internet connectivity and maintenance services, to support drone operations.
- **Technological Limitations:** Many drones are not fully equipped for agricultural tasks, and their limited battery life can restrict their use over large fields.

3. Economic Constraints

- **High Costs:** The initial investment required for drones, along with associated training and maintenance costs, is often prohibitive for small-scale farmers.
- **Limited Access to Credit:** Farmers struggle to obtain credit or financial support to invest in drones, further hampered by a lack of government subsidies or incentives.

4. Social and Cultural Constraints

- **Lack of Awareness:** Many farmers are unaware of the benefits of drone technology and lack the knowledge to operate drones effectively.
- **Resistance to Change:** Traditional farming practices and skepticism about new technologies can lead to resistance against adopting drones.

5. Environmental and Operational Constraints

- Drones are affected by adverse weather conditions, limiting their operational windows in agricultural regions.
- Pakistan's fragmented landholdings make efficient drone use challenging, particularly over small, scattered plots.

6. Security and Privacy Concerns

- **Data Privacy:** Concerns about the privacy and security of data collected by drones may deter farmers from using the technology.
- **Security Risks:** Drones near sensitive areas face restrictions due to security concerns, limiting their effectiveness.

7. Lack of Technical Support

- **Insufficient Support:** A shortage of technical support and after-sales service, especially in rural areas, poses a significant barrier to drone adoption.

8. Limited Integration

- **Adaptation Challenges:** Many drones are not fully adapted to local agricultural needs, reducing their practical applicability and value to farmers.

SUGGESTIONS TO OVERCOME THESE CONSTRAINTS WITHIN THE COUNTRY

1. Regulatory Reforms

- **Simplify Approval Processes:** Streamline the registration and licensing of agricultural drones with a dedicated regulatory framework, inspired by practices in countries like Japan and the USA.
- **Develop Clear Guidelines:** The PCAA should create specific guidelines tailored to agricultural drone use, with simplified regulations for small-scale farmers.

2. Technological Advancements

- **Infrastructure Investment:** Improve rural infrastructure, including internet connectivity and maintenance services, similar to efforts in India and Brazil.
- **Promote Innovation:** Encourage local development of drone technology to meet Pakistan's specific agricultural needs, through partnerships between universities, tech companies, and experts.

3. Financial Support and Incentives

- **Provide Subsidies and Grants:** Offer government subsidies and grants to reduce the cost of drones, following models in China and the European Union.
- **Improve Access to Credit:** Work with banks to offer low-interest loans or leasing options for drones, modeled on microfinance initiatives in Africa.

4. Education and Awareness

- **Training Programs:** Implement training programs nationwide to educate farmers on drone technology, similar to those in Australia.
- **Awareness Campaigns:** Launch campaigns and demonstration projects to showcase the economic benefits of drones in agriculture.

5. Environmental and Operational Adaptations

- **Develop Weather-Resilient Drones:** Promote drones that can operate in diverse climatic conditions, inspired by Israel's technology.
- **Adapt to Fragmented Lands:** Create drone solutions tailored to Pakistan's fragmented landholdings, including smaller drones and cooperative models.

6. Security and Privacy Measures

- **Establish Data Security Protocols:** Implement guidelines to protect farmers' data, modeled on the UK's agricultural technology policies.
- **Use Geofencing Technology:** Apply geofencing to prevent drones from entering sensitive areas, following practices in the USA and Europe.

7. Enhanced Technical Support

- **Set Up Local Service Centers:** Establish rural drone service and repair centers through public-private partnerships, similar to Canada's agricultural services.
- **Ensure After-Sales Support:** Encourage comprehensive after-sales support from manufacturers, including maintenance and software updates.

8. Integration with Existing Practices

- **Customize Technology:** Adapt drone technologies to local crops and conditions through collaboration with agricultural experts.
- **Promote Success Stories:** Showcase pilot projects where drones have improved productivity, as seen in India's agricultural initiatives.

CONCLUSION

Drone technology holds substantial potential to revolutionize farming practices, boost productivity, and promote sustainability in agriculture. However, realizing these benefits hinges on navigating a complex regulatory landscape shaped by safety, privacy, security, and environmental considerations. Understanding diverse regulatory frameworks' primary concerns and implications enables stakeholders, farmers, drone operators, and policymakers to collaborate effectively, fostering innovation while ensuring responsible and compliant drone use in agriculture. Despite all these regulatory constraints drone technology plays a revolutionizing role in Agriculture. In the years ahead, regulatory frameworks will evolve in response to technological advancements and stakeholder needs, driving progress toward sustainable and efficient agriculture globally.

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GENE REVOLUTION IN PAKISTAN

SOWING THE SEEDS OF CHANGE: PAKISTAN's TRANSITION FROM GREEN TO GENE

Ayesha Rahman

Agricultural revolutions around the globe have brought transformative improvements in food production, enhancing both its quality and quantity to meet the evolving needs of their times. Agricultural methodologies have evolved since the first Neolithic revolution (10,000 BC) characterized by a shift from hunter-gatherers to settled farmers and herders. The second agricultural revolution from the 17th to 19th century, also known as the British Agricultural Revolution, was marked by innovations like crop rotation and drainage, selective breeding, and drill mechanized operations that improved soil potency, yields, and agricultural efficiency. Subsequently, the third agricultural revolution from 1940 to 1960, universally known as the Green Revolution, is usually considered the most influential, followed by the fourth agricultural revolution i.e. present-day Digital farming. Each of these phases substantively raised food output and altered the agricultural landscape.

PAKISTAN-AN AGRARIAN ECONOMY

Pakistan's perspective as an agricultural economy descends from its origin. Deprived of industries, the nation's foreign exchange was dependent on agro-economy exports. To reduce import dependence, several initiatives were taken to achieve self-sufficiency, at least in the food sector of Pakistan. These efforts bore fruit in the 1960s with the adoption of high-yielding varieties, chemical fertilizers, mechanization, and irrigation

system upgrades, a period historically known as the 'Green Revolution'. It enhanced agricultural productivity by almost doubling the quantity of staple crops, and increased employment, and income. Backed strongly by the government, the technology was seen as a proponent of sustainable farming, augmenting yield by intensified agricultural practices (Dicks et al., 2019).

However, after the green revolution, a decline in the growth rate of crops specifically wheat can be attributed to a variety of factors including land degradation, lack of investment in infrastructure, water scarcity, lack of effective regulatory processes, and inability to adopt genetically modified (GM) crops to sustain the increment in yield (Byerlee, 1994)[49]. This lack of foresightedness on the part of the government led to decreased productivity and increased costs in comparison to its competitors who transitioned from the era of conventional breeding techniques (Green revolution) to more complex molecular structures.[50](Gene revolution) producing the same yield at a lower cost thus enhancing international competitiveness.

GENE REVOLUTION: A GLOBAL PERSPECTIVE

The Gene Revolution led to the development of genetically modified (GM) crops by utilizing biotechnology and genetic engineering to introduce specific desirable traits such as pest resistance, herbicide tolerance, and enhanced yields, all aimed at achieving socially beneficial outcomes.

The tobacco plant was the first genetically engineered herbicide-resistant crop developed in 1983 in a laboratory in Belgium. Followed by field trials in France and the US in 1986. The commercialization of transgenic crops was first done by 'The Republic of China' in 1992 introducing a virus-resistant tobacco. The global status of adoption of GM crops has increased significantly over the years with the US having the highest acreage of 74.4 million hectares followed by Brazil and Argentina. They have added more than 1 billion tonnes to global food, feed, and fiber production. According to a 2024 report of AgbioInvestor monitor, 11 commercially approved GM varieties have been planted by 27 countries, totaling 206.3 million hectares.[52] The most grown GM crops are cotton, maize, wheat, canola, rice, sugarcane, and soybean.

GENE REVOLUTION IN PAKISTAN: INITIATIVES & DEVELOPMENTS

Pakistan stepped into the exploratory world of modern biotechnology in 1985 by founding the National Centre for Excellence in Molecular Biology (NCEMB) in Lahore[53]. To achieve the objective of food security, 56 biotech institutes have been established which have made efforts to adopt and accelerate the pace of gene modification (Babar et al., 2021)[54]. Still, the scope has been limited to a few staple crops. The approval, cultivation, trading, and regulation of GM crops in Pakistan are managed by the National Biosafety Committee (NBC) and the Environmental Protection Agency (EPA). The Only GM crop permissible to be sown is BT cotton which is bollworm-resistant (Bakshs, 2016)[55]. Launched in 2010, GM cotton now expands to 2.3 million hectares accounting for approximately 95% of the total cotton farming area in Pakistan. It has improved dietary quality, increased yield, and positively affected the environment by reducing pesticide use. A pilot project of genetically engineered maize seeds by the Ministry of National Food Security & Research increased the production from 1 million metric tons (2013) to 10.5 million metric tons (2023). Recently, the EPA approved the commercialization of Pakistan's first GM food crop, sugarcane with insect-resistant and herbicide-tolerant traits (ISA, 2024)[56].

[49]Byerlee, Derek and Akmai Siddiq. "Has the Green Revolution Been Sustained? The Quantitative Impact of the Seed-fertilizer Revolution in Pakistan revisited." World Development Volume 22, Issue 9 September 1994: Pages 1345-1361.
[50]It refers to the arrangement of molecules in DNA that is modified by using advanced genetic engineering techniques to improve crop traits.
[51]Marc Van Montagu, "The Road to Plant Genetic Engineering," Annual Review of Plant Biology 62 (2011): 1-19, https://doi.org/10.1146/annurev-arplant-042110-103906.
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WHY PAKISTAN NEEDS A GENE REVOLUTION?

Presently, the agriculture sector of Pakistan contributes 24% of GDP and employs 37.4% of the labor force yet its low rank i.e. 102nd out of 125 nations in the Global Hunger Index, 2023, with annual food inflation of 18% and a poverty rate of 39.5% emphasize the dire need to attain food security possible via the adoption of GM crops. The catastrophic floods of 2022 caused an economic loss of $3.7 billion only in the agriculture sector with crops contributing up to 82%. (World Bank, 2022)[57]. The spillover effects of this loss in industry, trade deficit, and services sector strained the already struggling economy of Pakistan. Therefore, Pakistan needs to steer its cultivation in a direction that not only reaps the benefits obtained during the Green Revolution but can also withstand the challenges of present-day global warming, plant diseases, and depleting water resources. The key factors signifying the urgency of a gene revolution include:
Food Security: Enhancing crop yield by taking on high-quality seeds specifically GM seeds will help to achieve self-sufficiency in food.

Biofortification: It can also address issues like malnutrition improving overall public health e.g. Golden Rice enriched with vitamin A can help overcome blindness.
Crop Resilience: Pakistan, being one of the most vulnerable climatic regions of the world, needs the plantation of crops that can tolerate biotic as well as abiotic stress. Genetic manipulation has already helped in producing stress-responsive genes for drought, salinity, etc.

Economic Growth: High agricultural yield will lead to increased exports, more employment opportunities, and high incomes driving economic growth.

GENE REVOLUTION CONTROVERSIES

The major argument held against the adoption of GM crops is the potential health safety risk due to the substance 'glyphosate' extensively used in herbicide-resistant GM crops by humans. However, several studies have proven the safety of eating bio-engineered foods (US, FDA). Moreover, environmental degradation in the form of loss of biodiversity, religious norms, cultural beliefs, and lack of education also prevent the public from accepting them. The reluctance of Pakistan on the cultivation of GM crops also lies in the fact that most of its trading partners are non-GMO countries that prohibit the import of GM food.

GENETIC ENGINEERING IN LIVESTOCK:

The scope of genetic engineering is not only limited to crop modification, rather it has produced genetically engineered animals to increase yield, and cost-effectiveness by making them disease-resistant and to improve the quality of products obtained from them e.g. milk meat, and eggs. An impressive overall growth in the agricultural sector provided the much-needed kick to Pakistan's economy during the FY 2023-24 stabilization phase. A growth rate of 3.89% in livestock is a testimony of the potential for greater advancement through increased investment in gene editing technologies.

In the dairy sector, Pakistan is ranked among the top 5 milk producers globally. The average yearly production quadrupled from 12m MT in 1985-86 to 55m MT by FY23. However, its milking yield is one of the lowest i.e. 14 liters of milk per day by cattle compared to the global averages of as high as 40-55 liters per cattle per day specifically in the US and Netherlands[59]. Presently, there is no production or commercialization of GM animals in Pakistan. Genomic selection (selection of animals with competent genetic traits), cross-breeding of local cattle with the high breed, and implementation of milk pasteurization laws can lead to sustainable growth. Similarly, being the 11th largest poultry producer in the world, livestock diversification by the genetic breeding of ducks, pigeons, cows, goats, and fish can also ensure food independence and increased earnings.

For agriculture to be the real catalyst of Pakistan's economic growth and a reservoir of foreign exchange through its exports, lessons learned from the green revolution phase should be kept in view to reach conclusive sustainable agricultural practices that ensure food security and reduce import dependence. The importation of many crops can be avoided by allowing local cultivation of GM crops for example soybeans and canola are imported to make edible oil. Since 2015, Pakistan has exported 6.6 million tons of soybeans from the US and almost 95% of the soybeans were GE varieties. The same could have been planted in our country.

[57]World Bank. (2022). Pakistan Floods 2022: Post-Disaster Needs Assessment, Main Report. Retrieved from https://thedocs.worldbank.org/en/doc/4a0114eb7d1ce-cbbbf2f65c5ce0789db-0310012022/original/Pakistan-Floods-2022-PDNA-Main-Report.pdf
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CHALLENGES IN THE IMPLEMENTATION OF GMOs IN PAKISTAN

One of the most important parasites that sucks the development of the agriculture sector of Pakistan is the inefficient seed sector characterized by the availability of low-quality seeds, lack of effective regulatory policies, delayed seed approval certifications, marginalized private sector involvement, and financial constraints. Despite notable legal developments in the seed sector including the National Seed Act (1976, amended in 2015), the establishment of the Federal Seed Certification and Registration Department (FSC&RD), and the Plant Breeders' Rights Act (2016), the practical execution remains weak.

The lack of effective regulatory enforcement and intricate bureaucratic procedures failed to increase private participation in marketing creating the fear of seed piracy that led to the establishment of a large informal seed market. There is a critical need to redesign the seed sector to address governance and administrative issues and abolish the seed certification regime due to a large informal seed market. It should encourage research and development (R&D)[60], incentivize partnerships with MNCs, and monitor seed prices to avoid sharp fluctuations in the seed market. The development and exportation of 100 tons of heat-tolerant hybrid rice seeds to the Philippines in 2018 is a testament to the existing potential of the private sector to shoulder this responsibility and boost revenue through exports. Furthermore, new initiatives taken by the private investors with international collaborations e.g. technologies, table' by National Foods Limited, Nishat Sutas Dairy Limited by Nishat Mills Ltd will also uplift the agricultural sector by integrating advanced technologies hence improving product quality.

CLOSING REMARKS

Despite the present challenges, the potential benefits offered by the adoption of GM products cannot be negated. The global issue of food security coupled with climate change, population growth, and marginal cultivation space; all factors demand resilient crops adaptable to climate change. Pakistan, a land blessed with fertile soil and weather patterns can regain its strength as an agrarian economy by strategically devising its agriculture policies. A critical reevaluation of the existing agricultural policies, provision of high-quality certified seed to farmers, promotion of transgenic varieties, and participation of private markets necessitating a transparent intellectual property rights system (IPR) can bring agricultural boom. Additionally, a meticulously planned policy by experts targeting the genetic modification of animals should be designed to maximize the benefits of livestock. A robust regulatory system that guarantees safety supports innovation, and directs ethical concerns is fundamental to harnessing the benefits of GMO products.

To sum up,

"Transitioning from 'green' to 'gene' to 'keep the fields always green' is essential to bolster Pakistan's agricultural sector"

Ayesha Rahman is a Young Researcher at RASTA, PIDE.

MOVING FROM GREEN TO GENE REVOLUTION: SCOPE AND CHALLENGES FOR PAKISTAN

Waqar Younas & Uzma Zia

The agricultural sector of Pakistan, serving as a fundamental driver for the nation's economic progress, is currently confronted with notable challenges. The Green Revolution, which brought about substantial improvements in agricultural productivity during the 1960s and 1970s, has now reached its conclusion. Despite the ongoing discourse surrounding the prospects of a Green Revolution 2.0 and governmental initiatives such as the National Agriculture Emergency Program, it is imperative to facilitate a shift toward what is referred to as the Gene Revolution.

This transition holds significant importance for several reasons. Firstly, Pakistan's population currently stands at 241 million (Census 2023) and is expanding at a rapid pace of 2.55%. Using current population growth rates as a reference, it is projected that Pakistan's population will reach 263 million by 2030 and 283 million by 2050. Secondly, current farming techniques exhibit inefficiencies and are unsustainable, leading to low crop yields and a reliance on imported products. Lastly, the substantial concerns of climate change and water scarcity significantly impact agricultural productivity. In response, the Gene Revolution effectively addresses all of these challenges. By implementing genetic modification and modern biotechnology, Pakistan may create high-yielding, climate-resilient, and water-efficient crops, which will lead to higher crop yields, improved efficiency of resources, improved competitiveness, and new opportunities for farmers, entrepreneurs, and researchers. This modernization through the Gene Revolution has the potential to improve food security, drive economic growth, and establish Pakistan as a leader in agricultural invention.

With increasingly unpredictable weather patterns globally, the agriculture sector may face disruptions, exacerbating food insecurity and poverty. Accordingly, farmers will need to adapt. Enhancing agricultural productivity and implementing climate-resilient practices through modified technology can help sustain incomes and promote a shift towards new technologies. However, adopting new technologies is already challenging in many low-income countries, including Pakistan, due to various market inefficiencies. It is essential to address current environmental issues. In Pakistan, climate change threatens to derail efforts toward a Green Revolution.

GREEN REVOLUTION - PAKISTAN EXPERIENCE

In the perspective of Pakistan's agriculture, new technologies have had a significant economic, social, and environmental impact. . They have influenced the

relationship between inputs and outputs, as well as the interactions among social groups, income distribution, and the environment (Hussain, 2012). In fact, the Green Revolution in Pakistan worsened income inequality and regional financial disparities. The use of high yielding variety (HYV) seeds, which needed irrigation, led to faster income growth in the Punjab and Sindh regions compared to Baluchistan and Khyber Pakhtunkhwa. This resulted in increased income disparities within provinces between areas with irrigation and those without it (Hamid and Hussain, 1974). Furthermore, in Pakistan, poor farming techniques adopted by farmers have led to the overuse of land, resulting in declining fertility and crop production. Overall, productivity has dropped by almost one-third compared to the baseline production rates (Murgai et al., 2001). The soil is losing important nutrients, and there are concerns about water scarcity for the success of the Green Revolution in the future. Pesticides used to combat diseases and insects have increased crop input costs and caused health concerns .[61] Agricultural activities, including pesticide use, contribute to 30% of global emissions which contribute the climate change[62].

PATHWAYS FROM GREEN TO GENE REVOLUTION

The Gene Revolution showed the development and adoption of genetically modified organisms (GMOs) in agriculture. It follows the Green Revolution, which focused on improving crop yields through the use of high-yielding varieties, fertilizers, and irrigation. But the difference lies where Gene Revolution may take a form where crops are modified at the genetic level to exhibit traits such as pest resistance, herbicide tolerance, improved nutritional content, and enhanced tolerance to adverse environmental conditions (drought, salinity). The technology of genetically modified crops was adopted in Pakistan to deal with hunger and food scarcity on one side, but it also introduced expensive seeds, increased price of inputs irrigation issues, and costly fertilizers.

Scope

The Gene Revolution focuses on genetically modified (GM) products in health and agriculture. Pakistan has not benefited economically from this revolution. Today's GM crop products, such as herbicide-tolerant soybeans and stacking GM characteristics in selected crops, have the potential to reduce costs. However, it's important to note that GM products may only decrease production costs (Evenson et al., 2005).

Pakistan investigated genetically modified crops to evaluate their resistance to pests, high temperatures, and drought, comparing them with conventional cotton cultivars. The results indicated that GM crops have the potential to address major agricultural challenges in Pakistan, such as increasing productivity, enhancing disease resistance,[63] and the issue of climate change.

Potential

GM technology has significantly contributed to the increased global production of the four major crops such soybeans, cotton, maize, and canola. Since its introduction in the mid-1990s, the technology has led to a rise in global soybean and maize production by 122 million and 230 million tonnes, respectively. From 1990 to 2012 the farm incomes have improved by $116.6 billion (Brookes and Barfoot, 2014). Transgenic crops were grown extensively on about 81 million hectares across 17 countries, with 12 in developing countries. Developing countries accounted for 37% of the global transgenic crop area in 2004 and have improved consistently from 14% in 1997. Argentina, Brazil, and China were the top three producers among developing countries (James, 2004). In Pakistan, huge GMO production is required to meet rising food demand, driven by challenges such as high soil salinity, drought, insufficient irrigation, waterlogging, weed growth, and insect infestations (Hanif et al., 2023). Furthermore, the agriculture sector needs a Gene Revolution to stabilize yields under stress, produce biofuels, tackle climate change issues, boost animal husbandry, and reclaim marginal lands[64].

Challenges

Challenges associated with GM crops in developing nations can be categorized into three groups: political, technological, and socioeconomic. Pakistan is mainly facing technological and socio-economic challenges. Unfortunately, the country was not able to get full benefits initially due to the non-existence of laws. The Seed (Amendment) Act 2015 and the Plant Breeders' Rights Act 2016 were introduced but couldn't unleash the use of Genetically Modified (GM) seeds in the country. To address these challenges (Azadi et al., 2016) it is essential to first conduct experimental verification to determine the sustainability of the crops with small-scale farming practices and their suitability for agro-ecological conditions. Hence there are strong reasons to shift to this technology by overcoming certain impediments.

[61]https://agrihunt.com/articles/pak-agri-outlook/green-revolution-and-its-consequences-in-pakistan/
[62]https://www.pesticidereform.org/climate-change/
[63]https://allianceforscience.org/blog/2019/06/pakistan-likely-adopt-gmo-crops/
[64]https://www.brecorder.com/news/3388298

TECHNOLOGICAL CHALLENGES

- Lack of well-equipped laboratories to evaluate GM crop issues
- Absence of a comprehensive regulatory framework
- Shortage of trained human capital
- High cost and limited supply of GM seeds
- Inadequate information available for the adoption of GM technology

SOCIOECONOMIC CHALLENGES

- Non-existence of effective food laws initially hindered the full benefits of GM crops
- Lack of experimental verification to ensure the sustainability of GM crops at a small scale
- Affordability issues for farmers

SOLUTIONS

The solution can be producing GM crops that can withstand extreme weather conditions.

- Produce drought-resistant and flood-tolerant GM crop varieties to ensure survival and productivity in extreme weather conditions
- Create GM crops that require less water and are efficient in water usage to mitigate the impact of water scarcity
- Develop crops that are more resilient to pests/diseases, reducing the reliance on chemical pesticides and promoting an ecosystem
- Design GM crops that can bloom with diverse plant species, supporting overall biodiversity
- Develop salt-tolerant GM crops that can grow in soils with higher salinity levels, ensuring continued agricultural productivity in coastal areas
- Focus on creating GM crops that can adapt to the effects of climate change, such as variations in weather patterns and catastrophic floods

Concluding the discussion, Pakistan is facing a lot of challenges and moving towards the Gene Revolution offers Pakistan the tools needed to address those challenges. By adopting, updated laws and regulations for GM crops, Pakistan may build a robust agricultural sector proficiently surviving the adverse effects of climate change, ensuring better food security and sustainable development in future.

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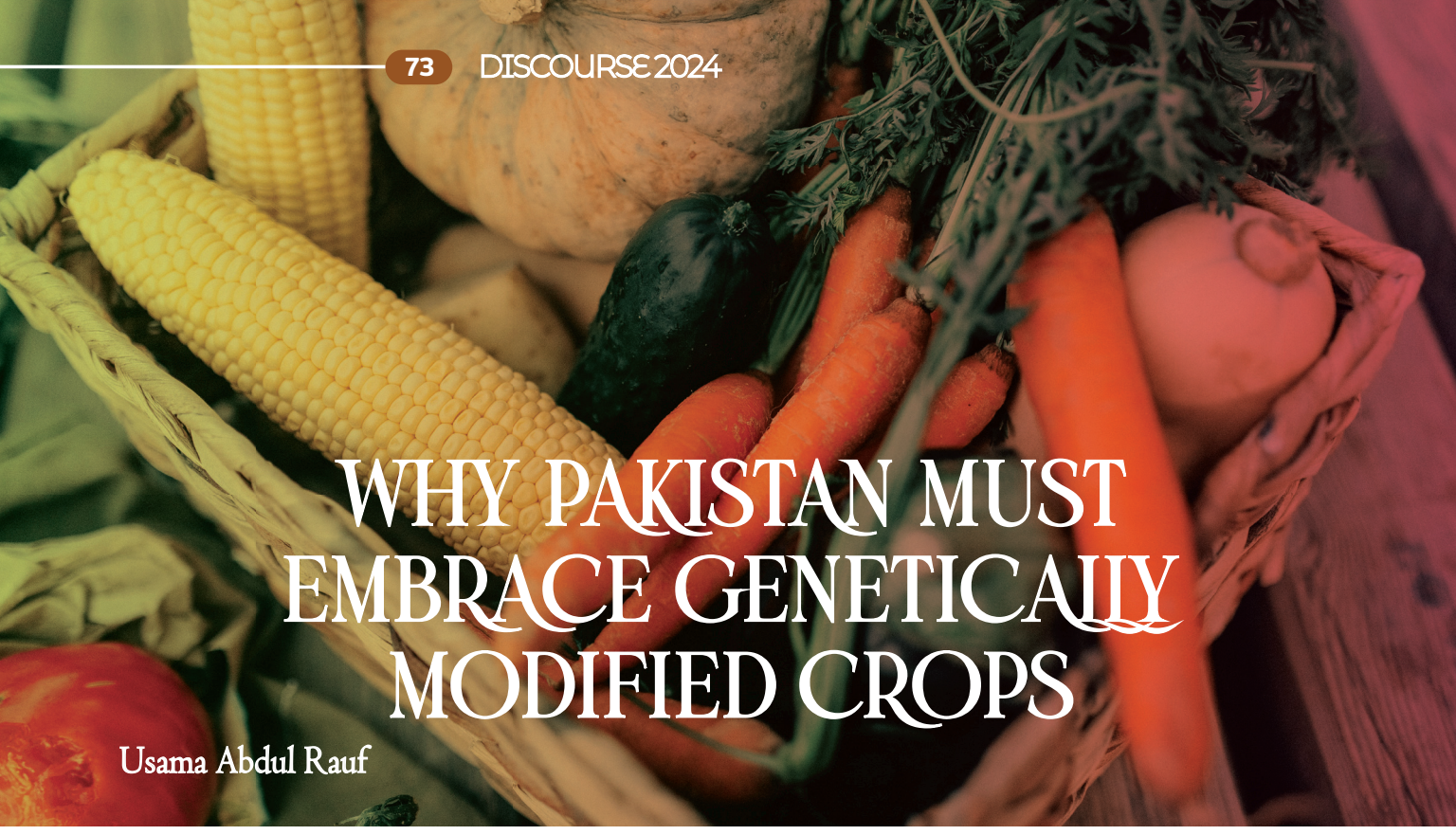

WHY PAKISTAN MUST EMBRACE GENETICALLY MODIFIED CROPS

Usama Abdul Rauf

The introduction of genetically modified (GM) crops represents a substantial advancement in agricultural methods, especially for nations like Pakistan where the agricultural sector is confronting many difficulties. Although high-yielding varieties (HYV) and chemical fertilizers helped the Green Revolution increase agricultural yields in the past, its shortcomings in terms of sustainability and environmental effects are coming to light. Genetically modified crops (GM) provide a viable substitute, with the possibility of increased yield, less dependency on chemical fertilizers, and enhanced resistance to environmental challenges. However, there are several obstacles to Pakistan's switch to genetically modified crops, such as inadequate infrastructure, negative public image, and regulatory barriers. This article explores the scope, potential, and challenges of transitioning from the Green Revolution to the Gene Revolution in Pakistan with the help of genetically modified crops.

AGRICULTURE IN PAKISTAN

Since gaining its independence in 1947, Pakistan's economy has been based primarily on agriculture. At first, the industry was defined by conventional farming practices that involved little use of technology. The 1960s saw the start of the Green Revolution, which resulted in large improvements in crop yields, especially for wheat and rice, with the use of chemical fertilizers, HYVs, and vast irrigation systems (PBC, 2023).

Because of these developments, Pakistan was able to become self-sufficient in food grains by the 1980s. However, there were drawbacks to the Green Revolution as well, like degraded soil, scarce water supplies, and a greater dependency on chemical inputs, all of which had long-term effects on the environment and the economy (FAO, 2023).

The growth and productivity of the agriculture sector have fluctuated during the past few decades. The industry grew by more than 4% annually on average between the 1970s and 2000. But after 2000, a number of issues including outmoded farming methods, wasteful water use, and a lack of funding for agricultural R&D caused this increase to drop to less than 3% yearly (World Bank, 2023). Pakistan's agriculture industry currently confronts several difficulties, such as low production, a lack of water, and climate change susceptibility. According to USAID (2023), the agriculture industry faces several challenges, including low investment in research and development (R&D), weak market linkages, and poor infrastructure.

NEED FOR GENETICALLY MODIFIED CROPS IN PAKISTAN

Several studies have demonstrated that traditional farming practices, which mostly rely on chemical

fertilizers and inefficient irrigation systems, are to blame for Pakistan's agricultural sector's yield growth plateau. Although these techniques were successful at first, they have threatened the nation's long-term food security by degrading the soil, reducing biodiversity, and decreasing agricultural yield returns.

The adoption of genetically modified crops offers a workable approach. Genetically modified crops have been modified to increase their resilience to environmental stressors, diseases, and pests. This has increased agricultural yield and decreased reliance on chemical inputs. Significant yield increases have been revealed by a meta-analysis of the effects of GM crops worldwide, especially in underdeveloped nations with comparable agricultural practices to Pakistan. For example, the introduction of BT cotton, into India produced better economic results for smallholder farmers by increasing cotton yields by 50% and reducing pesticide usage by 39% (Klümper & Qaim, 2014).

Success examples from nations like India and others imply that Pakistan stands to gain just as much from switching to genetically modified crops. This shift is necessary to advance the agricultural economy as well as to ensure food security. The overwhelming weight of data indicates that Pakistan must adopt GM agriculture to overcome the drawbacks of conventional farming and ensure long-term, sustainable agricultural growth (Khush, 2012; Qaim & Kouser, 2013).

WHY GENE REVOLUTION: THE GLOBAL EVIDENCE

With differing effects on food security, the introduction of genetically modified (GM) crops has greatly increased agricultural production worldwide. It is found that genetically modified crops, such as insect-resistant (IR) maize and herbicide-tolerant (HT) soybeans, have been linked to higher yields and lower pesticide usage. For instance, yields of HT soybeans increased by 12% in the US, whereas yield benefits of 5% to 25% were observed in South Africa with IR maize compared to traditional crops. By expanding the availability of crops, these advancements not only increase food security but also promote environmental sustainability by lowering the need for chemical inputs (James, 2022).

The financial gains from genetically modified crops are also noteworthy. Farmers throughout the world have witnessed significant increases in income, with smallholder farmers in poorer nations benefiting the most. In underdeveloped nations, the use of genetically modified crops has increased revenue by $100 per hectare on average; larger improvements have been seen in areas such as Sub-Saharan Africa, where agriculture plays a vital role in sustaining lives. By increasing rural people's purchasing power and reducing poverty, this economic growth contributes to increased food security in these areas (Brookes & Barfoot, 2022).

A decrease in the amount of land used for agriculture has also been connected to the widespread acceptance of GM crops. Genetically modified agriculture (GM) technology helps to preserve natural ecosystems and lessen deforestation by boosting crop yields, which allows more food to be produced on the same or even less territory. This component is essential for reducing the negative effects of agriculture on the ecosystem, especially in areas with abundant biodiversity. It is predicted that between 1996 and 2018, GM crops avoided the conversion of 23.6 million hectares of land to agricultural use. This represents a considerable contribution to worldwide environmental conservation efforts (Brookes & Barfoot, 2022).

POTENTIAL BENEFITS

The Gene Revolution in Pakistan has a lot of potential advantages. First, the productivity of agriculture can rise significantly as a result of GM crops. Comparing conventional kinds with genetically modified crops, like BT cotton, can result in yield increases of up to 30% (Ahmad et al., 2023). Pakistan can attain food security and lessen its reliance on food imports with the help of this productivity boost. Second, GM crops may lessen the need for chemical fertilizers and pesticides, which could result in cheaper production costs and less contamination of the environment. This is especially crucial for Pakistan, as overuse of agrochemicals has contaminated water and degraded soil (PBC, 2023).

Furthermore, Pakistan's agriculture may become more resilient to climate change if GM crops are adopted. Farmers can better adapt to the negative consequences of climate change by using crops that are bred for heat resistance, salinity tolerance, and drought tolerance. This will ensure steady harvests even in difficult situations. The gene revolution has the potential to alleviate public health problems and malnutrition by enhancing the nutritional value of crops. For example, vitamin A-enriched biofortified foods like Golden Rice can be quite helpful in preventing nutritional deficits (Ahmad et al., 2023).

HURDLES IN THE ADOPTION OF GM CROPS

Notwithstanding the Gene Revolution's exciting promise, several issues must be resolved for it to be successfully implemented in Pakistan. The legal structure controlling the use of genetically modified crops is one of the main obstacles. The biotechnology regulatory landscape in Pakistan is presently undeveloped, with convoluted clearance procedures and a lack of clarity about biosafety standards. The biotechnology industry may see a decline in investment and innovation as a result of this regulatory uncertainty (PBC, 2023).

Significant obstacles also lie in how the public views and accepts genetically modified crops. Farmers and customers alike are mostly ignorant of biotechnology, which contributes to their rejection and distrust of genetically modified crops. Strong public awareness campaigns and educational initiatives are needed to allay these worries by educating stakeholders about the advantages and security of genetically modified crops (Ahmad et al., 2023).

The requirement for large investments in R&D and infrastructure is another significant obstacle. The creation and marketing of genetically modified crops demand substantial financial and technological resources. To spur innovation and technological developments, Pakistan's existing expenditure in agricultural R&D is inadequate, and increased cooperation between universities, public research institutes, and private sector organizations is required (PBC, 2023). Furthermore, the successful distribution and commercialization of genetically modified agriculture is impeded by the absence of contemporary infrastructure, such as cold storage facilities and effective supply networks (NEPRA, 2023).

WAY FORWARD

We need to implement a number of well-considered steps in order to exploit the potential of GM crops. First and foremost, a comprehensive and encouraging regulatory environment for biotechnology must be created. This entails expediting the approval procedures for genetically modified crops, guaranteeing the implementation of biosafety protocols, and offering inducements to private enterprises to invest in biotechnology (PBC, 2023). Second, it's critical to raise public knowledge and educate the public about GM crops. To carry out awareness campaigns, workshops, and training programs for farmers and consumers, government agencies, research institutions, and civil society organizations should cooperate together.

Another essential element of this shift is funding R&D. To create genetically modified crops that are suited to a given region, the government ought to enhance its financial support for agricultural research and form alliances with global research institutions. Furthermore, bolstering the capabilities of research establishments and cultivating cooperation among scientists, policymakers, and industry participants can stimulate innovation and guarantee the flourishing commercialization of genetically modified crops (PBC, 2023).

Enhancing the infrastructure is also necessary to encourage the use of genetically modified crops. This entails making investments in cutting-edge cold storage facilities, irrigation systems, and effective transportation networks to minimize post-harvest losses and guarantee the prompt delivery of agricultural products to markets. Moreover, facilitating the adoption of GM crops and raising agricultural production can be accomplished by establishing an environment that encourages private sector involvement in agriculture. Examples of such environments include lending availability and technical assistance.

Pakistan has a great potential to upgrade its agriculture industry and achieve sustainable growth as the Green Revolution gives way to the Gene Revolution. Pakistan can effectively tackle issues of poor productivity, environmental degradation, and climate change, while also guaranteeing food security and economic feat, by harnessing the potential of genetically modified crops. But in order to fully realize this potential, all parties involved, the government, academic institutions, commercial industry, and civil society must work together. Pakistan may effectively traverse this transition and reap the full benefits of the Gene Revolution with the help of encouraging legislation, more R&D investment, improved infrastructure, and higher public awareness.

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THE SCOPE, POTENTIAL, AND CHALLENGES TO MOVE FROM THE GREEN REVOLUTION TO THE GENE REVOLUTION IN PAKISTAN

Wajhullah Fahim

WHY GENE REVOLUTION?

The "Gene Revolution" marks a significant leap in agricultural science, involving the artificial manipulation, modification, and recombination of DNA to alter an organism's characteristics. By transferring specific genes from one organism to another, the Gene Revolution enables the development of new traits that can vastly improve agricultural productivity and sustainability.

In agriculture, it represents a fusion of biotechnological advancements and innovations that have substantial benefits for the sector's growth. This technology holds great promise for boosting crop productivity, making it a vital tool in achieving Sustainable Development Goal 2, Zero Hunger.

One of the primary advantages of the Gene Revolution is its potential to create crops, fruits, and livestock with greater resilience against pests and diseases.

Reducing the reliance on chemical pesticides, not only cuts down on agricultural input costs but also mitigates environmental impact, promoting more sustainable farming practices. Furthermore, this biotechnology allows for the development of climate-resilient varieties of crops, fruits, livestock, and even fish, enabling agriculture to adapt to changing climate conditions. Ultimately, the Gene Revolution is instrumental in enhancing food security, advancing sustainable farming, and providing economic benefits, making it a transformative force in modern agriculture.

EVOLUTION OF GMOs

The evolution of GMOs can be traced back to the discovery of DNA. In 1953 Watson and Crick discovered DNA as a source for the transmission of traits and hereditary. Later in 1973, Berg's work at Stanford and in 1974 Boyer's work at the University of California further accelerated this evolution process. Based upon these works in 1982, the United States Food and Drug Administration (FDA) approved the first GMO product: human insulin to treat diabetes.

After this successful intervention, the government of America decided to develop a regulatory framework to regulate GMOs. In 1984, the first biosafety rules were introduced in America.

The first commercial GMO product came to market in 1994 when scientists created genetically modified tomatoes. Along with this product, this wave of GMOs produced various other products of GMOs such as summer squash, soybeans, cotton, corn, papayas, potatoes, and canola. But all were not available for sale. Now in 2023, 11 different GMO products are cultivated in 27 countries on an area of 206.3 million hectares.

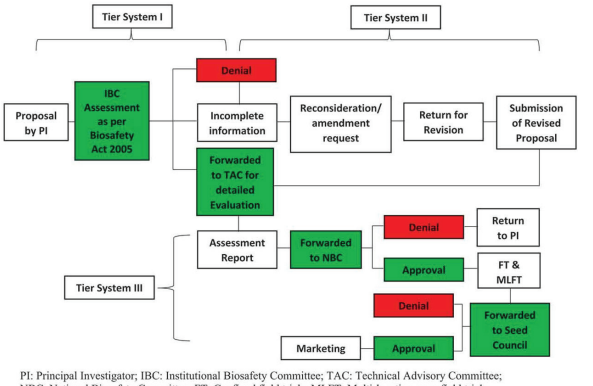
In 2005 under the provision of the 1997 Act of the Environmental Protection of Pakistan, the government of Pakistan established a three-tiered regulatory framework for GMOs and biosafety. The National Biosafety Committee (NBC) was established as the main body for the review and approval of GMO products in Pakistan. This committee consists of representatives from federal ministries, provincial governments, the Pakistan Agricultural Research Council, and the Pakistan Atomic Energy Commission. In addition, there are two apex bodies of NBC for technical support and approval process for GMOs. The Technical Advisory Committee (TAC) is responsible for reviewing new applications of GMOs. This committee is chaired by the Director General of the Environmental Protection Agency Pakistan and members are from all four provinces, Azad Jammu and Kashmir and Gilgit Baltistan. The second body is the "Institutional Biosafety Committee (IBC) which is responsible for risk assessment and monitoring and inspecting of research and development stages of the GMO.

The approval of GMOs in Pakistan consists of three tiers as explained in Figure 1. The first tier is the proposal submission to the IBC. The IBC assesses the proposal according to the Biosafety Act 2005. If the proposal is complete and meets all requirements, it will be forwarded to the TAC, otherwise, it may be denied (rejected) or a request for possible revisions. The second tier is the evaluation of the proposal by the TAC. After evaluation, the proposal may be approved to forward to NBC or like in the first tier, it may be denied (rejected) or sent back for possible revisions. Based on TAC recommendations, the NAC can approve the proposal for Confined Field Trail (FT) and Multi-Location Field Trails (MLFT) to evaluate open field trails. The NBC can deny the proposal or send it back for further revision. In the last tier, the Seed Council will evaluate the proposal. The Seed Council has the authority to reject the proposal or approve for use and marketing of GMO products.

According to Pakistan's Biosafety Rules of 2005, the timeline for the approval process is as follows:

Figure 1 GMO Approval Process in Pakistan

First Tier	60 days
Second Tier	90 days
Third Tier	120 days



PI: Principal Investigator; IBC: Institutional Biosafety Committee; TAC: Technical Advisory Committee; NBC: National Biosafety Committee; FT: Confined field trials; MLFT: Multi-location open field trials

(Source Babar et al., 2020)

CHALLENGES

Cultural and religious beliefs are other issues that prompted the gene revolution in Pakistan. Some religious leaders and local communities consider the gene revolution an alteration mechanism with natural processes and divine creation.

Lack of coordination and collaboration is another challenge to the gene engineering revolution in Pakistan's agricultural sector. The agriculture sector is not solely dependent upon the Ministry of Agriculture, but also closely related to other ministers and departments such as livestock, water and irrigation, and climate change. But after the 18th amendment, some ministers and departments such as the agricultural sector and irrigation were included in the provincial government subject, while some like Climate Change became part of the federal subject. In Pakistan coordination and collaboration between federal and provincial governments is very weak. Without effective cooperation between them, the gene engineering revolution in Pakistan is impossible. Along with these, a lack of coordination and collaboration between different government agencies, academia, and research think tanks is also a hindrance. In Pakistan, various public sector universities, different government agencies such as the Punjab Agriculture Research Board (PARB), Agricultural Linkages Program (ALP), and research think tanks such as Pakistan Agricultural Research Council (PARC), and Pakistan Science Foundation (PSF) are engaging in different projects of gene engineering. However, they have no proper mechanism for information sharing and coordination.

WAY FORWARD

For the growth and development of the agriculture sector of Pakistan, the gene engineering revolution has become necessary. Following are some ways forward for the gene engineering revolution in Pakistan.

REGULATORY FRAMEWORK

The government of Pakistan established NBC to ensure effective regulation of the GMOs in Pakistan. However, its efficacy is still lacking. The TAC is the apex body of NBC, but still, it lacks complete members. To effectively regulate GMOs, the local and lengthy process of biosafety certification needs to be replaced with certification third-party accredited biosafety certification bodies such as the International Organization for Standardization (ISO), and the Codex Alimentarius Commission (CAC). In this way, the lengthy procedure of GMO approval tiers 1 and 2 will be reduced. Furthermore, the direct involvement of the government in certification creates a conflict of interest in the private sector. Another way to reduce the lengthy procedure of approval of GMOs is to adopt E-governance. The online application system for GMOs will reduce unnecessary delays thus regulation of this

The role of the federal government should be limited to the imports and exports of GMOs while the provincial government should be involved in data-driven formulation and implementation of biosafety rules in their respective provinces. The provincial government can use different technologies such as satellite imaging and drones to develop data-driven biosafety rules.

ENGAGEMENT WITH RELIGIOUS LEADERS

Engagement with religious leaders for the gene revolution in Pakistan is a requisite condition. Like Turkey, the government of Pakistan should be involved in dialogue and conversation with religious leaders to address their concerns about the gene revolution. The Turkish government is involved in a series of consultative processes with religious leaders to address their concerns. Furthermore, they also arranged open public discussions and seminars with religious leaders. They also established ethical review boards including academia and religious leaders to align genetic advancement according to cultural and religious principles.

EFFECTIVE COORDINATION

A special committee should be formed consisting of agriculturalists, environmentalists, researchers, and representatives from federal and provincial governments so that information sharing and coordination between all levels can improve. The committee should arrange meetings quarterly and share information with all relevant stakeholders.

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