
Agricultural mechanization perspective in Pakistan: present challenges and digital future

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Table S1. Major ICT platforms working in agriculture sector in Pakistan to support the digitalization of the sector.

ICT Platform	Description of work
Farmdar	Provides precise and actionable crop data using AI and remote sensing technology to help farmers monitor crop health and predict pest attacks.
BaKhabar Kissan	Offers a mobile app that provides farmers with information on soil preparation, crop management, weather updates, and pest control through audio, video, and pictorial presentations.
Ricult Pakistan	Enhances productivity and profitability for small farmers by providing agricultural information, solutions, and access to credit and marketplaces.
Kisan Zar Zameen	Uses multi-spectral imagery from satellites to provide soil condition and crop health analysis, weather updates, and drone spraying services.
Kissan Bazaar	An online marketplace where farmers can buy and sell agricultural items, including fruits, vegetables, poultry, and livestock.
Agri Smart	Launched by the Punjab Public Management Reform Program, this app offers services like farmer training sessions, pest warnings, monitoring agricultural inputs, and soil sampling.

Table S2. Government subsidy schemes for mechanization and on farm water management during last five years.

Project	Objectives/ key components	Department/ duration	Status
Mechanized management of rice crop residue	Provision of 500 rice straw choppers to farmers and service providers Provision of 500 Pak seeders to farmers and service providers	Field Director General Agriculture/ 2020-2022	Completed
Chief Minister green tractor scheme	Provision of 9500 tractors to farmers on subsidised rates	Government of Punjab/ 2024-Ongoing	Ongoing
Promotion of mechanized agriculture for increasing crop productivity	Provision of efficient agricultural machines and implements on cost sharing basis to 7285 agricultural mechanization service providers Capacity building of farmers and service providers for optimum operation and maintenance of agricultural machinery	Field Director General Agriculture/ 2021-2026	Ongoing
Punjab resilient and inclusive agriculture transformation (PRIAT)	Supporting climate-resilient agriculture by promoting reformatory crop production, renewable energy, and on-farm water management technologies (Related with mechanization)	On Farm Water Management Punjab/ 2022-2027	Ongoing
National program for enhancing command area in Barani areas of Pakistan	Provision of 500 Laser land levellers to farmers and service providers	On Farm Water Management Punjab/ 2020-2025	Ongoing
National program for improvement of watercourses in Pakistan (Phase-II)	Provision of 9,500 Laser land levelers to the farmers/ service providers	On Farm Water Management Punjab / 2019-2024	Completed

Table S3. Arguments and counterarguments for testing and certification.

Argument	Counterargument	Possible responses
Digitization of agricultural machinery: digitizing agricultural machinery and registering manufacturers will help in identifying the number of machines available, forecasting future demand, and aiding policymakers in launching relevant projects.	Cost and bureaucracy: establishing a certification body and digitizing machinery may involve significant costs and bureaucratic hurdles.	Long-term benefits: while initial costs may be high, the long-term benefits of improved quality, safety, and marketability of agricultural machinery outweigh these costs. Streamlined processes and digital records can reduce bureaucratic inefficiencies over time.
Need for standardization: standardization, testing, and certification are essential for ensuring the quality, safety, and trustworthiness of agricultural machinery, facilitating smoother trade.	Adaptability of local manufacturers: local manufacturers may struggle to adapt to new regulations and standards.	<p>Support measures: the government can provide support through training programs, subsidies, and phased implementation (voluntary at initial stage) of regulations to help local manufacturers adapt.</p> <p>Involvement of stake holders: establishment of standards should not be one party job. All the stake holders, manufacturers, researchers, academia, farmers and service providers should be the part of this process.</p>
Third-party certification: third-party certification is crucial for impartial assessment and avoiding conflicts of interest that may arise with in-house testing and certification.	Effectiveness and impartiality: there may be concerns about the effectiveness and impartiality of third-party certification bodies.	Accreditation and oversight: accreditation of certification bodies ensures they operate to international standards, providing an extra layer of confidence in their impartiality and effectiveness. Regular audits and oversight can further ensure their reliability.
Ongoing initiatives: the establishment of a testing, evaluation, and certification centre by the agriculture department of Punjab is a positive step towards digitization and quality control.	Harmonization challenges: varying interpretations of methodologies can impact test results and create challenges in harmonizing standards.	International collaboration: international organizations like ANTAM and OECD play a vital role in establishing clear and consistent standardization, testing, and certification processes. Collaboration among these organizations can help address and mitigate harmonization challenges.