Potential and Prospects of Mechanized Agriculture and Smart Agri: Techniques in the Context of Industrial Development in Pakistan

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Abstract:

This report explores the transformative potential of mechanized agriculture and smart agricultural techniques in addressing Pakistan's agricultural challenges. With agriculture contributing 23% to GDP and employing 38% of the labor force, the sector remains constrained by outdated practices, fragmented policies, and limited access to modern technologies. Historical trends reveal gradual progress from land reforms and the Green Revolution to recent initiatives focusing on climate-resilient and digital agriculture. Analytical frameworks highlight key gaps, including inadequate infrastructure, lack of cohesive policies, and weak stakeholder coordination, while emphasizing opportunities for public-private partnerships, capacity building, and policy reforms. Mechanized and smart agriculture offer significant potential to enhance productivity, sustainability, and industrial development.The proposed actionable recommendations aim to foster collaboration, improve financing, and integrate advanced technologies, ensuring measurable progress through a strategic log frame.

Key words: *Mechanized Agriculture, Smart Agricultural Techniques, Agricultural Challenges, Policy Reforms and Collaboration, Climate-Resilient Agriculture*

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Introduction

Agriculture sector of Pakistan supplements around 23 percent to the GDP of Pakistan, and 37.4 percent towards the labour force of the country. Among the total exports of the country, around 70 percent of exports are directly or indirectly derived from agriculture. About 47 percent of the national land, around 30.5 million hectares, is agricultural land, which is higher than the global average of 38 percent. Two major cropping seasons in Pakistan are Kharif and Rabi, with a total water availability of 72.7 MAF. The irrigation of cultivated land is carried out for more than 82% through irrigation, whereas 18% is through rain-fed methods. In the rain-fed areas, around 60% is used for growing winter season crops, which are barley, wheat, lentils, grams, canola, mustard, and rapeseed, etc. The two major staple crops are wheat and rice, bookkeeping for 37 and 11 percent of the full edit region, respectively. Sugarcane and cotton are the two major cash crops, contributing 09 and 03 percent of the GDP individually (FAO Pakistan, 2025).

Be that as it may, the farming generation is much littler in Pakistan than in other nations of the world. Primary imperatives in expanding rural efficiency are the non-availability of cultivate apparatus to the agriculturists at the right time and at reasonable costs. Cultivate mechanization implies the use of machines and innovation within the farming division. Cultivate mechanization infers the use of mechanical innovation within the shifted cultivating operations, such as sowing, collecting, sifting, leveling, watering, splashing, weeding, and comparable other cultivate operations. The cultivate mechanization incorporates chemical innovation, plant assurance measures, hydrological innovation, and tube wells. Web of things (IOT), mechanical autonomy, manufactured insights, and mechanical innovation, which incorporate tractors and tractor-driven executes, threshers, and bulldozers, hence the use of all said innovative angles are included within the cultivate mechanization. The commitments of agrarian mechanization in various arrange of trim generation can be seen as sparing in seeds 15-20%, sparing in fertilizers 15-20%, sparing in time 20-30%, reduction in labor 20-30%, expanding in trimming escalated 5-20%, and higher efficiency 10-15%. Agribusiness mechanization in Pakistan is restricted to tractorization with cultivator, as it were in Pakistan, due to need of innovation utilization in the agribusiness segment; we face the issue of crops yields crevices. The normal yields generation within the horticulture segment of Pakistan is distant underneath the level of those nations that utilize the innovation in their farming division. The level of yields of different crops is 50-83% lower than the normal of other nations of the world.

The foremost well-known shapes of mechanization in Pakistan are bulldozers, control rigs, tube wells, and tractors with cultivators, wheat threshers, sprayers, and trailers with almost negligible use of smart practices and techniques in the agriculture practices in Pakistan.

Problem Statement

Pakistan's agricultural sector contributes 23% to the GDP and employs 38% of the labor force, yet reliance on traditional farming methods restricts productivity. The lack of mechanization and limited access to smart agricultural technologies are perceived as major barriers to growth and industrial development. Therefore, this research aims to identify the challenges impeding the adoption of mechanized and smart agricultural techniques in Pakistan, explore their potential to enhance productivity, sustainability, and industrial development, and propose policy recommendations to overcome these barriers and drive progress in both agriculture and industry

Scope

This study focuses on analyzing the challenges and opportunities in adopting mechanized and smart agricultural technologies in Pakistan during the period 2020-21 to 2023-24. This study shed light on the traditional farming techniques and practices for its impact on productivity and all such challenges which are acting as an impediment in the way of mechanization and availability as well as adoption of smart practices in the Agriculture sector.

This study also gives an insight a relationship for identifying impact of these technological upgradation with multifaceted aspects like productivity as well as industrial development.

This study, with basic aim of proposing policy-based recommendations which could be practical and of immense importance for the technological based uplift of both agriculture and associated industrial sector.

Research Methodology

In this research mixed method approach has been employed i-e both qualitative and quantitative methods and has consumed both the primary and secondary data sources. Similarly, analytical techniques like Historical Analysis, Situational Analysis, Institutional Analysis, Legal framework Analysis, SWOT & EETH analysis, Gap Analysis, Stakeholders Analysis etc

Historical Analysis

Early Post-Independence Era (1947-1960)

Soon after the independence the biggest challenge was to address the food security and to take steps for the uplift of the agriculture sector which was under threat due to the sudden paradigm shift as a result of partition of subcontinent.

Key Events:

- In 1959, the government launched a series of land reforms designed to promote social equity by redistributing land among small farmers. This initiative aimed to empower those who had previously been marginalized and to enhance agricultural productivity.

- To further support the agricultural landscape, the establishment of the Agriculture Department was a critical step. This organization was tasked with implementing policies and programs to improve farming practices and assist farmers in their efforts. (Jehangir, 2018)

Green Revolution Era (1960s-1970s)

In this period of time the focus was further broadened towards those seeds which could give high yields and introducing chemical fertilizers as well as introducing feasible irrigation techniques and methods.

Key Events:

- Launch of the Green Revolution with the support of international organizations.
- Expansion of irrigation systems (e.g., Tarbela Dam). (EVENSON, 2005)

Mechanization and Institutional Support for Agriculture (1980-1990s)

Focus on improving productivity through mechanization and introducing modern farming techniques through Agriculture development programs. (FAO, 2022)

Key Events:

- Agricultural Development Programs like Command Area Development programs, Integrated rural Development Programs, tractor financing schemes etc.
- Institutional Support: Establishment of various agricultural research institutions to support mechanization and training etc

Mechanization and Institutional Support for Agriculture (1990-2000s)

In this era focus was on financial assistance, empowering women and biotechnology promotion
Key Events:

- Financial Assistance: Programs to provide loans and grants to small farmers for purchasing machinery and technology.
- Empowerment of Women: Initiatives focused on improving the role of women in agriculture through training and access to resources.
- Biotechnology Promotion: Encouragement of biotechnological advancements in agriculture.

Modernization and Globalization Era (2000s-2010s)

Focus on sustainable practices, biotechnology, and global market integration.

Key Events:

- o Implementation of the National Agriculture Policy in 2009.
- o Emphasis on organic farming and environmental sustainability. (Zubair, 2010)

Recent Developments (2020-Present)

Challenges from climate change and a need for technological advancement in agriculture.

Key Events:

- o Launch of initiatives for climate-resilient agriculture.
- o Growing emphasis on digital agriculture and agri-tech startups. (Khan, 2021), (Bhatti, 2022)

Situational Analysis

Here in this section situational analysis has been covered in different aspects like mechanization impacts on enhancing yield, potential of smart agri techniques, prospects, competitiveness and contribution as follows;

Mechanization in Agriculture: Enhancing Yield and Sustainability

Mechanization in agriculture has become a vital component for enhancing yield production and sustainability in Pakistan's agribusiness. The use of mechanization, such as tractors, harvesters, and tube wells, has somehow allowed the farmers to move away from traditional labor-intensive methods toward more efficient cultivation practices. However, the level of mechanization as well as advance agriculture techniques still varies significantly across regions and farm sizes, reflecting the challenges and opportunities in this field (Ali, 2011).

Potential of Mechanized Agriculture and Smart Agriculture Techniques

In Pakistan, mechanization is more widespread in provinces like **Punjab and Sindh**, where large-scale farming makes the use of machinery such as tractors, harvesters, and tube wells more practical. These mechanized tools are essential for soil preparation, crop transportation, and efficient harvesting, significantly improving productivity and reducing labor costs. However, the adoption of mechanization remains limited in regions like **Khyber Pakhtunkhwa (KP) and Baluchistan**, where smaller, fragmented landholdings and resource constraints hinder the uptake of such technologies (Pakistan Bureau of Statistics, 2021).

Alongside mechanization, **smart agriculture techniques** are gaining attention as innovative solutions to address the challenges faced by the sector. Although still in its early stages, smart agriculture practices—such as **precision farming**, **drones for monitoring crops**, **IoT-based soil sensors**, and **satellite imagery** are beginning to be implemented in select regions, primarily on **5% of agricultural land** (Ministry of National Food Security and Research, 2020). These technologies enable farmers to make data-driven decisions, optimize resource use, and monitor crop health more effectively. As these technologies continue to evolve, their integration into Pakistan's agricultural landscape holds significant potential for improving yields, reducing input costs, and promoting sustainability across the sector (Zafar et al., 2022).

Preparedness for Mechanized Agriculture and Smart Agri Techniques

To promote mechanization in the agriculture sector, the government has launched various initiatives for the adoption of advanced approaches. The **Special Investment Facilitation Council (SIFC)** has undertaken significant initiatives to modernize Pakistan's agricultural sector, focusing on both **mechanized** and **smart agriculture** practices. A notable endeavor is the **Green Pakistan Initiative**, which aims to enhance agricultural productivity through the adoption of **precision agriculture** techniques. This initiative seeks to improve crop yields by utilizing advanced technologies, thereby reducing labor time and ensuring efficient management of fertilizers and irrigation processes. The overarching goals include eliminating malnutrition, reducing food imports, and increasing exports. (Pakistan, 2024)

In addition to the Green Pakistan Initiative, SIFC has launched the **Land Information and Management System (LIMS)**, a

comprehensive project designed to revolutionize agriculture through modern techniques. LIMS consolidates data on land, crops, weather, water resources, and pest control, providing farmers with real-time information to make informed decisions. This integrated approach leverages modern technology on underutilized and low-yielding agricultural lands, aiming to attract significant foreign investment and enhance food security. (Malik, 2024)

Competitiveness of Mechanized Agriculture and Smart Agriculture Techniques

Pakistan is significantly behind in the **competitiveness** of **mechanized** and **smart agriculture** techniques when compared to other nations. While large-scale farms in Punjab and Sindh have increasingly adopted mechanized tools like tractors, harvesters, and irrigation systems, many smaller farms, especially in Khyber Pakhtunkhwa and Baluchistan, continue to rely on traditional farming methods due to financial constraints and fragmented landholdings. **Smart agriculture** techniques, including **precision farming** and **IoT-based tools**, are still in the early stages of adoption in Pakistan, with limited use mainly by larger, resource-rich farms. Despite the potential of these technologies to optimize resource use and boost productivity, the country lags in integrating these innovations on a broader scale due to high upfront costs, lack of technical expertise, and limited infrastructure. However, there is a strong desire among farmers and policymakers to enhance agricultural productivity and competitiveness. This desire to be more successful has driven initiatives like government subsidies, private sector investments, and public-private partnerships aimed at bridging the technology gap. For Pakistan to catch up and become more competitive, significant investment in technology, infrastructure, and farmer education is essential (Ministry of National Food Security and Research, 2020; Zafar et al., 2022).

Contributions of Mechanized Agriculture and Smart Agri Techniques

Mechanized and smart agriculture techniques offer significant contributions to Pakistan's agricultural sector by improving efficiency, productivity, and sustainability. Mechanization, including tractors and harvesters, reduces labor costs and boosts crop yield, particularly in large-scale farms. Meanwhile, **smart agriculture** technologies like **precision farming**, **drones**, and **IoT solutions** help optimize resource use, reduce waste, and increase productivity through real-time data on soil health and crop performance. Few Government initiatives and private sector investments are supporting the adoption of these technologies, paving the way for improved food security, better livelihoods for farmers, and increased competitiveness in global markets (Zafar et al., 2022; Ministry of National Food Security and Research, 2020).

Legal Framework Analysis

These are the policies, rules and regulations etc. which are directly or indirectly related to the agriculture sector but upon vetting it has been learnt that there is no specific mention of the mechanization or adoption of smart agriculture techniques, with exception to the National Food Security Policy 2018, in very few policies there is only mention of technological advancement and innovation, which, if checked on the ground, haven't been able to yield projectable results or path towards the mechanization as well as adoption of smart techniques in the agriculture sector. Further, none of them are stressing on end to end mechanization and smart agriculture techniques. Few policies of the government have been given as under;

1. **National Food Security Policy 2018:** This policy aims to make sure everyone has enough food. It outlines ways to achieve this, like improving farming, keeping food prices stable, and providing support for those in need. In this policy there is mention of mechanization in section 6.1.1 with an attempt to cover the broader area of mechanization but it has not been focusing explicitly on the aspect of smart agriculture

techniques, rather it focuses on adoption of the climate smart technology.

2. **Pakistan Agricultural Research Council (PARC) Ordinance, 1981**: is a law that established PARC as a premier research organization in Pakistan.

3. **Seed Law 1976:** This law ensures that farmers can buy good quality and certified seeds.

4. **Pesticide Ordinance 1971:** This law controls the import, production, sale, and use of pesticides to ensure they are safe.

5. **Food Safety Laws:** Various laws, including the Pure Food Ordinance 1960, set standards for how food is made and sold to protect people from unsafe food.

6. **Water Laws:** Laws related to water management are key to ensuring that farmers have proper access to water.

7. **Environmental Laws:** These laws aim to protect the environment, covering issues like land use and water quality to promote sustainable farming.

8. **Punjab Agriculture Policy 2018:** This policy highlights the need to modernize and improve farming methods in Pakistan.

9. **Seed Amendment Act 2015:** This act allows for the registration and regulation of high-yield, disease-resistant seeds for better farming.

10. **Punjab Agriculture Marketing Regulatory Authority Act 2018:** This act oversees how farm products are sold in Punjab, helping to adopt better farming techniques.

11. **Sindh Agriculture Market Regulatory Authority Act 2019**: Similar to the Punjab act, this law manages the marketing of farm products in Sindh.

12. **Sindh Agriculture Policy 2018-2030:** Primarily focuses on land tax and agricultural income tax amendments, rather than directly addressing agricultural techniques or mechanization.

13. **Khyber Pakhtunkhwa Agricultural and Livestock Produce Markets Act, 2007**. This Act more focusing on to regulate the purchase and sale of agricultural and livestock produce, ensuring fair practices and efficient market operations.

14. **KP Agriculture Policy 2015-2025:** In this policy it is mentioned too that the government will create laws, support partnerships, and promote farm mechanization suited to local needs. It will provide financial and technical help to scale innovations, strengthen supply chains, and build private sector capacity for modern farming.

15. **Baluchistan Agricultural Produce Markets Act, 1991**: This Act is designed to better regulate the purchase and sale of agricultural produce and to establish markets for such produce within the province.

16. **Baluchistan Agriculture Sector Policy and Strategy:** The focus seems to be on water resource management, value addition to crops, and enhancing market linkages, along with promoting collaboration among stakeholders.

Institutional Analysis

Key institutions of the government sector involved in agricultural mechanization which include the Ministry of National Food Security and Research (MNFS&R), provincial agriculture departments, research organizations, and local manufacturers. However, these entities often operate in silos, resulting in inefficiencies and duplication of efforts. Strengthening coordination and fostering collaboration between these stakeholders are critical for achieving policy goals.

The organizations dealing with the issues related to the agricultural sector in Pakistan which includes;

1. **Ministry of National Food Security & Research**: Responsible for formulating policies and strategies for agricultural development.

- **Fault line 1:** Slow implementation of agricultural policies and strategies at the grassroots level. (*Food Security Report*, Ministry of National Food Security & Research, 2023)

  Example: The delayed implementation of the National Water Policy 2018 has resulted in underperformance of irrigation systems at the grassroots level, affecting small-scale farmers.

- **Fault line 2:** Lack of coordination between federal and provincial agricultural departments, affecting unified policy execution. (Agricultural Policy and Governance in Pakistan, Pakistan Institute of Development Economics, 2022.)
  Example: Disjointed efforts between the Ministry of National Food Security & Research and provincial agriculture departments led to ineffective implementation of the *Crops Insurance Scheme* in various provinces.

2. **Special Investment Facilitation Centre:** Drives the advancement of mechanized and smart agriculture in Pakistan by facilitating investments, providing policy support, and developing critical infrastructure like high-efficiency irrigation systems.

- **Fault line 1:** Inadequate follow-up on investments due to bureaucratic delays.
  Reference: (Asian Development Bank, 2023)

  Example: Despite SIFC's efforts to attract foreign investments for smart irrigation systems, delays in project approvals have postponed the roll-out of efficient irrigation systems in Punjab.

- **Fault line 2:** Insufficient focus on the promotion of local agricultural technology innovations in investment schemes. (World Bank, 2023.)

  Example: SIFC's lack of emphasis on local startups has led to an over-reliance on foreign agricultural technology, leaving domestic innovations underfunded.

3. **Research and Development institutions, mainly Agricultural & Biological Engineering Institute (ABEI), NARC, Islamabad under Pakistan Agricultural Research Council (PARC) at Federal level**: Conducts research and development in agriculture, including mechanization and smart agri techniques.

- Fault line 1: Limited collaboration between R&D institutions and the private sector, slowing commercialization of innovations. Reference: "The Role of Agricultural Research and Development in Pakistan," *Pakistan Agricultural Research Council,*2023.

Example: Despite developing innovative mechanized machinery, R&D institutions struggle to partner with manufacturers for large-scale production, limiting the impact of these innovations.

- Fault line 2: Inconsistent funding for long-term research projects, leading to disrupted development cycles. (Agricultural Economics Review, 2023)
- Example: The Bio-engineered Crop Development Project faced funding cuts, resulting in the delay of research on drought-resistant crops.

4. **Agricultural Mechanization Research Institute (AMRI), Multan under Government of Punjab**: Conducting research on agricultural mechanization and technology, developing and testing new agricultural machinery and equipment and improving existing agricultural machinery and equipment.

Fault line 1: Lack of sufficient testing facilities for new machinery prototypes under local environmental conditions. Reference: (Assessment of Agricultural Mechanization in Punjab," Journal of Agricultural Engineering, 2022)

Example: AMRI faced challenges testing the newly developed rice harvester prototypes in various terrains of Punjab, affecting their commercial viability.

Fault line 2: Limited interaction with farmers to understand real-time needs and challenges for developing effective machinery. (International Journal of Agricultural Sustainability, 2023)

Example: The lack of farmer feedback during the testing of a new plowing machine led to low adoption rates, as it failed to meet local farming conditions.

5. **Agricultural Mechanization Research Cell (AMRC)Tandojam under Government of Sindh:** Conducting Research and Development, Testing and Evaluation, Training and Extension, Technology Transfer, Collaboration and Partnerships

- Fault line 1: Inadequate infrastructure for large-scale testing and implementation of new technologies. (Agricultural Technology Adoption and Extension in Sindh, Sindh Agriculture University Journal, 2023)
Example: AMRC struggled to set up adequate testing sites for a newly developed irrigation system in Sindh's varied soil types, delaying the technology's adoption.

- Fault line 2: Insufficient outreach and training programs for small-scale farmers to adopt mechanized solutions. (Challenges in Agricultural Mechanization: A Sindh Perspective," International Food Policy Research Institute, 2023)
Example: The lack of sufficient extension services led to limited adoption of the tractor-based tilling equipment among smallholder farmers in Sindh.

6. **Centre for Agricultural Machinery Industries, Mian Channun under Government of Punjab**: Design and Development, Manufacturing and Fabrication, Training and Capacity Building and Promotion and Marketing

- Fault line 1: Limited financial support for local manufacturers to scale production of high-quality agricultural machinery. (Challenges in Agricultural Machinery Manufacturing in Pakistan, Punjab Industrial Development Board, 2023)

   Example: Local manufacturers faced challenges scaling up production of seeders due to a lack of affordable credit from financial institutions.

- Fault line 2: Challenges in maintaining quality standards and competitiveness against imported machinery. (The Impact of Imported Agricultural Machinery on Local Industries," Pakistan Bureau of Statistics, 2023)
   Example: Locally produced tractors faced stiff competition from cheaper imported models, leading to a loss of market share for domestic manufacturers.

7. **Agricultural Light Engineering Program (ALEP), Mardan**: under Government of Khyber Pakhtunkhwa; agricultural machinery manufacturers, Collaboration and Partnerships, Promotion and Dissemination, Training and Capacity Building etc

- Fault line 1: Limited capacity to meet growing demand for training and capacity building in the agricultural machinery sector. (Agricultural Mechanization and Capacity Building in Khyber Pakhtunkhwa," Government of Khyber Pakhtunkhwa Annual Report, 2023)

Example: ALEP was unable to cater to the growing demand for training on mechanization due to insufficient training facilities and instructors.

- Fault line 2: Inadequate market access for locally produced agricultural machinery to reach a wider national audience. (Market Access for Agricultural Machinery in Pakistan," Khyber Pakhtunkhwa Investment Promotion Agency, 2023)
  Example: Locally manufactured planting equipment faced barriers in accessing larger regional markets due to inadequate marketing and distribution networks.

8. **Financial institutions;** Federal and Provincial autonomous bodies; provincial directorates of agricultural engineering; and, agro-services providers

- Fault line 1: Difficulty in securing low-interest loans for small and medium-sized farmers to invest in modern machinery. (Agricultural Credit and Financing in Pakistan," State Bank of Pakistan Report, 2023)
  Example: Small farmers in rural Punjab were unable to access financing options for modern tractors, limiting their ability to increase productivity.

- Fault line 2: Lack of awareness about available financial products tailored to agriculture-focused investments. (Financing Options for Agricultural Investments in Pakistan," National Bank of Pakistan Report, 2023)
  Example: Many farmers were unaware of government-backed agricultural loan schemes, missing out on financial opportunities for mechanization.

9. **Academia:** Higher Education Commission; Pakistan Engineering Council; University of Arid Agriculture, Rawalpindi; Sindh Agriculture University, Tandojam

- Fault lines 1: Limited integration of practical field experiences into the academic curriculum for agricultural engineering students. Reference: "Improving Agricultural Engineering Education in Pakistan," *Higher Education Commission Report*, 2023.
Example: Agriculture students at the University of Arid Agriculture struggled to find internships with active farming operations, limiting their real-world exposure.

- Fault line 2: Insufficient research funding for innovative agricultural technologies, limiting academic contributions to the sector. (Trends in Agricultural Research Funding in Pakistan," Higher Education Commission Report, 2023)
Example: The Precision Agriculture Research Project at Sindh Agriculture University was delayed multiple times due to lack of dedicated research funding.

Stakeholder Analysis

There is immense potential for adoption of mechanized agriculture and smart agricultural techniques in Pakistan for enhancing productivity, sustainability, and industrial development. However, the success of this transition depends on the active involvement and alignment of key stakeholders, including the government, research institutions, farmers, the private sector, and financial institutions. A thorough stakeholder analysis helps identify the roles, interests, and challenges faced by these entities, particularly in the context of promoting industrial growth through modernized agriculture. Addressing these fault lines is critical to leveraging agricultural innovation as a catalyst for economic transformation in Pakistan.

Government:

Policy-makers, regulatory bodies, and public institutions that can support or hinder the adoption of mechanized agriculture and smart agri techniques through policies, subsidies, and infrastructure development.

- Policy Disconnect: Government policies often prioritize the needs of large-scale farmers over smallholders, leaving many rural farmers without adequate support. (Ali, 2020)

- Lack of Infrastructure Investment: Insufficient government investment in rural infrastructure, such as roads and storage facilities, hampers the adoption of mechanized agriculture in remote areas. (Bashir, 2021)

- Uncontrolled Sprawl of Housing schemes: Now it's a trend of housing schemes on the cultivable land all over the country and this sprawl is increasing day by day which is drastically decreasing the availability of cultivation for cultivation and there is no strict control of the government to protect. (Dawn. (2023).

- Threats to Pakistan's food security from farmland conversion. Retrieved from https://www.dawn.com)

Research Institutions:

Universities, research centers, and organizations that develop and test new agricultural technologies and techniques.

- **Fault line: Technology Relevance:** Research institutions may develop agricultural technologies that are not well-suited to Pakistan's diverse climates, crop types, or local farming practices. This mismatch reduces the chances of successful implementation on the ground.

- **Example**: In 2019, the Pakistan Agricultural Research Council (PARC) introduced a variety of drought-resistant wheat. However, the variety performed poorly in certain regions of Sindh due to the soil conditions, limiting its adoption by farmers. (Iqbal, 2019)

- **Fault line: Slow Adoption of Research Innovations**: There is often a delay in the adoption of innovations from research institutions by farmers. Lack of awareness, training, and trust in new technologies hinders this transition from research to real-world application.

- **Example**: The slow uptake of precision farming technologies, such as soil moisture sensors, is a result of insufficient training programs for farmers, despite their demonstrated effectiveness in improving water use efficiency. (Zaman, 2021)

Farmers:

Beneficiaries of mechanized agriculture and smart agri techniques, which can increase efficiency, reduce labor costs, and improve crop yields.

- **Fault line: High Initial Costs**

- **Explanation**: The initial investment required to adopt mechanized equipment and smart technologies is often too high for smallholder farmers, limiting their ability to access such innovations.

- **Example**: In Punjab, smallholder farmers have expressed concerns over the high upfront cost of acquiring modern machinery such as combine harvesters, which can cost upwards of PKR 1.5 million. This price point is prohibitive for many. (World Bank, 2020)

- **Fault line: Lack of Training and Knowledge:**

- **Explanation**: Farmers often lack the necessary skills and knowledge to operate modern farming equipment, leading to inefficient use of available technologies and machinery.

- **Example**: In Khyber Pakhtunkhwa, farmers who received subsidized drones for crop monitoring found them difficult to use due to inadequate training programs, leading to underutilization of the technology. (Garforth, 2021)

- **Fault line Lack of Farmer Associations:** The absence of strong farmer associations limits farmers' ability to collectively advocate for their needs, access resources, or negotiate better prices for inputs and equipment.

- **Explanation**: Without a unified platform, farmers are often unable to benefit from economies of scale, lobbying for favorable policies, or collective bargaining with suppliers of seeds, machinery, or credit. The fragmentation of farmers' interests makes it difficult to implement policies that address the real issues faced by smallholder farmers.

- **Example**: In the absence of farmer associations, many farmers in Sindh and Baluchistan have struggled to negotiate fair prices for their produce, leading to exploitation by middlemen who offer low rates. This further limits their access to resources like subsidized machinery or training. (Shah, Hussain, 2022)

Private Sector

Companies that manufacture and supply agricultural machinery, technology providers, and input suppliers (e.g., seeds, fertilizers, pesticides).

- **Private Sector: Fault line: Over-Regulation by Government**

- **Explanation**: Over-regulation by the government can create barriers for the private sector in terms of innovation and the development of new agricultural technologies and machinery. Strict rules may lead to delays in introducing new products to the market.

- **Example**: The introduction of precision farming tools such as soil sensors and automated irrigation systems has been delayed in Pakistan due to government approval processes and the lengthy registration of new technologies. (Sullivan, 2021).

- **Fault line: Market Access for Smallholders:** The private sector often prioritizes larger farms with better purchasing power, leaving smallholder farmers with limited access to high-quality machinery and agri-tech solutions.

- **Example:** Companies that manufacture high-tech irrigation systems and smart tractors often focus on larger commercial farms, such as those in Punjab, while smallholder farmers in remote areas face barriers to accessing these technologies. (Patel, 2020)

Financial Institutions:

Banks, microfinance organizations, and other financial institutions that provide loans and other financial services to farmers and agricultural businesses.

- **Fault line: Reluctance to Offer Loans:** Financial institutions are often hesitant to provide loans to farmers for purchasing machinery or adopting smart agri-tech due to the perceived high risk of investment in agriculture.

- **Explanation**: **Example**: In 2020, despite government initiatives to provide subsidized loans to farmers, many smallholders in Sindh struggled to secure financing for purchasing mechanized equipment due to banks' stringent lending policies. (Bock, 2022)

- **Fault line: Unfavorable Loan Terms:** Even when loans are available, the terms are often not favorable for smallholder farmers, with high-interest rates or strict repayment conditions that discourage borrowing for mechanization.

- **Example**: In the 2019 Punjab Tractor Scheme, farmers faced repayment terms that were difficult to meet, especially during drought years when crop yields were low, thus deterring them from adopting mechanized solutions. (Ruthenberg, 2021)

Comparative Analysis

Israel has been chosen for comparison with Pakistan in agricultural mechanization and smart farming techniques due to its remarkable advancements in overcoming resource constraints. Despite having arid conditions and limited arable land, Israel has emerged as a global leader in innovative agricultural practices, leveraging technology to achieve exceptional productivity and sustainability. This makes Israel an ideal benchmark for exploring how modern mechanization and smart farming methods can address challenges such as water scarcity, labor efficiency, and crop yield enhancement issues that Pakistan also faces.

By understanding Israel's best practices, valuable insights can be gained to modernize Pakistan's agriculture sector and unlock its potential.

Difference of mechanized and smart agriculture practices between Pakistan and Israel has been given in the following table on different steps; (Security, 2025), (FAO, 2022), (Waggoner, J. D., & Shklar, A.2023).

Step	Machines Used in Pakistan for Wheat	Machines Used in Pakistan for Rice	Best Practices in Israel for Wheat	Best Practices in Israel for Rice
1. Land Preparation	Tractors & Tine Cultivators	Tractors and Rotary Tiller Cultivator	GPS-guided Tractors, Conservation Tillage, Rotary Cultivators	
2. Sowing	Seed Drills (Cedar, Disc)	Rice Transplanters (Kubota)	High-Efficiency Seed Drills, No-Till Planting (Zero tillage)	Smart Sowing Systems (Drones), Precision Seeders
3. Watering	Water Pumps (Diesel, Submersible), Sprinkler Systems (Center Pivot)	Water Pumps (Diesel, Submersible), Flood Irrigation	Drip Irrigation, Smart Water Management, Automated Irrigation Systems	Automated irrigation system to optimize soil moisture
4. Weeding	Weeding Tools (Manual, Power Weeders)	Power Weeders (Rotary, Walk-Behind), Manual Weeders	Autonomous Weeding Robots, Cover Crops, Biological Pest Control	
5. Fertilization	Fertilizer Spreaders (Broadcast, Pendulum)	Fertilizer Spreaders (Granular), Fertilizer Injectors	Variable Rate Fertilizer, Fertigation, Controlled-Release Fertilizers	
6. Pest and Disease Control	Hand Sprayers, Aerial Sprayers (Drones)	Aerial Sprayers (UAVs, Drones), Hand Sprayers	Integrated Pest Management (IPM), Biological Pest Control, Smart Pest Monitoring (Drones)	
7. Harvesting	Manual Harvesting (Sickle), Combine Harvesters	Manual Harvesting (Sickle), Combine Muddy Harvesters	Smart Harvesters, Robotic Harvesting, AI-Driven Harvest Timing	Smart Harvesters, Robotic Harvesting, Robotic Combine Harvesters

Blavatnik Governance Model

The Blavatnik Index of Public Administration 2024 evaluates public administration effectiveness across 120 countries, offering actionable insights into areas of strength and weakness. For Pakistan, the Index provides a diagnostic tool to identify governance gaps, compare performance with peers, and guide reforms in critical public service sectors.

The Public Administration:

In public administration, mechanization remains an overlooked priority. By integrating it into institutional strategies and leadership, Pakistan can revolutionize its agriculture sector and modernize public operations. Strengthening policymaking processes with a focus on mechanized farming and modern technologies will be instrumental for progress.

Governance:

The Blavatnik Index emphasizes governance through strategic capacity, collaboration, and innovation. Pakistan needs to improve institutional collaboration and adopt anti-corruption measures to rebuild public trust. Mechanization could serve as a key governance reform, driving agricultural modernization and sustainable growth. Incorporating data-driven governance, regulatory frameworks for mechanization, and smart agriculture policies are critical to ensuring effective oversight and resource allocation.
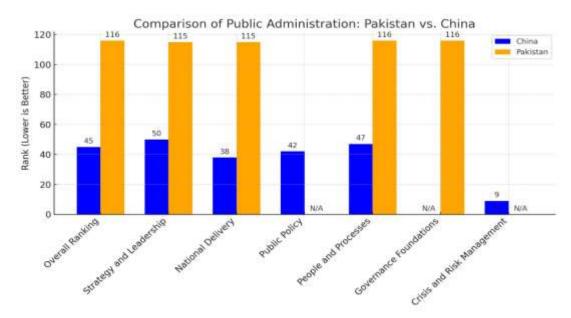
Service Delivery:

Modernizing service delivery is essential for Pakistan's development. Mechanization efforts should focus on timely delivery of subsidized machinery, enhanced digital platforms for farmers, and improved access to resources for mechanized farming. Tax system reforms, efficient social welfare programs like BISP, and workplace technologies can support the integration of mechanization into Pakistan's agricultural and public service sectors, improving overall productivity and efficiency.

Here is a tabulated comparison of **Pakistan** and **China** based on the **Blavatnik Index of Public Administration 2024**. Each aspect includes a reference to support the data.

Aspect	China	Pakistan
Overall Ranking	45th	116th
Strategy and Leadership	Ranked 50th	Ranked 115th
National Delivery	Ranked 38th	Ranked 115th
Public Policy	Ranked 42nd	Not explicitly ranked
People and Processes	Ranked 47th	Ranked 116th
Governance Foundations	Moderately ranked (exact rank not specified)	Ranked 116th
Crisis and Risk Management	Ranked 9th (tied with other countries)	Not ranked in the top tier

For better understanding and illustration, the comparison has been given in the following bar chart

SWOT Analysis

The Pakistan Agricultural Research Council (PARC) is the leading national organization for agricultural research and development in Pakistan. Established under the PARC Ordinance of 1981, it aims to enhance agricultural productivity, ensure food security, and promote sustainable farming practices. With a network of research centers across the country, PARC addresses region-specific challenges and facilitates the adoption of modern agricultural technologies, playing a crucial role in the advancement of Pakistan's agriculture sector. In this Section SWOT analysis of the (Pakistan Agricultural Research Council Ordinance, 1981 (Ordinance No. XXX of 1981)

Detailed analysis has been given in the following table;

Aspect	Details
Strengths	1. **Established Mandate**: The PARC serves as the central authority for agriculture, food security, and allied sectors. 2. **Legal and Institutional Framework**: Pakistan Agriculture Research Council (PARC) Ordinance 1981 that governs the activities of PARC, aiming to coordinate and promote agricultural research in Pakistan. It ensures the development, dissemination, and adoption of new agricultural technologies to improve productivity and sustainability in the sector. 3. **Crisis Management Capability**: Coordinates responses to food security issues during emergencies such as floods and droughts. 4. **International Engagement**: Strong collaboration with organizations like FAO, WFP, and donors for funding and technical assistance.
Weaknesses	1. **Lack of Strategic Vision**: The PARC is not consistently focused on long-term strategies for modernizing agriculture. 2. **Policy Implementation Gaps**: Weak execution due to inadequate resources and interprovincial coordination. 3. **Fragmented Legal Framework**: Overlaps and inconsistencies between federal and provincial laws after the 18th Amendment and it has failed in developing synergy and harmony in this context among the federation and provinces.

	4. **Limited Technological Expertise**: Insufficient adoption of modern technologies in operations and policy enforcement. 5. **Weak Institutional Capacity**: Limited trained personnel and lack of advanced technical resources to support modern agriculture. 6. **Un-Utilization of Imported Machinery:** PARC has received state of the art agriculture machinery costing Rs. 1139 million from China and still no utilization. (List of machinery is attached as Annexure-A)
Opportunities	1. **Policy Reforms**: Opportunity to align policies with modern agricultural practices and international standards. 2. **Digital Transformation**: Scope for adopting technology such as GIS, precision agriculture, and data analytics for policy monitoring and implementation. 3. **Private Sector Collaboration**: Potential for fostering Public-Private Partnerships (PPPs) to enhance agricultural infrastructure and practices. 4. **Global Climate Initiatives**: Access to funding and expertise under climate-focused programs and agreements such as SDGs. 5. **Capacity Building**: Training programs to develop expertise in climate-smart agriculture and mechanization techniques.
Threats	1. **Political Instability**: Frequent changes in leadership and policy priorities disrupt continuity. 2. **Limited Funding:** Insufficient government funding and financial constraints can hinder the council's capacity to undertake large-scale research and development projects in the agricultural sector. 3. **Lack of Infrastructure:** Inadequate infrastructure, including research facilities and modern technologies, can impede the effective implementation of agricultural innovations and research programs.

EETH Analysis

Category	Actionable Points
Enhance	Develop and implement a **National Smart Agriculture Policy** to drive innovation and modernization.
	Expand training programs and research for IoT-based monitoring, AI-driven data analysis, and drone technology.
	Strengthen international partnerships (e.g., FAO, WFP) for funding and technical expertise in smart agriculture.
	Establish robust monitoring mechanisms for assessing the adoption and impact of mechanized and smart agriculture practices.
Eliminate	Address the **absence of a National Smart Agriculture Policy** by prioritizing its formulation and adoption.
	Streamline resource allocation and interprovincial coordination to close policy implementation gaps.
	Reconcile inconsistencies between federal and provincial policies to support smart agriculture.
	Strengthen institutional capacity by recruiting and training professionals in smart agriculture technologies.
Take Advantage	Use the policy gap as an opportunity to establish PARC as a leader in developing a **Smart Agriculture Policy**.
	Leverage technological tools like GIS, AI, and data analytics for policy monitoring and implementation.
	Foster partnerships with the private sector to expand access to smart agriculture technologies.
	Capitalize on climate-focused funding and international programs to introduce adaptive and resilient agricultural practices.
	Organize farmer training programs to enhance awareness and adoption of smart agriculture techniques.
Hedge Against	Advocate bipartisan support to ensure policy continuity despite political changes.
	Diversify funding sources through international donors, climate funds, and private sector investments.
	Invest in climate-smart agriculture to mitigate the effects of extreme weather and changing climate patterns.
	Upgrade research infrastructure to facilitate the adoption of mechanized and smart agriculture practices.
	Address farmer reluctance by providing subsidies, education, and showcasing the benefits of smart agriculture through pilot projects and success stories.

Gap Analysis

The agriculture sector is the primary source of livelihood in Pakistan. It not only contributes substantially to the country's GDP but also ensures food security and supports related industries, making it a cornerstone of Pakistan's socio-economic framework. However, it faces critical gaps that hinder its progress toward modernization and sustainability. The lack of comprehensive policies, limited access to financing, technological shortcomings, and inadequate infrastructure impede the adoption of mechanized and smart agricultural practices. Conducting a gap analysis is essential to identify these challenges and develop targeted solutions that can enhance productivity, foster industrial development, and ensure long-term food security in the country.

Absence of a Comprehensive National Policy

- There is no integrated national policy addressing mechanization and smart agriculture as a cohesive strategy, leading to fragmented efforts and lack of direction.
- Stakeholder engagement in policy-making remains limited, resulting in policies that fail to address the specific needs of diverse farming systems across Pakistan.

Limited Access to Affordable Financing

- Smallholder farmers struggle to access affordable financial products, such as low-interest loans or leasing options, to invest in machinery and smart agriculture tools.
- Financial institutions lack tailored schemes to address the specific requirements of mechanization and smart technologies, further marginalizing resource-poor farmers.

Weak Coordination Between Federal and Provincial Agencies

- Inadequate collaboration between federal and provincial governments leads to inefficient implementation of mechanization and smart agriculture initiatives.
- No established inter-agency frameworks exist to align efforts, creating overlaps and inefficiencies.

Technological Gaps in Mechanization

- Low penetration of mechanized equipment, particularly among smallholder farmers, due to high costs and lack of accessibility in remote areas.
- Limited availability of locally adapted machinery suitable for Pakistan's diverse agro-climatic regions hinders widespread adoption.

Slow Adoption of Smart Agriculture

- Smart agriculture techniques, such as precision farming, IoT, and drones, are not widely adopted due to limited awareness, high costs, and lack of technical expertise.
- Inadequate infrastructure, such as reliable internet and electricity in rural areas, restricts the implementation of technology-driven solutions.

Insufficient Training and Capacity Building

- Farmers, technicians, and operators lack the necessary skills to effectively use and maintain mechanized and smart agriculture technologies.
- Collaboration between agricultural universities, vocational centers, and private companies is weak, limiting the availability of structured training programs.

Lack of Quality Standards for Locally Manufactured Machinery

- Domestically produced agricultural machinery often does not meet durability and efficiency standards, resulting in lower farmer confidence and reduced adoption.
- Limited certification systems and testing facilities fail to ensure compliance with international standards, weakening competitiveness.

Underdeveloped Research and Innovation

- Research on mechanized and smart agriculture is insufficiently tailored to Pakistan's diverse farming conditions, limiting the relevance of innovations.
- Weak public-private partnerships in research and development result in a lack of cost-effective, scalable technologies for smallholder farmers.

Minimal Public-Private Collaboration

- Public-private partnerships to promote affordable and accessible mechanization and smart agriculture solutions for smallholders are underutilized.
- Private sector engagement in developing and distributing modern machinery and technologies remains limited, leading to high costs and reduced availability.

Inadequate Infrastructure for Smart Agriculture

- Poor rural infrastructure, such as unreliable electricity and internet connectivity, prevents the implementation of IoT and precision farming solutions.
- Lack of data-driven platforms and real-time analytics tools limits farmers' ability to make informed decisions.

Ineffective Monitoring and Evaluation Mechanisms

- Mechanisms to monitor and evaluate mechanization and smart agriculture programs are weak or non-existent, hindering the assessment of progress and policy effectiveness.
- Insufficient data collection on machinery usage, smart agriculture adoption, and productivity impacts limits evidence-based decision-making.

Issues and Challenges

Lack of Dedicated Policy on Mechanization and Smart Agriculture Techniques:

Problem: Absence of a robust national policy focusing explicitly on mechanization, with current frameworks addressing only specific items like tractors.

Impact: Fragmented efforts and lack of direction hinder the widespread adoption of advanced farming technologies.

High Costs and Limited Accessibility to Machinery:

Problem: The majority of smallholder farmers cannot afford modern agricultural machinery due to high upfront costs and limited financing options.

Impact: Low adoption of mechanization leads to inefficient farming practices and lower yields.

Fragmented and Small Landholdings

Problem: Small and fragmented farms make it financially unfeasible to invest in machinery or implement large-scale mechanization solutions.

Impact: Limits economies of scale and the efficiency of mechanized tools.

Limited Access to Financing

Problem: Small-scale farmers face significant barriers in obtaining affordable loans to purchase agricultural equipment.

Impact: Mechanization remains limited to large-scale farmers, widening the productivity gap.

Inadequate Capacity Building and Training

Problem: Farmers lack the technical knowledge and skills to use and maintain modern machinery effectively.

Impact: Leads to inefficiencies, reduced productivity, and suboptimal use of resources.

Poor Coordination among Stakeholders

Problem: Weak collaboration between federal and provincial governments, research institutions, and the private sector.

Impact: Reduces the effectiveness of mechanization initiatives and leads to duplication of efforts.

Conclusion

The analysis highlights the need for mechanization and smart agriculture to address Pakistan's low productivity and outdated practices. Bridging policy gaps, fostering collaboration, and adopting advanced technologies are crucial for sustainable growth. Key insights of conclusion is given as under;

The agriculture sector is crucial to Pakistan's economy, contributing significantly to GDP and employment, yet it lags in mechanization and smart agriculture adoption due to fragmented policies, limited infrastructure, and high costs.

Mechanized tools and innovative smart technologies such as IoT and precision farming have immense potential to enhance productivity and sustainability.

The analysis highlights disparities in technology adoption, with large-scale farms benefiting more than smallholders due to financial and resource constraints.

Gaps in institutional coordination and an absence of comprehensive national policies hinder modernization efforts.

Stakeholder collaboration, especially between government, private sector, and research institutions, remains weak, resulting in inefficient implementation and missed opportunities.

Comparative studies emphasize the need for Pakistan to emulate countries like Israel, which have successfully integrated advanced agricultural technologies despite resource limitations.

Legal frameworks and policies addressing mechanization and smart agriculture are insufficient, necessitating reforms to align with global best practices.

SWOT and EETH analyses reveal strategic opportunities in capacity building, public-private partnerships, and leveraging global climate initiatives for funding and expertise.

The integration of modern technologies must be supported through farmer training, infrastructure development, and financial accessibility.

For Pakistan to achieve sustainable growth and industrial development, focused efforts are required to bridge existing gaps, adopt innovation, and ensure equitable resource allocation.

Uncontrolled sprawl of the housing schemes on the agriculture land is alarmingly squeezing the availability of agri land in the country.

Recommendations
Policy:

Agricultural sector is a major contributor to the country's economy. There should be a comprehensive policy for covering all aspects of mechanization and smart agriculture setting aim to modernize farming practices, enhance productivity, and promote sustainable practices.

Ban on Housing schemes on the Agriculture Land:

Implement a robust policy both at Federal and Provincial level to protect agricultural land from being converted into housing societies. To achieve this hallmark of safeguarding agricultural land, stringent zoning regulations may be implemented, protecting designated farming zones from real estate development. A specialized task force may be constituted to monitor land usage, ensuring that unauthorized conversions of agricultural areas are quickly detected and stopped. To promote adherence to these rules, landowners who maintain their properties for agricultural use will be provided with financial incentives like tax reductions or subsidies.

Furthermore, national and provincial public awareness initiatives will be introduced to inform the community about the vital significance of conserving agricultural land for food security and sustainable growth.

Usage of Imported Machinery from China:

The PARC must prioritize the use of the unused machinery imported from China to guarantee optimal resource utilization. This approach can also be implemented through reverse engineering in local industries, particularly in Gujranwala, to create advanced and customized machinery that meets the specific needs of Pakistan.

Public Private Partnership:

The government should implement a Public-Private Partnership (PPP) program to import advanced agricultural machinery. Under this initiative, machinery will be:

Subsidized: Offered at a 20-80% subsidy and the cost of such machinery shall be borne by the govt: and progressive farmers respectively.

Rental Service: These machineries made available through rental basis in each district, allowing small farmers to rent equipment at affordable rates.

Development of Curricula:

Government institutions such as Provincial Agriculture Extension, Agriculture Research, Academia, and NAVTTC will collaboratively design and implement a comprehensive curriculum for training agricultural technicians.

Formers Associations:

Farmer Associations at the District Level for Mechanized a Smart

Agriculture are critical catalysts in transforming traditional farming systems into advanced, efficient, and sustainable agricultural enterprises.

These associations can drive the widespread adoption of cutting-edge mechanized and smart farming technologies, equip farmers with essential skills and knowledge, and establish a robust network that promotes collaboration, resource-sharing, and greater market access. By empowering farmers with the tools, training, and support they need, these associations can unlock the full potential of modern agriculture, boosting productivity, sustainability, and economic resilience.

Log Frame

Goal	Objectives	Activities	Indicators	Costs (PKR)	Responsible Government Departments
Enhance agricultural productivity and sustainability.	Comprehensive policy for mechanization and smart agriculture.	1. Develop policy framework for mechanization and smart agriculture.	Policy document completed and approved.	1,000,000	Ministry of Agriculture
	Protect agricultural land from conversion to housing schemes.	2. Implement zoning regulations and establish a task force for land protection.	Number of unauthorized conversions detected/stopped.	500,000	Ministry of Housing and Urban Development, Provincial Agriculture Departments, Local Governments
		3. Launch public awareness campaigns on the importance of agricultural land conservation.	Community awareness levels (pre- and post-campaign).	1,500,000	Ministry of Information, Ministry of Agriculture
	Promote optimal utilization of imported machinery from China.	4. Assess unused machinery and implement reverse engineering initiatives in local industries.	Number of machinery items optimized/engineered.	2,000,000	Pakistan Agricultural Research Council (PARC
	Facilitate access to advanced agricultural machinery through PPP.	5. Establish PPP program for importing machinery with subsidies and rental services.	Number of farmers accessing subsidized machinery.	10,000,000	Ministry of Agriculture, Ministry of Finance
		6. Create rental service for machinery in each district.	Utilization rates of rental machinery.	4,000,000	Provincial Agriculture Departments
	Develop comprehensive	7. Collaborate with	Number of trained technicians and	1,000,000	National Vocational

	curricula for training agricultural technicians.	institutions to design and implement training programs.	curricula developed.		and Technical Training Commission (NAVTTC), Ministry of Education
	Strengthen Farmer Associations for mechanized and smart agriculture.	8. Support the formation and development of farmer associations at the district level.	Number of associations established and active.	2,000,000	Provincial Agriculture Departments, Ministry of Agriculture
			Total Estimated Costs:	PKR 22,000,000	

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