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Report of Policy Lab on Bridging Gaps in Implementation of Industrial & Economic Development Strategies in Pakistan

پاکستان میں اقتصادی اور صنعتی ترقی
کے عمل میں حائل رکاوٹوں کا خاتمہ

Policy Analysis & Recommendations- Part-7 of 11

Bridging Policy & Implementation Gaps for Mechanising Agriculture and Smart Agri Practices

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Bridging Gaps in Agriculture Mechanization and Smart Agricultural Policies and Implementation Strategies in Pakistan

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PREFACE

Public policy design, implementation, and evaluation are intricate processes that require a holistic approach to address the multi-faceted challenges of governance, economic development, and industrial transformation. The interplay of theoretical understanding, political economy dynamics, stakeholder engagement, and evidence-based decision-making is essential for crafting impactful policies. The concept of the Policy Lab emerges as a vital tool to address these complexities. Globally, renowned universities and government entities, particularly in the EU and North America, have adopted Policy Labs as platforms for analyzing public policies, their implementation mechanisms, and resultant impacts.

Policy Labs aim to bridge the critical gaps in communication, collaboration, and coordination among academia, policy practitioners, and stakeholders. They serve as incubators for innovative ideas, allowing for rigorous pre-policy analysis, mid-term critical reviews, and post-policy evaluations. By simulating real-world challenges in a controlled environment, Policy Labs foster evidence-based policy-making processes that are both practical and adaptable to dynamic socio-economic contexts.

The National School of Public Policy (NSPP) in Pakistan, through its Policy Simulation Exercises (PSE) at its training units such as the National Institute of Management (NIM), has embraced the concept of Policy Labs. These exercises are designed to mimic the global trends of Policy Labs, creating a focused research environment where government officers from diverse academic and professional backgrounds engage with ground realities. The outcomes of these simulations offer actionable insights and policy recommendations for government entities, enhancing their operational effectiveness and societal impact.

In January 2025, NIPA, Peshawar organized a comprehensive Policy Lab designed and supervised by Dr. Muqeem Islam Soharwardy, Chief Instructor, NIPA Peshawar, addressing 11 critical dimensions of policy design, implementation, and facilitation to support economic and industrial development in Pakistan. These dimensions included:

1. Bridging Gaps in Industrial Policy Design and Facilitation at the National Level
2. Bridging Gaps in SEZ Policies and Implementation: A Case Study of Rashakai SEZ
3. Bridging Gaps in TVET Policies and Practices: Evaluating Their Impact on Employment and Industry in Pakistan
4. Bridging Gaps in IT Export and Freelancing Policies: Analyzing Economic Impacts on Pakistan
5. Bridging Gaps in Automobiles and Transportation Industry Policies: A Critical Evaluation for Industrial Development in Pakistan
6. Bridging Gaps in Labour Policies, Regulations, and Welfare Practices: Implications for Industrial Development and Social Protection in Pakistan
7. Bridging Gaps in Mechanized Agriculture and Smart Agricultural Techniques: Exploring Their Potential for Industrial Development in Pakistan
8. Bridging Gaps in Policies for High-Tech and Innovative Industries: Lessons from China’s Reverse Engineering Strategies for Pakistan
9. Bridging Gaps in the Textile Sector of Pakistan: A Critical Analysis and Way Forward

10. Bridging Gaps in Policies and Practices for the Export Sector of Pakistan: An Evaluation for Enhanced Global Competitiveness
11. Bridging Gaps in Energy, POL, Gas/LNG Policies and Strategies: Supporting Industrial Development in Pakistan

The Policy Lab highlighted the urgent need to address fragmentation in policy design and implementation, emphasizing the critical role of integrated planning, stakeholder collaboration, and the use of advanced tools like Input-Output Models. For example, the session on high-tech industries demonstrated how Pakistan could benefit from reverse engineering strategies, as successfully implemented by China, to develop its industrial base. Similarly, the focus on SEZ policies and Rashakai SEZ showcased the potential of targeted interventions to optimize economic zones for industrial growth.

This initiative underscores the importance of fostering collaboration between academia and policy practitioners. Universities in Pakistan are encouraged to establish Policy Labs to complement government efforts and contribute to evidence-based policy research. Such partnerships can pave the way for a prosperous and industrially developed Pakistan, where robust policies drive sustainable economic growth and social progress.

The lessons drawn from these exercises are not only relevant for Pakistan but also hold universal applicability for nations seeking to bridge gaps in policy design, implementation, and facilitation. The NSPP's Policy Simulation Exercise sets a precedent for how structured, collaborative efforts can generate innovative solutions to complex developmental challenges, making it a cornerstone for future policy reforms.

This report in your hands addresses only the first topic: Bridging Gaps in Agriculture Mechanization and Smart Agricultural Policies and Implementation Strategies in Pakistan. The remaining topics have been analyzed and documented in separate reports, crafted individually to provide in-depth insights and actionable recommendations specific to each area.

It is hoped that this document will serve as a significant milestone in the design, implementation, and facilitation of policies, paving the way for broader economic and industrial transformation in Pakistan, انشاءاللہ .

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EXECUTIVE SUMMARY

The report explores the potential and prospects of mechanized agriculture and smart agricultural techniques as drivers of productivity, sustainability, and industrial development in Pakistan. With agriculture contributing 23% to GDP and employing 38% of the labor force, its modernization is critical to addressing challenges like low productivity and inefficient practices. The analysis emphasizes the importance of adopting innovative technologies and implementing cohesive policies to unlock the sector's potential.

Pakistan's agriculture sector plays a pivotal role in the economy, yet it struggles with outdated practices and limited mechanization. Mechanized tools and smart agriculture technologies, such as IoT and precision farming, can transform farming practices, reduce costs, and enhance yields. However, barriers such as fragmented landholdings, high costs, and limited access to financing hinder progress.

Agricultural development in Pakistan has evolved through several phases: Post-Independence Era (1947-1960), which focused on food security and land reforms; the Green Revolution (1960s-1970s), which introduced high-yield seeds, chemical fertilizers, and expanded irrigation; Mechanization Initiatives (1980s-1990s), which promoted tractors, threshers, and irrigation systems; Modernization and Globalization (2000s-2010s), which shifted toward sustainable practices and biotechnology; and Recent Developments (2020-Present), emphasizing climate-resilient agriculture and digital solutions.

The report employs multiple analytical frameworks, including situational analysis, which highlights the uneven adoption of mechanization and smart technologies across regions; stakeholder analysis, which identifies key players such as government, research institutions, farmers, private sector, and financial institutions while noting weak coordination; SWOT analysis, which points out strengths like a large agricultural base and international collaboration, weaknesses like fragmented policies, opportunities in public-private partnerships, and threats from political instability; and gap analysis, which reveals critical gaps in policy, infrastructure, and farmer training, limiting the adoption of advanced technologies.

Key challenges include the lack of a comprehensive national policy on mechanization and smart agriculture, high costs of machinery and limited financing options for small farmers, inadequate infrastructure and fragmented landholdings, insufficient training programs and technical support, and weak coordination among federal and provincial stakeholders.

Mechanized and smart agricultural techniques offer transformative potential for Pakistan's agriculture sector. However, existing gaps in policies, infrastructure, and collaboration must be addressed to achieve sustainable growth and industrial development.

The report proposes actionable recommendations: develop a cohesive national policy focused on mechanization and smart agriculture, invest in rural infrastructure including electricity, internet, and storage facilities, provide low-interest loans and subsidies to make technologies affordable for smallholders, promote public-private partnerships to facilitate access to advanced equipment, launch extensive training programs to build farmers' capacity, and leverage underutilized imported machinery while promoting local manufacturing through reverse engineering.

A detailed log frame outlines the strategic objectives, activities, timelines, and key performance indicators for implementing the proposed initiatives. This structured approach ensures measurable progress and accountability in transforming the agriculture sector.

Mechanization and smart agriculture are vital for transforming Pakistan's agricultural sector, enabling higher productivity, sustainability, and profitability. Agriculture plays a significant role in Pakistan's economy, contributing substantially to GDP, employment, and exports. However, there is a pressing need to improve its efficiency through mechanization and the adoption of modern technologies to ensure that the sector remains competitive and resilient in a rapidly changing global market.

1. Importance of Mechanization in Agriculture

Mechanization involves using machinery to carry out agricultural tasks that were traditionally done by hand or animal labor. The importance of mechanization in Pakistan's agricultural sector can be understood through the following points:

- **Increased Productivity:** Mechanization leads to faster and more efficient planting, harvesting, and processing of crops. This is particularly crucial for a country like Pakistan, where a large agricultural base is facing increasing labor shortages and rising wages.
- **Cost-Effectiveness:** Mechanized farming reduces the dependence on manual labor, providing cost savings in an economy where labor costs are steadily increasing. This is vital for maintaining competitiveness in both domestic and international markets.
- **Consistency and Precision:** Machines offer greater precision in applying fertilizers, pesticides, and irrigation, resulting in more consistent crop yields and

reducing waste. Precision farming is particularly important for high-value crops that require specific growth conditions.

- **Increased Scale:** Mechanization facilitates large-scale farming, which is essential for achieving economies of scale. This is particularly beneficial for large landholders, allowing them to operate more efficiently and sustainably.

2. Dimensions of Smart Agriculture

Smart agriculture integrates digital technologies, data-driven decision-making, and automation to optimize farming practices. Key dimensions of smart agriculture include:

- **Precision Agriculture:** The use of GPS, Internet of Things (IoT) devices, and remote sensing technologies helps monitor soil health, crop growth, and water usage. This allows for more accurate farming decisions and resource allocation.
- **Data-Driven Decision Making:** Smart farming leverages big data and artificial intelligence (AI) to make informed decisions regarding irrigation, pest management, crop rotation, and market trends. This optimizes farm management and ensures greater productivity.
- **Sustainable Practices:** Smart agriculture promotes environmentally friendly farming practices by improving resource management, reducing pesticide use, and enhancing water conservation methods.
- **Integration of Renewable Energy:** The integration of solar and wind energy in farming operations reduces dependency on traditional energy sources, providing a more sustainable and cost-effective alternative for farmers.

Recommendations for Mechanization and Smart Agriculture

1. **Expanding Mechanization and Smart Agriculture in Pakistan: Leveraging Innovation and Reverse Engineering for Local Adaptation**

In the context of Pakistan, agriculture remains the backbone of the economy, contributing significantly to GDP, employment, and exports. Despite its centrality, the sector faces numerous challenges related to productivity, sustainability, and outdated farming practices. Mechanization and smart agriculture are poised to address these issues, but adapting modern technologies to local needs is essential for long-term success. One potential solution lies in leveraging **smart reverse engineering** to replicate and adapt advanced agricultural machinery from countries like China, the United States, Israel, and India, tailoring these machines to local conditions without incurring prohibitive costs.

The Role of Reverse Engineering in Mechanization

Reverse engineering refers to the process of deconstructing existing machinery to understand its components, functionalities, and design, which allows for its reproduction or adaptation to local needs. This process can benefit Pakistan by allowing the country to replicate machinery from global leaders in agricultural technology, making it more affordable and suited to Pakistan's unique agricultural environment. Below, we explore how smart reverse engineering, combined with local manufacturing capabilities, can benefit Pakistan by enhancing productivity and lowering costs.

Case Study: Innovation and Technological Advancements from Global Leaders

1. **China**:
   - **Innovation in Cost-Effective Machinery**: China has made significant strides in creating cost-effective agricultural machinery for small-scale and large-scale farmers alike. Chinese agricultural technology is known for its affordability and high efficiency, catering to the needs of countries with large agricultural sectors like Pakistan. By reverse engineering Chinese machinery, Pakistan can adapt this technology for local soil types, crops, and climatic conditions. With large-scale manufacturing capabilities in cities like **Gujranwala** and **Faisalabad**, Pakistan can develop advanced machinery suited to local requirements, increasing productivity and reducing dependence on imported equipment.
   - **Cost Savings**: Reverse engineering Chinese machines will cut down on the high costs of importing these machines, making them more accessible to Pakistani farmers, especially smallholders who traditionally lack access to modern farming tools.
2. **United States**:
   - **High-Precision Farming Equipment**: The United States is a global leader in the development of high-precision farming equipment, particularly machinery for precision planting, irrigation, and harvesting. By reverse engineering U.S.-developed equipment, Pakistan can replicate these technologies on a local scale, using Pakistan's own resources and knowledge to reduce costs. Additionally, Pakistani engineers can innovate on the existing designs, improving them to suit the specific challenges faced by the country, such as erratic weather patterns and water scarcity.
   - **Data-Driven Agricultural Solutions**: U.S. companies have also pioneered the integration of **Internet of Things (IoT)** and **Artificial Intelligence (AI)** into agricultural machinery, enabling real-time data collection and analysis. Pakistan can adopt and adapt these systems to

optimize water usage, fertilizer application, and pest control. This would not only increase yields but also promote more sustainable farming practices in Pakistan, especially in the face of mounting water scarcity.

3. **Israel**:
   - **Water-Efficient Machinery**: Israel has long been a leader in developing technologies that address water scarcity, a critical challenge for Pakistan. Israeli innovations in drip irrigation and water-efficient crop management technologies have transformed agriculture in arid regions. By reverse engineering Israeli irrigation technologies, Pakistan can develop locally tailored, cost-effective systems to manage its scarce water resources more efficiently. Localizing these systems can provide significant water savings, leading to more sustainable agricultural practices.
   - **Desert Farming Technologies**: In addition to irrigation systems, Israel has also developed technologies for farming in arid and semi-arid regions, making agriculture viable even in regions with limited rainfall. By adapting these technologies to Pakistan's agricultural landscape, particularly in arid regions like Sindh and Balochistan, Pakistan can increase the productivity of areas previously deemed unsuitable for conventional farming.
4. **India**:
   - **Adapting Affordable Technologies for Small Farmers**: India has seen a surge in innovations designed to address the challenges faced by smallholder farmers. By reverse engineering Indian agricultural machinery, Pakistan can access affordable, simple-to-use machinery tailored to smaller landholdings. India's success in promoting **micro-irrigation systems**, **small-scale tractors**, and **manual equipment** can be replicated and scaled in Pakistan, enabling greater mechanization at the grassroots level.
   - **Mechanized Harvesting Solutions**: India has also focused on developing cost-effective, **low-maintenance mechanized harvesters** for various crops, including rice and wheat. Replicating these solutions through smart reverse engineering can lead to significant time and labor savings, reducing the dependency on manual labor, which is becoming increasingly scarce and expensive in Pakistan.

Leveraging Reverse Engineering for Local Adaptation and Affordability

Through reverse engineering, Pakistan can achieve the following key outcomes:

1. **Cost Reduction**: Importing advanced machinery can be prohibitively expensive due to high customs duties and shipping costs. By reverse engineering existing

models from China, the U.S., Israel, and India, Pakistan can reduce costs, making advanced agricultural technologies affordable for farmers across the country. This can be especially beneficial for smallholder farmers who otherwise may not have access to mechanization due to financial constraints.
2. **Local Adaptation**: Reverse engineering enables Pakistan to modify machinery to suit the local agricultural context. Pakistan has diverse farming conditions, from flood-prone areas in Punjab to dryland farming in Balochistan, and adapting machinery to these conditions is crucial. By using reverse engineering, Pakistan can tailor equipment for local soil types, weather patterns, and crop varieties, enhancing both efficiency and sustainability.
3. **Boosting Local Manufacturing**: Reverse engineering allows Pakistan to develop a robust domestic manufacturing industry focused on agricultural machinery. By collaborating with local engineering firms and technical institutes, Pakistan can build a sustainable ecosystem of machinery production, creating jobs, supporting small and medium enterprises (SMEs), and strengthening its industrial base. The **Gujranwala Industrial Estate**, for example, could become a hub for manufacturing customized agricultural machinery, benefiting both the agricultural sector and the local economy.
4. **Incentivizing Innovation**: As local manufacturers gain experience in reverse engineering and adapt technologies to local needs, they will also be encouraged to innovate. With the right investment in research and development (R&D), Pakistan can develop its own unique agricultural technologies that could be exported to other countries with similar agricultural challenges.

Key Recommendations for Implementing Smart Reverse Engineering

1. **Develop Strong Policy Frameworks**: The government of Pakistan should create policies that support the development of local agricultural machinery through reverse engineering. This could include offering subsidies or tax incentives for companies engaged in the production of locally adapted machinery. Additionally, creating a **National Machinery Innovation Fund** could provide seed funding for small and medium-sized enterprises (SMEs) involved in reverse engineering and manufacturing.
2. **Public-Private Partnerships (PPP)**: The government should foster PPPs to facilitate the import and local adaptation of advanced machinery. This could include joint ventures between Pakistani companies and global machinery manufacturers, ensuring the sharing of technology and expertise. For instance, working with Chinese or Indian manufacturers to set up local assembly lines would lower costs and ensure that machines are produced in-country.
3. **Invest in Skill Development**: Reverse engineering requires a skilled workforce capable of understanding and adapting foreign designs. Pakistan should invest in technical education and training programs for engineers, technicians, and

farmers to develop the necessary skills for machinery adaptation and operation. Technical institutes like **NAVTTC** and universities specializing in agricultural engineering could play a vital role in providing this training.

4. **Strengthen Infrastructure**: For reverse engineering to be successful, Pakistan must invest in the infrastructure needed for machinery production and testing. This includes improving power supply, road networks, and internet connectivity to rural areas, which would facilitate the widespread adoption of mechanization.
5. **Collaborate with International Experts**: To successfully replicate and adapt advanced machinery, Pakistan should collaborate with international experts from countries like China, the U.S., Israel, and India. This could include setting up joint R&D centers and innovation hubs that focus on creating solutions for local agricultural challenges.

- By harnessing the potential of **smart reverse engineering**, Pakistan can make significant strides in mechanizing its agricultural sector, addressing the challenges of low productivity, outdated farming practices, and resource inefficiency. Through strategic partnerships, local manufacturing, and adaptation of global innovations, Pakistan can ensure that its farmers, both small and large, have access to affordable, efficient, and sustainable agricultural machinery. By embracing reverse engineering as a key enabler of innovation, Pakistan can transform its agricultural landscape, increase productivity, and improve food security for future generations.

- **Skill Development and Innovation:** Technical institutes and universities should be encouraged to engage in reverse engineering and research and development (R&D) of agricultural machinery. This would help build a skilled labor force capable of sustaining the initiative and fostering innovation in the sector.

2. Large-Scale Farming with High-Yield Practices

Mechanization plays a key role in enabling large-scale, high-yield farming, which is essential for improving food production and meeting the growing demand for agricultural products. Key recommendations include:

- **Land Consolidation:** Encouraging land consolidation can increase farm size, making it easier to adopt mechanized practices. Supporting cooperatives and community farming initiatives will allow smaller farmers to access machinery and resources.
- **Access to High-Yielding Varieties:** Developing and promoting high-yielding crop varieties can significantly increase food production, especially when combined with mechanized farming techniques.

- **Agri-Tech Investments:** Both public and private investments in agri-tech startups can lead to the development of innovative farming technologies that increase yield per hectare and optimize resource use.

Relationship Between Community and Corporate Farming in Pakistan

Both community farming (smallholder farming) and corporate farming play crucial roles in Pakistan's agricultural sector. A balanced approach that integrates both models can help address challenges and drive innovation.

- **Community Farming:** Smallholder farmers make up the majority of Pakistan's agricultural producers. However, they face challenges like limited access to modern machinery, poor credit access, and outdated farming practices. Mechanization and smart agriculture can significantly enhance their productivity and improve their livelihoods.
- **Corporate Farming:** Large-scale commercial farms have the advantage of economies of scale, making it easier for them to adopt mechanization and modern technologies. They can also serve as demonstration hubs, showcasing the benefits of mechanization to smaller farmers.

The challenge lies in bridging the gap between these two models. By fostering cooperation between community and corporate farming, both can benefit from mechanization and smart agricultural practices.

Key Issues and Challenges

Despite the potential benefits of mechanization and smart agriculture, several challenges hinder their widespread adoption in Pakistan:

1. **High Initial Cost of Machinery:** Even locally produced machinery can be expensive for smallholders. Financial support, subsidies, or easy financing options are necessary to make machinery affordable.
2. **Lack of Infrastructure:** Poor rural infrastructure, including roads and electricity, limits the reach of mechanized farming technologies.
3. **Inadequate Training:** Many farmers lack the technical knowledge to operate modern machinery effectively. Capacity-building programs are needed to address this gap.
4. **Land Fragmentation:** Smallholder farmers often have fragmented land holdings, which makes mechanization more challenging. Land consolidation efforts are essential.
5. **Water Scarcity:** Efficient water management is critical, and smart irrigation technologies need to be promoted to address Pakistan's water scarcity issues.

6. **Resistance to Change:** Cultural practices and traditional farming methods often make farmers hesitant to adopt new technologies.

Recommendations to Overcome Challenges

To address these challenges, the following measures are recommended:

1. **Government Support for Mechanization:** The government should provide subsidies or low-interest loans to enable farmers to purchase machinery.
2. **Infrastructure Development:** Improved rural infrastructure, including roads, electricity, and internet connectivity, is crucial for the success of mechanization and smart agriculture.
3. **Capacity-Building Initiatives:** Training programs should be designed to teach farmers how to use new machinery and technologies. Extension services can play a vital role in this effort.
4. **Support for Smallholder Farmers:** Farmer cooperatives or groups should be formed to pool resources and share machinery, making mechanization more accessible.
5. **Research and Development:** Public and private institutions should invest in R&D to develop machinery and high-yielding crop varieties suited to local conditions.
6. **Water Management Technologies:** Introducing smart irrigation technologies, such as drip irrigation and automated sprinklers, will improve water efficiency and help manage scarce water resources.

Mechanization and the adoption of smart agriculture are essential for enhancing Pakistan's agricultural productivity and ensuring food security. By focusing on local production of machinery through reverse engineering, promoting large-scale farming, and embracing high-yield practices, Pakistan’s agricultural sector can significantly improve. Bridging the gap between community and corporate farming models, supporting capacity-building initiatives, and addressing infrastructure and financial constraints are key to overcoming challenges and unlocking the full potential of the sector.

To achieve sustainable agricultural growth, Pakistan must prioritize policy reforms, increase investments in innovation, and promote a coordinated approach across all stakeholders, including the government, private sector, and research institutions.

Contents

1. 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.**Historical Analysis**

5.1 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)

5.2 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)

5.3 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

5.4 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.

5.5 Modernization and Globalization Era (2000s-2010s)

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

Key Events:

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

5.6 Recent Developments (2020-Present)

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

Key Events:

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

6 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;

6.1 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).

6.2 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).

6.3 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)

6.4 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).

6.5 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).

7 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.

9 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.

9.1 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)

9.2 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)

9.3 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)

9.4 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)

9.5 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).

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

11. 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.

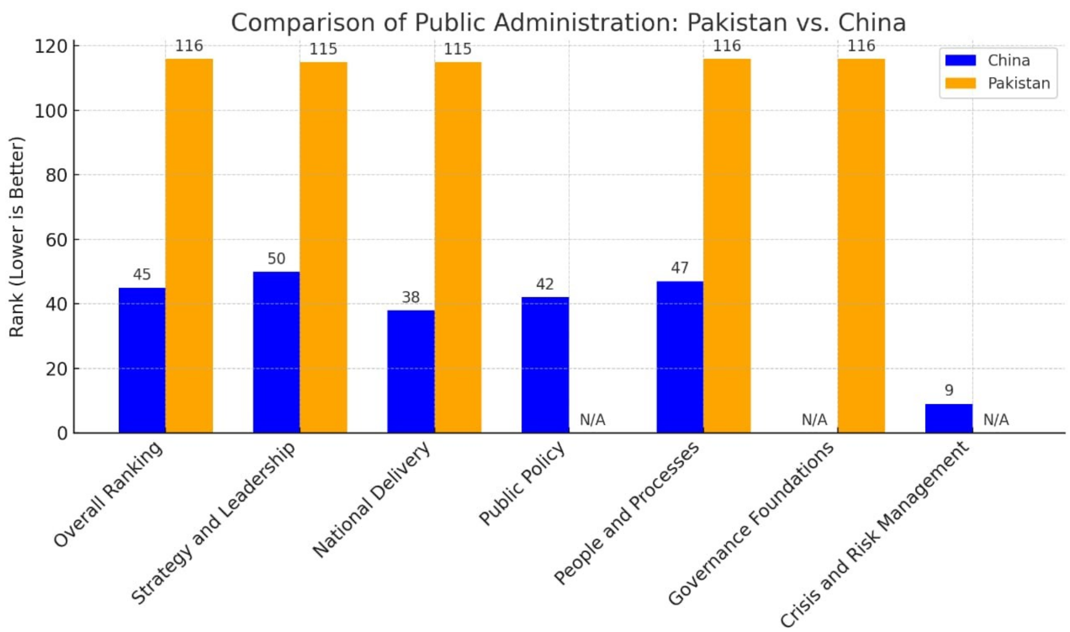
Service Delivery:

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



12. 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 have 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.

13. EETH Analysis

The EETH Analysis identifies areas where PARC can enhance its strengths, eliminate weaknesses, capitalize on emerging opportunities, and hedge against potential threats, enabling it to better fulfill its mandate and contribute to sustainable agricultural development.

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.

14. 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.

1. **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.
2. **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.
3. **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.
4. **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.
5. **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.

6. **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.
7. **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.
8. **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.
9. **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.
10. **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.

11. **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.

15. Issues and Challenges

15.1 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.

15.2 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.

15.3 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.

15.4 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.

15.5 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.

15.6 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.

16. 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;

1. 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.
2. Mechanized tools and innovative smart technologies such as IoT and precision farming have immense potential to enhance productivity and sustainability.
3. The analysis highlights disparities in technology adoption, with large-scale farms benefiting more than smallholders due to financial and resource constraints.
4. Gaps in institutional coordination and an absence of comprehensive national policies hinder modernization efforts.
5. Stakeholder collaboration, especially between government, private sector, and research institutions, remains weak, resulting in inefficient implementation and missed opportunities.
6. Comparative studies emphasize the need for Pakistan to emulate countries like Israel, which have successfully integrated advanced agricultural technologies despite resource limitations.
7. Legal frameworks and policies addressing mechanization and smart agriculture are insufficient, necessitating reforms to align with global best practices.
8. SWOT and EETH analyses reveal strategic opportunities in capacity building, public-private partnerships, and leveraging global climate initiatives for funding and expertise.
9. The integration of modern technologies must be supported through farmer training, infrastructure development, and financial accessibility.
10. For Pakistan to achieve sustainable growth and industrial development, focused efforts are required to bridge existing gaps, adopt innovation, and ensure equitable resource allocation.
11. Uncontrolled sprawl of the housing schemes on the agriculture land is alarmingly squeezing the availability of agri land in the country.

17. Recommendations and Way Forward

17.1 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.

17.2 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.

17.3 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.

17.4 Public Private Partnership:

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

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

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

17.5 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.

17.6 Formers Associations:

Farmer Associations at the District Level for Mechanized and 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.

18. 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 curricula for training agricultural technicians.	7. Collaborate with institutions to design and implement training programs.	Number of trained technicians and curricula developed.	1,000,000	National Vocational 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	

19. References

1. Ministry of Finance. (2024). Pakistan economic survey: Agriculture. Retrieved from https://finance.gov.pk/survey/chapter_24/2_agriculture.pdf
2. Jahangir's World Times. (n.d.). A brief review of land reforms in Pakistan. Retrieved from [website URL, if available].
3. (n.d.). The green revolution and the gene revolution in Pakistan: Policy implications. Retrieved from [PDF URL, if available].
4. Zubair, S. F. (2010). Sustainable agriculture in Pakistan.
5. Khan, A. M. (2021). Agriculture and climate change in Pakistan: Impact and policy responses.
6. Bhatti, H. A. (2022). Digital agriculture in Pakistan: Opportunities and challenges.
7. Ahmed, N., & Mustafa, M. (2017). Challenges in adopting modern agricultural technology in Pakistan. Journal of Agriculture and Technology, 12(3), 45–58.
8. Ali, R. (2011). Agricultural mechanization in Pakistan: Current trends and future directions. Pakistan Agricultural Journal, 34(2), 21–28.
9. Khan, A., Farooq, U., & Mahmood, K. (2019). Infrastructure limitations and agricultural development in rural Pakistan. Rural Development Review, 16(4), 67–85.
10. Ministry of National Food Security and Research. (2020). Annual report on agriculture mechanization. Islamabad, Pakistan.
11. Pakistan Bureau of Statistics. (2021). Agricultural census of Pakistan 2021. Islamabad: Government of Pakistan.
12. World Bank. (2021). Transforming agriculture in South Asia: Challenges and solutions. Washington, DC: World Bank Publications.
13. Zafar, S., Ahmed, F., & Javed, M. (2022). Advancing precision agriculture in Pakistan: Opportunities and challenges. Journal of Agronomy and Crop Science, 15(1), 34–49.
14. Crop2x. (n.d.). Smart agriculture: Nurturing the future of Pakistan. Retrieved from https://crop2x.com/smart-agriculture-nurturing-the-future-of-pakistan

15. Pakistan Bureau of Statistics. (2021). Agricultural census report. Islamabad: Government of Pakistan.
16. Ministry of National Food Security and Research. (2020). Farm mechanization and smart agriculture initiatives in Pakistan. Islamabad, Pakistan.
17. Zafar, A., Ali, S., & Shah, R. (2022). Technological innovations in agriculture: A path toward sustainability in Pakistan. Journal of Agricultural Research.
18. Pakistan Development Review. (1994). Women in agriculture in Pakistan: The role of agricultural policies.
19. Pakistan Agricultural Research Council. (1997). The role of biotechnology in Pakistan's agriculture.
20. Pakistan Agricultural Research Council Ordinance. (1981). Ordinance No. XXX of 1981.
21. Ali, A., & Byerlee, D. (2020). Agricultural policy and mechanization: Addressing regional gaps. Pakistan Journal of Agriculture Studies.
22. Bashir, A., & Zulfiqar, S. (2021). Infrastructure development and its role in agricultural modernization in rural Pakistan. Journal of Rural Development.
23. Iqbal, M., & Ahmad, M. (2019). Research and innovation gaps in agricultural technologies. Journal of Agricultural Research and Technology.
24. World Bank. (2020). Financial accessibility and mechanization in South Asia: The case of Pakistan's smallholder farmers. Washington, DC: World Bank Publications.
25. Garforth, C., et al. (2021). The role of extension services in enhancing technology adoption in agriculture. Agricultural Innovation Journal.
26. Shah, I. A., & Hussain, M. (2022). Farmer associations and the promotion of agricultural innovation in Pakistan. International Journal of Rural Development and Policy.
27. Sullivan, M. E. (2021). Regulatory challenges for agricultural innovation in Pakistan. South Asian Business and Technology Review.
28. Raza, H., & Patel, S. (2020). Mechanization and market access for smallholder farmers in Pakistan. Journal of Agricultural Economics.

29. Bock, B. B., & Noske, K. (2022). Financial access and mechanization in rural Pakistan. Journal of Rural Financial Services.
30. Ruthenberg, H. (2021). Financing mechanization and smart agriculture: Constraints and opportunities. Agricultural Finance Journal.
31. Assessment of Agricultural Mechanization in Punjab," *Journal of Agricultural Engineering*, 2022.
32. Agricultural Innovation Adoption in Pakistan," *International Journal of Agricultural Sustainability*, 2023.
33. "Agricultural Policy in Pakistan: An Evaluation of the National Agriculture Policy 2017," *Food Security Report*, Ministry of National Food Security & Research, 2023.
34. Agricultural Policy and Governance in Pakistan," *Pakistan Institute of Development Economics*, 2022
35. Policy and Investment Review in Pakistan's Agricultural Sector," *Asian Development Bank*, 2023.
36. Public-Private Partnerships in Agriculture in Pakistan," *The World Bank*, 2023.
37. The Role of Agricultural Research and Development in Pakistan," *Pakistan Agricultural Research Council*, 2023.
38. Pakistan's Agricultural Research Funding Trends and Gaps," *Agricultural Economics Review*, 2023.
39. Assessment of Agricultural Mechanization in Punjab," *Journal of Agricultural Engineering*, 2022.
40. Agricultural Innovation Adoption in Pakistan," *International Journal of Agricultural Sustainability*, 2023.
41. Agricultural Technology Adoption and Extension in Sindh," *Sindh Agriculture University Journal*, 2023
42. Challenges in Agricultural Mechanization: A Sindh Perspective," *International Food Policy Research Institute*, 2023
43. The Impact of Imported Agricultural Machinery on Local Industries," *Pakistan Bureau of Statistics*, 2023.

44. Agricultural Mechanization and Capacity Building in Khyber Pakhtunkhwa," *Government of Khyber Pakhtunkhwa Annual Report*, 2023
45. Market Access for Agricultural Machinery in Pakistan," *Khyber Pakhtunkhwa Investment Promotion Agency*, 2023.
46. Agricultural Credit and Financing in Pakistan," *State Bank of Pakistan Report*, 2023
47. Financing Options for Agricultural Investments in Pakistan," *National Bank of Pakistan Report*, 2023
48. Improving Agricultural Engineering Education in Pakistan," *Higher Education Commission Report*, 2023.
49. Trends in Agricultural Research Funding in Pakistan," *Higher Education Commission Report*, 2023.
50. Dawn. (2023). Threats to Pakistan's food security from farmland conversion. Retrieved from https://www.dawn.com