EXPLORING THE AVENUES OF ADOPTION OF AGRICULTURAL UAVS BY THE SMALL -TO- LARGE LANDHOLDINGS FARMERS

Shoaib Rashid Saleem, Muhammad Faisal Ali, Muhammad Naveed Tahir, and Abdul Saboor

(CGP # 06-194)

5TH RASTA CONFERENCE
Wednesday, January 26 & Thursday, January 27, 2025
Roomy Signature Hotel, Islamabad

This document is unedited author's version submitted to RASTA.

RESEARCH FOR SOCIAL TRANSFORMATION & ADVANCEMENT

Competitive Grants Programme for Policy-oriented Research

Pakistan Institute of Development Economics

ABSTRACT

Pakistan's agriculture has been playing vital role as it contributes about 25% in national GDP. Unmanned Aerial Vehicles (UAVs) are proving to be fast and effective methods of crop monitoring and agrochemical spraying. However, adoption rates of UAVs in Pakistan are very low, and a comprehensive study is required to determine the limiting factors and identify constraints in adoption of UAVs technologies in Pakistan. A survey-based study was planned in the cotton belt of the Punjab province to identify the willingness of farmers in adopting UAVs in different cropping systems with a special focus on cotton and maize. Farmers and other stakeholders were requested to participate in this study along with available secondary datasets. Secondary datasets and key informant interviews (KIIs) have been conducted to identify the key constraints in the adoption of the UAVs. These constraints helped to crystallize the development of farmer survey for data collection purposes. Young and educated farmers showed significant interest in use of UAVs technologies in agriculture. However, large number of farmers showed concerned about the cost of UAVs. Also, the study identified constraints in development of national policy for UAVs adaptation in Pakistan. The findings of this research will help in devising comprehensive strategy to adopt UAVs at large scale and develop national policy to propagate UAVs technologies in Pakistan.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

1.1 Background and Context of the Study

Pakistan's agriculture plays a vital role in ensuring both the nation's food security and its national security. The Government of Pakistan has recently launched a significant initiative, establishing the Special Investment Facilitation Council (SIFC), with a particular focus on revitalizing key industries, including agriculture. Agriculture not only contributes around 22.9% to Pakistan's GDP but also engages approximately 37.4% of the total workforce in the country (GoP, 2023). The agriculture sector is facing several challenges which include issues such as poor seed quality and management, limited adoption of technology, a shortage of skilled labor, and the prevalence of small landholdings. Consequently, progressing the agricultural sector is essential to bolster Pakistan's fragile economy. To address these challenges effectively, the agricultural sector requires the implementation of efficient, sustainable, innovative, modern, and environmentally friendly approaches. These measures are crucial for bridging the yield gaps per acre between Pakistan and developed countries.

Precision Agriculture, as defined by the International Society for Precision Agriculture, is a management concept rooted in intensive data collection and processing to inform targeted actions aimed at enhancing the efficiency, productivity, and sustainability of agricultural practices. This approach encompasses various technological domains, ranging from data collection methods such as remote sensing, field proximal sensing, and geographic information systems, to advanced data processing techniques like artificial intelligence (AI), deep learning (DL), machine vision, and image processing. Additionally, precision agriculture involves technological innovations such as smart sprayers, smart spreaders, digital sensors, and auto guidance systems (Lamb et al., 2001; Fulton et al., 2018).

The introduction of Unmanned Aerial Vehicles (UAVs) is one of the latest additions in the Precision Agriculture gadgets to manage crop growth and quality efficiently. Crop monitoring through UAVs using various types of sensors has huge potential to map crop growth and identify yield-limiting factors. Many researchers have seen promise in different machine vision and other sensing systems with crop growth parameters in various cropping systems. Agrochemical application according to crop and soil needs can enhance crop yield, improve quality, reduce cost of production, and reduce environmental impacts. Spraying on crops is another major application area of UAVs (Moskvitch, 2015). Spraying through UAVs is proven to be faster, efficient, effective, less laborious, and cost effective as compared to traditional technologies being used for agrochemical spraying (Moskvitch, 2015). Proper planning and management of targeting hotspots of weeds and pests through UAVs can minimize and save large amounts of unnecessary chemical applications.

Knapsack and boom sprayer requires operators to be directly in contact with the pesticide and could ultimately result in excessive exposure. Extended exposure to these agrochemicals can lead to severe health issues and can cause many diseases in humans including respiratory disorders and cancer. However, UAVs operators can easily position themselves outside the field and can avoid direct contact with pesticides. UAVs are also ultra-low volume (ULV) systems when compared to conventional spraying techniques. Therefore, they reduce the impact of chemical residues on nature and people compared to traditional spraying methods. Overall, adoption of UAVs could be farmer and

end user friendly which could also result in improved soil fertility and minimal harmful impacts on human health.

The regulatory framework governing UAV operations is another challenge in Pakistan and limited availability of technical expertise and training programs remains a significant bottleneck. The maintenance and operation of UAVs require specialized skills in drone piloting, sensor calibration, data collection, and processing using advanced software. However, most farmers and agricultural scientists lack background knowledge to benefit from UAV technology efficiently. Establishing capacity-building initiatives, promoting public-private partnerships (PPE), and integrating UAV training into agricultural education are essential steps to increase the potential of UAVs adoption. Pakistan's small landholdings are one of the major challenges for the farmers to adopt the UAVs and other precision agriculture technologies due to the linking of economic challenges faced by small farmers. High initial investments, unskilled operators, lack of technical training facilities , and unavailability of technical training are potentially main constraints for lower adoption rates of UAVs. The need for farmer friendly regulations, structured approval mechanism from relevant governmental bodies, and a detailed policy framework is imperative for wide-scale adoption of UAV-based precision agriculture in Pakistan. The introduction of subsidized programs, leasing models, and cooperative ownership of UAVs can also propagate this technology to small and medium-scale farmers. Additionally, integrating UAV into existing agricultural extension programs and forming UAV service cooperatives can provide farmers with on-demand access to drone-based monitoring and spraying services without requiring direct ownership. The UAV-based precision agriculture techniques, demonstrating significant improvements in yield optimization, resource efficiency, and environmental conservation in China, USA, and Japan.

In Precision agriculture, use of UAVs for climate resilience and environmental sustainability. Conventional agriculture practices often lead to the use of excessive agrochemicals, inefficient water use, and soil degradation. UAV-based spraying reduces chemical runoff and pollution. Remote sensing allows early detection of crop stress, pest infestations, and soil moisture variability, reducing yield losses due to climate-induced factors. Despite these challenges, the long-term benefits of UAV adoption in precision agriculture outweigh the initial hurdles. With appropriate policy interventions, increased awareness, and investment in research and development, UAVs can play a transformative role in optimizing resource use, improving farm productivity, and ensuring environmental sustainability. As Pakistan strives to modernize its agricultural sector under initiatives like the Special Investment Facilitation Council (SIFC), prioritizing UAV technology can serve as a key enabler in achieving precision agriculture goals. By addressing existing barriers and fostering an ecosystem conducive to UAV adoption, Pakistan can enhance food security, strengthen its agricultural economy, and move towards a more sustainable and technology-driven farming landscape.

A comprehensive study is required to not only identify major constraints from regulatory point of view, but also integrate the farmers perspective into the potential policy document for nationwide plan of propagating these technologies. By adopting UAV-based precision agriculture, Pakistan may improve farm efficiency, manage resources sustainably, enhance food security, and contribute to national economic stability, potentially making agriculture a more resilient and high-performing industry in the future.

1.2 An Economic Overview of the UAVs

Average crop spraying UAV costs about 2-5 million PKR depending on the country of manufacturing and spray tank volume. The average area required to spray to cover the initial capital investment without considering the labor charges and movement costs varies from 4,000 to 10,000 acres at a spraying cost of 500 PKR per acre (without addition of cost of spraying chemicals). However, adding the skilled labor cost (PKR 200/acre) and movement charges (PKR 100/acre), the number of acres required to spray increases up to 10,000 to 25,000 acres. An average drone can cover between 10 to 50 acres in one day depending upon the climatic conditions and transportation time required between different agriculture fields. Therefore, the period required in terms of numbers of operational days to cover the initial capital investment to purchase a drone is between 1000 days (10 acres/day) to 200 days (50 acres/day) for a drone costing PKR 2 million while numbers of operational days to cover the initial capital investment to purchase a drone is between 2500 days (10 acres/day) to 500 days (50 acres/day) for a drone costing PKR 5 million.

Table 1: UAV Capital Costs and Cost Recovery

Drone Cost (million)	**Acres of Spraying Required (@500PKR/acre)**	**Acres of Spraying Required after deducting labor & fuel costs (@200PKR/acr**	**Days Required to Cover Capital Costs @10acres/day**	**Days Required to Cover Capital Costs @25acres/day**	**Days Required to Cover Capital Costs @50acres/day**
2 million	4,000	10,000	1,000	400	200
3 million	6,000	15,000	1,500	600	300
4 million	8,000	20,000	2,000	800	400
5 million	10,000	25,000	2,500	1,000	500

1.3 Purpose and scope of the study

This study aims to examine the factors influencing farmers' readiness to embrace agricultural UAVs, focusing particularly on three crops: Cotton, Sugarcane, and Maize. The choice of these crops is deliberate, as they require intensive spraying, which will further facilitate the development of UAV services/products. Additionally, the study seeks to offer valuable insights to policymakers for crafting a comprehensive strategy to establish and promote a national UAV policy for agriculture. To achieve this, a qualitative approach will be employed to pinpoint the key regulatory barriers impeding the advancement of the UAV market in Punjab. Thus, the study has three primary objectives:

1. Identify various constraints including regulatory constraints linked with the adoption of UAV technologies and their import.

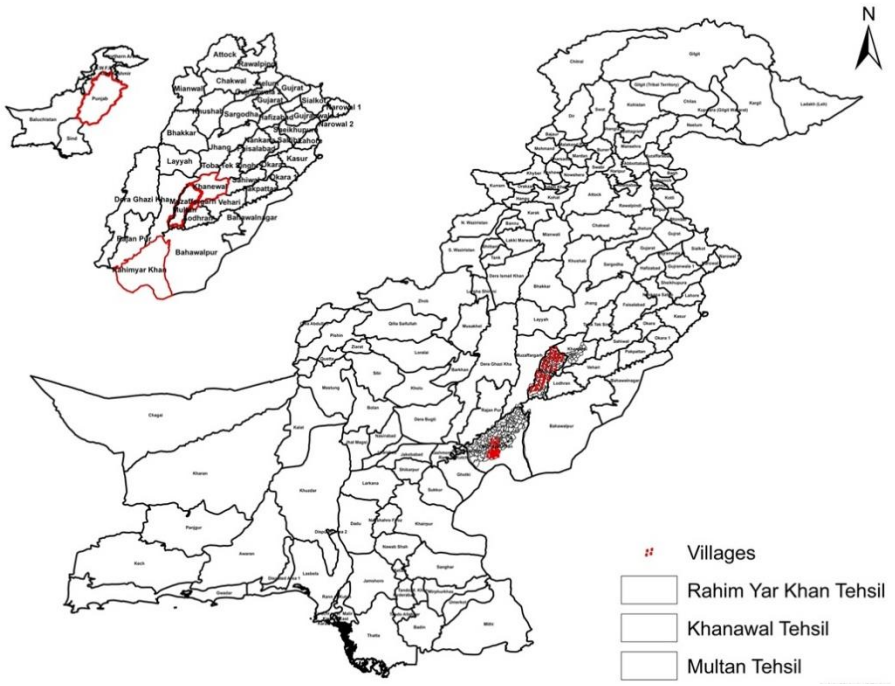
2. Assess the willingness to pay of farmers to adopt UAV technologies for both monitoring and spraying purposes.
3. Present recommendations based on the study's findings.

METHODOLOGY

2.1 Sampling Locations

The study was designed to collect survey-based information from the major agricultural cities of Pakistan especially focusing on cotton belt of Pakistan (Multan, Rahim Yar Khan, and Khanewal) (Figure 1). This selection was primarily motivated by the significant number of agrochemical applications required in these districts, ranging from approximately 8 to 10 during the cotton crops' growing season to mitigate pest and weed damage.

Figure 1: Survey Districts of Pakistan for the Study on UAVs Adoption



The study was divided into two major segments: interviews with stakeholders and farmers surveys.

2.2 Interviews with Stakeholders

Interviews were conducted with key stakeholders to gather comprehensive insights into the integration of UAVs in the agricultural sector. The stakeholders interviewed were private service providers, agrochemical companies, government institutions, national agricultural research centers, and agricultural universities in Punjab. The interviews explored various aspects such as the constraints faced in purchasing and importing UAVs, service delivery and pricing mechanisms, operational challenges and skill requirements, market limitations, and necessary improvements. Additionally, the interviews focused on input on governmental support needed, current policies and regulations, and the potential role of UAVs in enhancing agricultural productivity.

The questions asked to the relevant stakeholders is provided in Annexure-A.

2.3 Farmer Surveys

The selected districts of Multan, RYK, and Khanewal was visited, and surveys were conducted from cotton, sugarcane, and maize farmers. The sampling was semi-biased as both progressive and unprogressive farmers, small and large landholding farmers were targeted in these three districts. Additionally, farmers from each administrative unit were selected based on their proportional representation. A total of 228 farmers were interviewed during the study and questionnaire is attached in Appendix-B. The focus of the questions was the availability of drones in the locality, willingness to adopt, willingness to pay, constraints and challenges faced by farmers, and how demographics such as age groups and literacy rates are affecting the adoption of UAVs.

2.4 Research Plan

The research plan of the study is summarized in Table 2.

Table 2: Research Plan

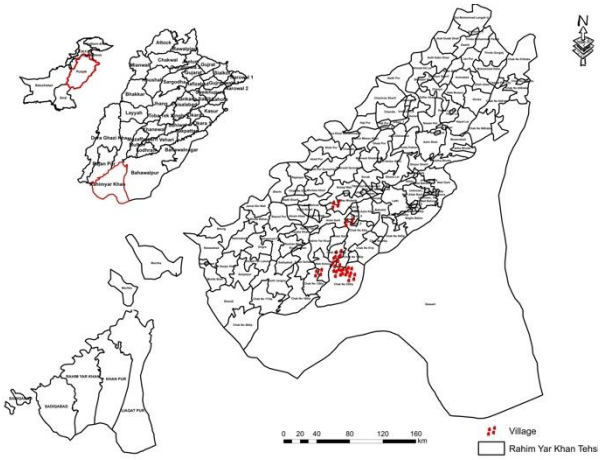
Research Methodology	**Questionnaire, Case Study**
Research Strategy	**Exploratory Research**
Instruments	**Structured and Semi-Structured interviews, Questionnaires**
Time Horizon	**6 months**
Budget	**2.6 Millions**
Locations	**Cotton Districts (Multan, Rahim Yar Khan, Khanewal)**
Industry	**Agriculture**
Respondents	**Farmers (Traditional & Progressive) & Other Stakeholders**
Techniques	**Surveys**
Sample Size	**384 (statistically justified sampling size)**

Rahim Yar Khan: A total of 07 villages were visited and a total of 100 farmers were interviewed during the study period (Figure 2a).

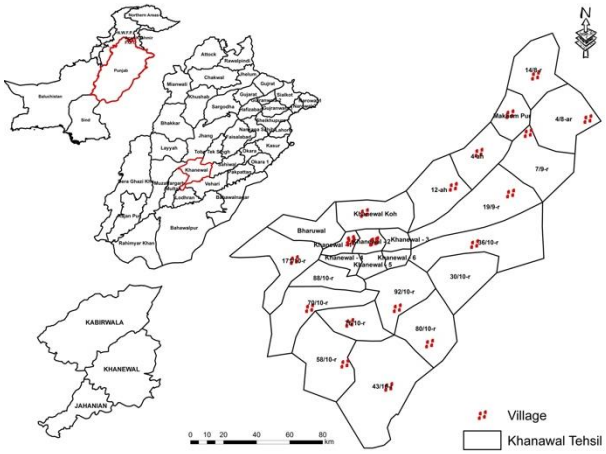
Khanewal: A total of 18 villages were visited and a total of 55 farmers were interviewed during the study period (Figure 2b).

Multan: A total of 16 villages were visited and a total of 73 farmers were interviewed during the study period (Figure 2c).

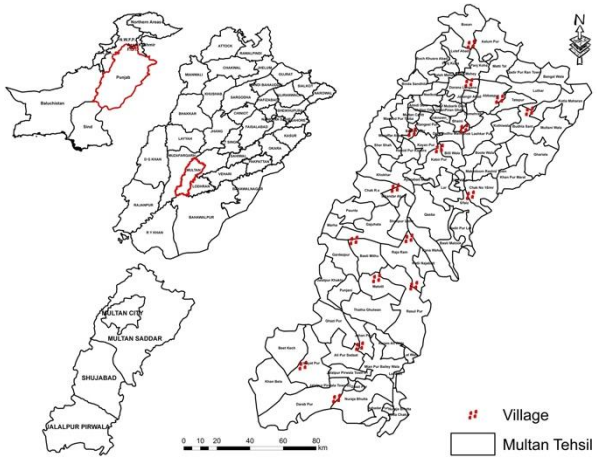
Figure 2: Sampling Locations of Villages in (a) Rahim Yar Khan (b) Khanewal (c) Multan


N
0 20 40 80 120 160
km
Village
Rahim Yar Khan Tehsil

(a)


N
KABIRWALA
KHANEWAL
JAHANIAN
0 10 20 40 60 80
km
Village
Khanawal Tehsil

(b)


N
MULTAN CITY
MULTAN SADDAR
SHUJABAD
JALALPUR PIRWALA
0 10 20 40 60 80
km
Village
Multan Tehsil

(c)

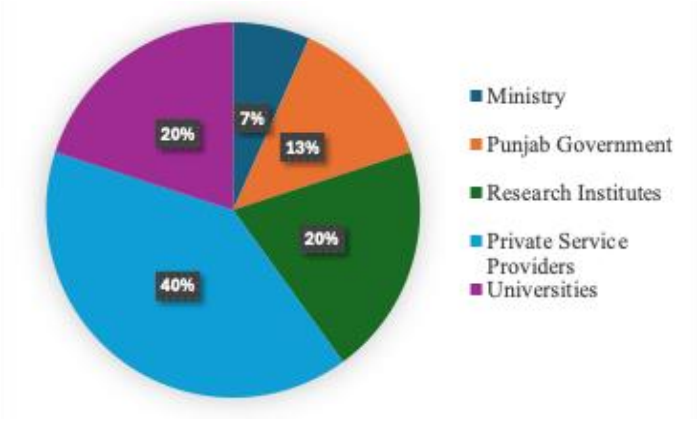
RESULTS AND DISCUSSION

3.1 Interviews with Stakeholders

A total of 15 stakeholders were interviewed during the study (Figure 3). This stakeholder feedback was crucial in identifying regulatory and policy hurdles, informing a robust policy framework for UAV integration, and evaluating the commercial viability and market development potential of UAVs in agriculture. This information was assessed through content analysis.

Furthermore, these interviews also provided a solid foundation by identifying the representative attributes and their levels for developing a product or service for farmers that is generally accepted and economically feasible, helping to determine their willingness to pay.

Figure 3: Proportions of Stakeholders Interviewed during Key Informant Interviews (KIIs)



3.1.1 Key Constraints and Challenges Identified:

Policy Challenges

Major findings during the KIIs were the absence of national drone policy for agriculture. All stakeholders discussed that the difficulties in UAVs adoption at national level was mainly due to the challenges faced by these organizations in importing UAVs in Pakistan. All stakeholders were on board in terms of earliest availability of national drone policy. One of the interesting arguments made by a PSP was that easy documentation and approval process is mandatory during the policy development as the tedious policy could further discourage the UAV adoption. Another suggestion put forward by the Agriculture Department representative was the development of safe zones for UAVs operation that would reduce the unnecessary approval processes in the safe zones.

Technical Awareness and Lack of Research

The very limited availability of UAVs for the research institutes are major limitation in creating the awareness among agriculture extension workers and PSPs. The representatives from research institutions, GoP representatives, and PSPs highlighted that more technical awareness is needed to increase adoption rate among farmers. Study conducted by PMAS-Arid Agriculture University (PMAS-AAUR) revealed that ROI of 2 to 5 years for more than 500 acres coverage per year. Preliminary findings of the research work conducted in few of the major crops are benefits in terms of labor savings and time saving between 10 to 40% depending on the sprayed acreage. One of the interviewees made an argument that research will strengthen the rapid technology transfer to the farmers.

Famers Interests

The KIIs revealed that farmers showed high interest in adoption of the UAVs highlighting its cost and time-saving benefits. However, due to lack of infrastructure, current adoption rates are very low. Two PSPs highlighted that government subsidies and loaning will improve the overall adoption rates of the UAVs. However, PSPs informed that the willingness to pay varies from region to region and crop to crop. The price ranges from 400 to 2400 per acre per spray.

Details of these surveys are provided in the Appendix-A.

3.2 Famers Interviews

The use of Unmanned Aerial Vehicles (UAVs), or drones, is gaining recognition in agriculture for their potential to improve efficiency in crop monitoring, pesticide spraying, and overall farm management. However, the adoption of UAV technology in the agricultural sectors of Khanewal, Multan, and Rahim Yar Khan districts is still in the early stages. The survey conducted in these areas aimed to assess the awareness, adoption, and challenges surrounding UAV technology among local farmers.

3.2.1 Current Status of Drone Technologies in Khanewal, Multan, and Rahim Yar Khan Districts

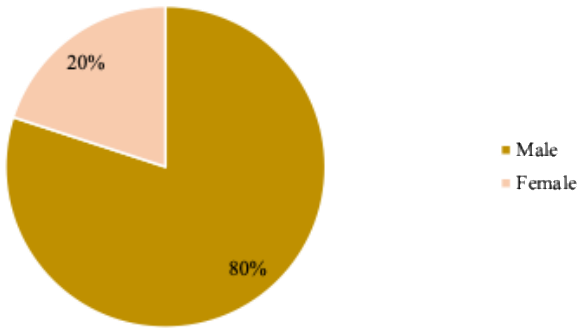
3.2.1..1 Demographic Breakdown of Drone Adoption

The demographic profile of the respondents provides valuable insights into the factors that influence the adoption of UAV technology in these districts.

GENDER DISTRIBUTION

The gender distribution among the survey respondents revealed that 80% of the farmers were male, while 20% were female (Figure 4). This is consistent with the typical gender roles in rural agricultural communities, where farming is traditionally managed and operated by men. This gender disparity could impact the adoption of drone technology, as men are the primary decision-makers when it comes to technology investments on farms.

Figure 4: Gender Distribution of Interviewees

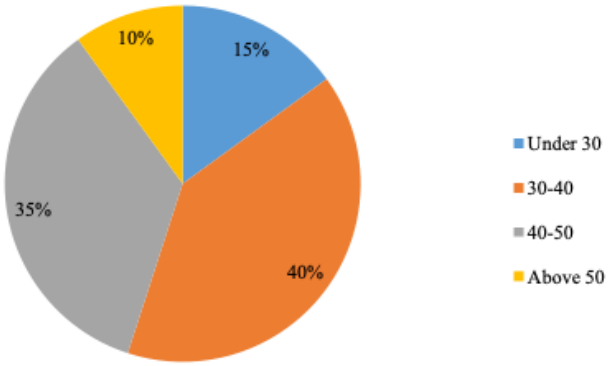


AGE DISTRIBUTION

Age played a significant role in the likelihood of adopting UAV technology. The age distribution revealed that 40% of the respondents were between 30-40 years old, and 35% were in the 40-50

years range (Figure 5). Younger farmers (under 30 years) made up 15% of the respondents, while 10% were above 50 years.

Figure 5: Age Distribution of Interviewees

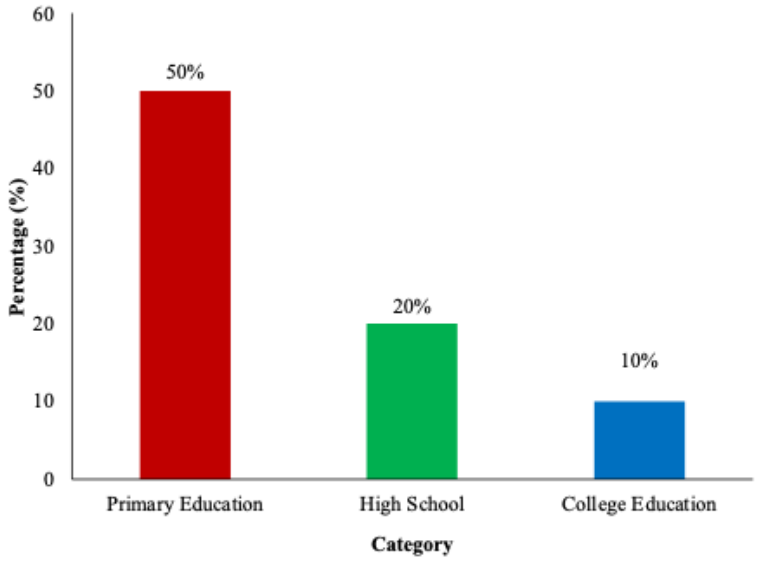


This suggests that most respondents, especially those in the 30–50-year age group, are in their prime working years and may have the financial stability to invest in new technologies. However, younger farmers were more likely to embrace new technology, with 50% of them expressing an interest in using UAVs if the costs were reduced.

EDUCATION LEVEL

Education was another significant factor influencing UAV adoption. 50% of the farmers in Khanewal, 60% in Multan, and 40% in Rahim Yar Khan had only completed primary or middle school education (Figure 6). Only 20% of the respondents had completed high school, and 10% had received some form of higher education (college or university). Farmers with higher levels of education were more likely to understand and appreciate the potential of drone technology, with 60% of those with a college education expressing interest in UAV adoption. In contrast, only 30% of those with a primary education showed interest, underscoring the need for targeted education and awareness programs to bridge the knowledge gap.

Figure 6: Literacy Rate among Interviewees

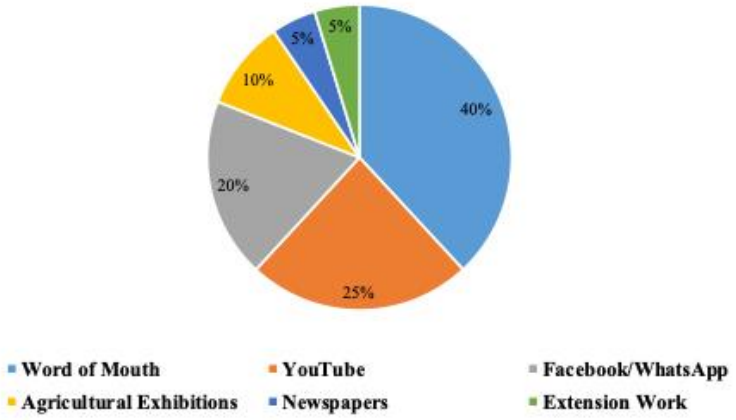


3.2.1.2 Awareness and Adoption of UAV Technology

According to the survey, 40% of the respondents in Khanewal, 35% in Multan, and 25% in Rahim Yar Khan districts reported being aware of UAV technology (Figure 7). While this suggests a relatively high level of awareness, active usage of UAVs in farming remains limited. Only 15% of the total respondents across the three districts used drones for agricultural activities such as crop monitoring, pesticide spraying, or field surveying. This significant gap between awareness and actual adoption indicates that while the potential benefits of UAV technology are recognized, the barriers to active use such as cost, availability, and knowledge remain substantial.

The survey also sought to understand how farmers became aware of UAV technology. The responses revealed that the primary sources of information were personal interactions and social media. 40% of farmers in the surveyed districts mentioned that they learned about UAVs through word of mouth from fellow farmers or community members. 25% of respondents reported learning about UAVs through YouTube, which has become a popular platform for agricultural demonstrations and drone technology tutorials. 20% were introduced to UAVs via Facebook or WhatsApp, highlighting the role of social media in spreading information about new technologies. Agricultural exhibitions were another key source, with 10% of farmers attending these events to see UAV technology in action. Smaller groups of respondents mentioned newspapers (5%) and extension work (5%) as the source of their awareness (Figure 7). These findings suggest that while formal education channels like extension services have limited reach, social media platforms and community-based word-of-mouth communication are crucial in spreading knowledge about UAVs.

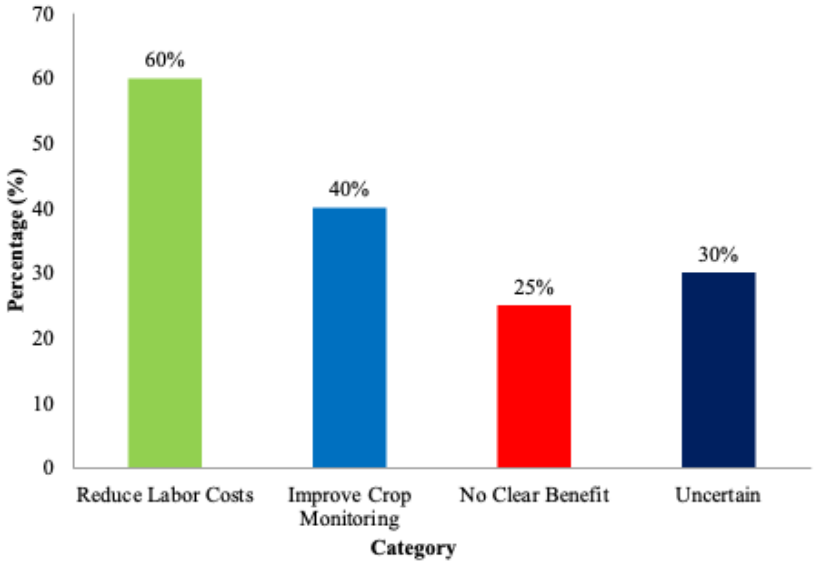
Figure 7: Source of Information for Farmers through Different Platforms



3.2.1.3 Perceived Benefits of UAV Spraying

Despite the limited use, many farmers recognized the potential benefits of UAV technology as 60% of respondents believed that UAVs could help reduce labor costs, especially for tasks like pesticide spraying, which is time-consuming and labor-intensive (Figure 8).

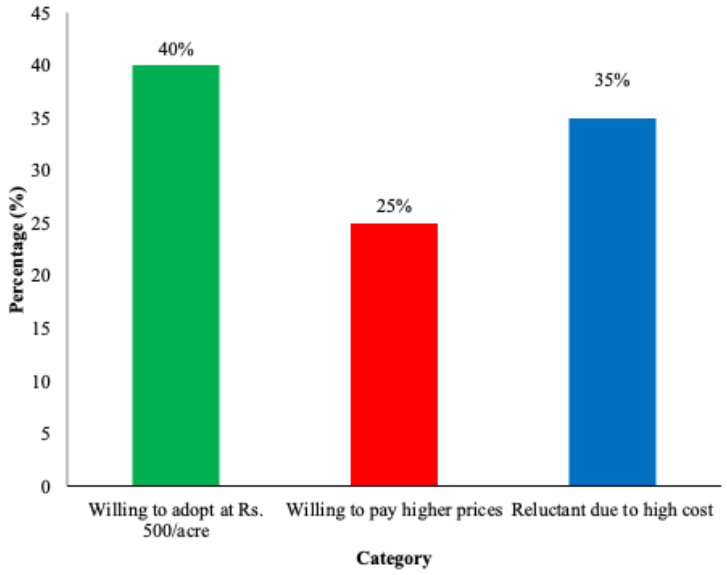
Figure 8: Perception of Farmers about the UAVs Spraying



3.2.1.4 Willingness to pay for UAV Spraying

About 40% of farmers were willing to pay at Rs. 500 per acre acknowledging that UAVs could improve crop monitoring, making it easier to detect pests and diseases early, which could lead to better crop yields and reduced pesticide use (Figure 9). However, about 25% were willing to pay higher price for drone spraying while 30% were reluctant in adoption of UAV spraying due to high cost of service.

Figure 9: Willingness to Pay Per Acre Charges for UAVs Spraying Services



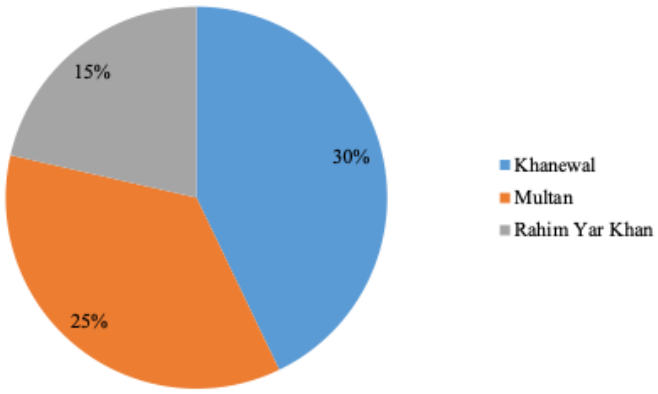
3.2.2 Current Infrastructure for Drone Adoption in Khanewal, Multan, and Rahim Yar Khan Districts

While the awareness and potential for UAV technology in agriculture are evident, the infrastructure to support its widespread adoption remains underdeveloped. Key elements of this infrastructure include the availability of UAV service providers, training programs, and technical support.

3.2.2.1 Service Providers and Availability

The availability of local UAV service providers is a significant factor influencing adoption. According to the survey, only 30% of respondents in Khanewal had access to local UAV service providers, 25% in Multan, and 15% in Rahim Yar Khan (Figure 10). This shows that many farmers in these districts still rely on informal sources or local vendors for UAV services. Additionally, while 40% of farmers in Khanewal acknowledged the existence of UAV services, they noted that these services were expensive and often beyond their financial reach. In Rahim Yar Khan and Multan, 60% of farmers indicated that drone services were either not available or too expensive.

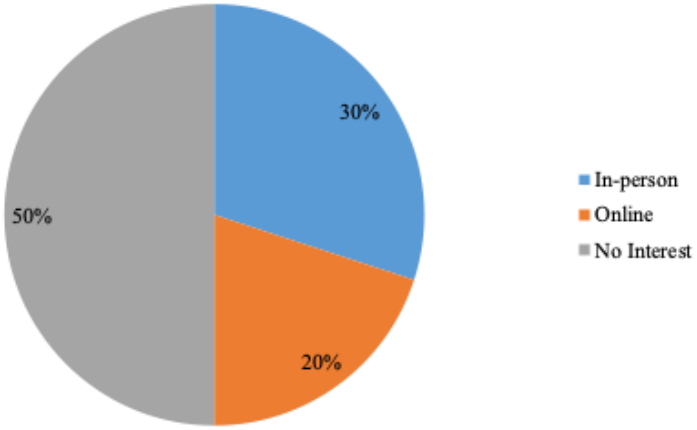
Figure 10: Availability of Service Providers in Sampling Districts for UAVs Spraying Services



3.2.2.2 Training and Technical Support

Another barrier to the adoption of UAVs is the lack of accessible training programs. The survey revealed that only 15% of respondents had attended a training session related to UAV usage, and most of these training programs were informal or provided by local agricultural cooperatives (Figure 11). About 50% of the farmers expressed interest in receiving training on UAV usage, but only 20% preferred online training, while the remaining 30% wanted in-person sessions. This highlights the demand for more structured, accessible, and affordable training programs to equip farmers with the skills needed to operate drones effectively.

Figure 11: Trainings and Technical Support to the Farmers and Service Providers in the Sampling Districts

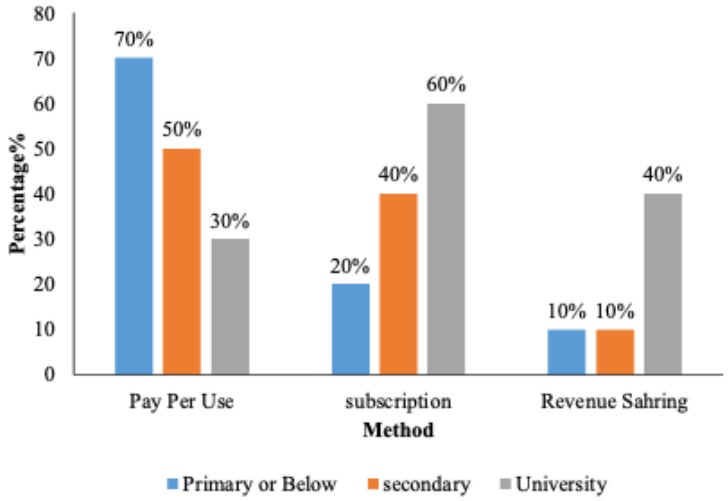


3.2.3 Proposed Payment Models

3.2.3.1 Education Level

Preferred payment method was strongly linked with the literacy rates of the farmers as lower-educated farmers strongly favor pay-per-use models and demand awareness campaigns about UAV benefits. About 60% of the farmers with university education was more inclined towards subscription model as they were more concerned on timely application of the agrochemicals (Figure 12). Also, same group of farmers (about 40%) were ready for revenue sharing mode for UAV spraying.

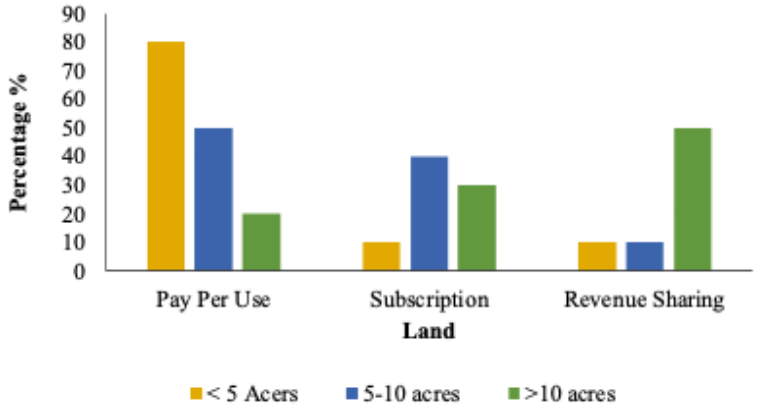
Figure 12: Choice of Payment Methods among Farmers with Different Literacy Rates



3.2.3.2 Landholdings

Preferred payment models by landholding Size showed that smallholders were more in favor of pay-per-use, while larger landholders were more inclined towards revenue-sharing models (Figure 13).

Figure 13: Choice of Payment Methods among Farmers with Different Landholdings

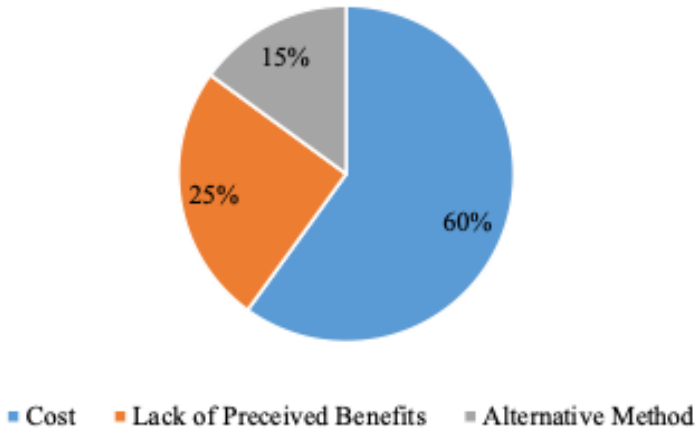


3.2.4 Constraints Identified during Famers Survey

3.2.4.1 Reliance on Traditional Methods

One of the main constraints in adoption of the UAVs spraying is the reliance of farmers on traditional methods especially medium-scale farmers (5–10 acres) who are using knapsack or tractor-mounted sprayers (Figure 12). Over 70% of respondents in this category expressed doubt about whether UAVs would significantly outperform their current methods.

Figure 14: Famers Reliance on Traditional Methods of Spraying



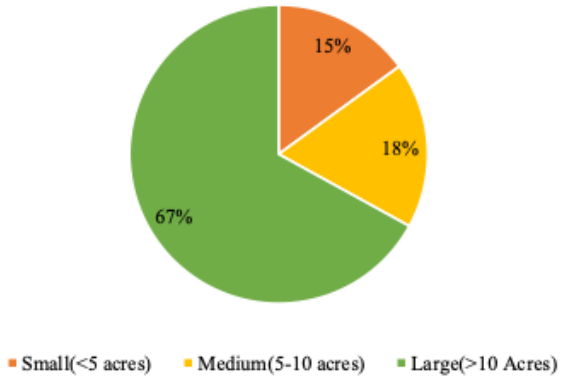
3.2.4.2 Age of the Farmers

Age was one of the critical factors in reasoning of the adoption or non-adoption of UAVs for spraying. Younger Farmers (<35 Years) were found more open to UAVs technology adoption but 50% showed concerned about the technology price citing limited access to credit or subsidies. Middle-aged Farmers (35–50 Years) showed concerns about both cost (50%) and perceived benefits (30%). The main reasons for non-adoption were their scepticism about return on investment (ROI) and lack of demonstrations of UAV spraying systems. Older Farmers (>50 Years) were more reluctant in adoption of UAVs as they were heavy relying on traditional methods (50%) of spraying and also showed their doubts on lack of perceived benefits (40%).

3.2.4.3 Landholding Size

Landholding size was one of the major constraints in adoption of the UAVs spraying as identified in KIIs. Small Landholders (<5 Acres) were using knapsack sprayers and cost of spraying using UAVs was not justified as they were more inclined towards government subsidies (Figure 13).

Figure 15: Distributions of Landholdings Size of Farmers



Medium Landholders (5–10 Acres) were partially open to UAVs spraying but they were more inclined towards traditional spraying mechanisms. They were more opened to opt for seasonal subscriptions or installment-based services. On the other hand, large Landholders (>10 Acres) were more

concerned about the efficacy of UAV sprayers and lack of widespread availability of UAV services or technical support.

CONCLUSIONS

The focus of the conducted study was on both opportunities and challenges associated adoption of Unmanned Aerial Vehicles (UAVs) in Pakistan's agricultural sector in small-to-large landholding farmers. The results of KIIs indicated that although UAVs offer promising solutions for precision agriculture in terms of reducing costs, enhancing efficiency, and minimizing environmental impact, their adoption remains limited due to various types of constraints. The major constraint identified during KIIs (Private service providers, agrochemical companies, and government institutions) was lack of a national drone policy. The absence of structured mechanism and regulations have complicated the import process, approval process, that ultimately is resulting in lower adoption rates. Moreover, shortage of technical awareness less availability of UAVs at research institutions are also contributing in low propagation rates of UAVs spraying in Pakistan. Results of farmer surveys revealed that awareness of UAVs technology is growing especially in young and more educated farmers. However, actual adoption remains low due to high initial costs, high spraying costs, limited access to service providers, and lack of training programs. Smallholder farmers more inclined towards government subsidies or pay-per-use models. The study also highlighted farmers in areas with better exposure to technology showed a higher inclination toward adoption, while others showed their reliance on traditional methods. The major solutions to the highlighted challenges are development of a national UAVs policy for agriculture use, introducing service providers models, and integrating UAV training into educational programs. Addressing these barriers will be ensure successful wide-scale adoption of UAVs technologies in Pakistan’s agricultural industry that will ultimately improve farm productivity and food security.

POLICY RECOMMENDATIONS

Following policy recommendations are necessary for adoption of UAVs in agrciulture among small-to-large landholdings famers based on key informant interviews (KIIs) and farmer surveys

1. Clear and well-structured national UAVs for agriculture use policy framework is needed. National UAVs policy should streamline the approval process covering all operational safety standards and legal concerns.
2. Approval process under one minitry and one application is required to reduce bureaucratic hurdles. Online application system for drone import, purchase, and operation could boost the UAVs use in Pakistan.
3. Financial assistance programs need to be introduced including subsidized loans and tax exemptions which will help farmers and service providers to afford UAVs technology.
4. Universities and research institutions need to play pivotal role in UAVs training centers to provide technical knowledge on UAVs use in different crops. TEVTA/NAVTC can also introduc short courses to train various age group farmers and service providers.
5. Collaborations between government institutions, private service providers, and agrochemical companies needed to be developed which will help in introducing affordable UAV service structure for smallholder farmers.
6. One of the major constraints in UAVs adoption is the access to UAVs in the local regions. Development of private or governmental UAV service hubs in key agricultural regions can increase the UAVs spraying among small scale farmers.
7. Agriculture extension department can play pivotal role in conducting targeted awareness campaigns through demonstration events to educate farmers on economic and environmental benefits of agricultural UAVs.
8. Establishement of local workshops for repair and assembling of UAVs is necessary to provide timely maintenance services and reduce reliance on expensive imports.

Implementation of these policy recommendations will boost the adoption rates of UAVs in Pakistan and overall precision agriculture technolgoies. Pakistan need to incorporate these technologies to ensure sustainable crop production and food security.

REFERENCES

Fulton, J. P. & Port, K. (2018). Precision agriculture data management. In D. K. Shannon, D. E. Clay, & N. R. Kitchen (Eds.), *Precision agriculture basics.*; Wiley Online Library: Hoboken, NJ, USA.

Lamb, D. W. & Brown, R. B. (201). Pa—Precision agriculture: Remote-sensing and mapping of weeds in crops. *J. Agric. Eng. Res., 78*, 117–125.

Moskvitch, K. (2015). Take off: are drones the future of farming? *Engineering \& Technology, 10*, 62–66.

APPENDIX A: KEY FINDINGS FROM THE INTERVIEWS WITH KEY STAKEHOLDERS

****Private Service Providers, Agrochemical Companies****

1. Constraints in Purchasing/Importing UAVs:
   - What challenges do you face when purchasing or importing UAVs?
   a. No availability of policy document for guidelines to import, purchase, and usage of drones
   b. Lack of clear guidelines and organizations to contact for obtaining NOCs to operate and import drone.
   c. Lengthy and repetitive documentation
   d. Unnecessary delays in various national and local administrative offices for application of purchase licensing
   e. No clear background check mechanism
   f. High purchase cost of UAVs
   g. Absence of competing markets to purchase drones at reasonable prices
   h. Importation of parts are easier compared to a complete UAV.
   i. Absence of after sale markets to purchase parts to repair drones
   j. Use of private channels to import undocumented drones because of large demand
   k. Currently, MoD and Interior Ministry are issuing NOCs for importation of drones to some large groups.

2. Service Delivery and Pricing Mechanism:
   - How is your current service delivery structured?
     a. Service delivery model.
        i. Traditional In-Person Model: Agrochemical companies are providing the in-person model by providing information to farmers at their distribution centers. Mainly agrochemical companies *(Star Group (Pvt) Limited)*. They have private drone operators in their contacts.
        ii. eCommerce Model: Companies rely on eCommerce such as Facebook *(GrowTech (Pvt) Limited*). *Sapphire, Concave Agri,* and *AeroVision (Pvt) Limited* are also relying on their web platform for acquisition of services.
        iii. Pier to Pier Model: *FACE* is using the platform of *FFC* to provide drone services to their customers. *RaviEngineering (Alkaram AgroTech Services) are* using the leads generated by the *Syngenta* distribution network for acquisition of drone for spraying by the farmers in their localities.
   - What is your pricing model?
        i. Usage-Based Model: Usage based models are adopted by the *GrowTech, Sapphire group, FACE, RaviEngineering*. Their pricing structure varies from 700 per acre to 2400 per acre. The conditions are minimum landholdings (ranges between 5 acres to 500 acres) and average distance from distribution centers.
        ii. Per-Added-Module Model: *Star Group (Pvt) Limited* is offering their customer discounted rates for drone spraying with purchase of agrochemicals from their distribution centers.
        iii. Per-User Model: *GrowTech* is also relying on per-user model to execute their spraying for small landholding farmers by managing the leads generated in the same vicinity on same day. However, their minimum acreage is 5 acre/farmer.

   - What are the main factors driving the current pricing mechanism?

a. Availability of drones in the vicinity
b. Minimum acreage
c. Fuel and other commodities prices.
d. Distance from the service provider base

3. Operational Constraints and Skill Requirements:

- What operational challenges do you encounter?
  a. Skilled labor shortage to operate drone.
  b. Technology integration and propagation at farmer's level
  c. Regulatory compliance in some areas is restricted by the local administrations.
- What skills are necessary to effectively operate UAVs?
  a. Crop knowledge, diseases, and pests' knowledge.
  b. Drone operating skills, safety measures, technical education.
  c. Climatic conditions awareness such as temperature and wind
- What is your opinion regarding the skillset of UAV operators? Should he/she be certified by any national institute such as TEVTA/NAVTCC?
  a. Proper courses on drone usage
  b. Crop identification and classification knowledge as modules.
  c. Certification and background clearance to operate drones.
  d. Training courses should be offered as per market demand as it is a very specialized field.

4. Market Constraints and Limitations:

- What is the general response of farmers regarding willingness to adopt UAVs in agriculture?
  a. Overwhelming positive response among farmers
  b. Less interest by older farmers
  c. More interest by young farmers
  d. Few concerns regarding availability during field season

- What are the current market limitations for UAVs?
  a. Small landholdings of farmers
  b. Lack of infrastructure to provide services at village level
  c. Economic conditions of farmers
  d. Less demand due to limited availability of drones
- How do you see market expansion if UAV policy is launched?
  a. Local purchase will be easier.
  b. Establishment of service stations
  c. More market competition
  d. Easy procedure for drone imports
  e. Policy must be service provider friendly, and farmer friendly as stringent policies will discourage service providers.
- How do you see the role of commercial banks in a widescale spread of UAVs in agriculture?
  a. Rapid expansion as initial price is very high.
  b. Inclusion in the subsidized packages offered by the Government through banks.
  c. Depends on the market demand as banks might be reluctant to include UAVs in their loanable items.

5. Required Changes:
   - What changes do you believe are necessary for improvement?
     a. Easy access to drone service providers for farmers
     b. More literature availability for extension staff to aware the farmers about the benefits of drone usage
     c. Trained UAVs operators with basic agriculture background

6. Governmental Support:
   - What kind of support is required especially from Govt. side?
     a. Availability of policy to use drones
     b. Subsidy on drone purchase
     c. Better training of farmers and drone service providers

****Government Institutions****

- **Ministry:**
   - What is the current policy regarding UAVs?
     a. No policy is in the implementation stage.
     b. Drone use policy for agriculture purposes is being devised in final stages by Interior Ministry and MoD
     c. Punjab government have developed SoPs for use of drone through Home Department and DC office.
   - What role does your department play concerning UAVs?
     a. MoST has devised the initial policy with the cooperation of all stakeholders.
     b. Provide technical feedback on issues regarding the safe use of drones.
   - What should be done about UAVs?
     a. Regularization of existing use
     b. Better background checks
     c. Development of safe zones for agriculture usage
   - What are the current regulations concerning UAVs?
     a. No current official regulations. NOCs can be issued by the Ministry of Interior and Ministry of Defense for importation of drones.
   - Are there any commercial companies approaching to get NOCs for drone importation?
     a. Yes, AlKaram Agroctech has obtained NOC to import XAG drones in Pakistan.
     b. Few other companies have also contacted to obtain licenses to operate drones.
   - Is there any kind of demand from farmers regarding drone importations/implementation in agriculture?
     a. Few corporate farmers have contacted to allow drone purchase.
     b. Feedback from field office of agriculture department is informed ministry that farmers are interested in drone purchase.
   - What is the current procedure such as no. of NOC required, the time required for the complete procedure when allowing someone to buy/use UAVs.
     a. NOCs of the Ministry of Interior, Ministry of Defense, Ministry of Agriculture, and DC office are required to operate drones. However, the proper procedure has not been devised to date.
   - How many drones are allowed to date or for what purposes can you share data?
     a. There is not much information about it.

b. Few centers received as Gift from China while FACE –Rahim yar Khan announced availability of 50 UAVs for the farmer's service. Some startups are providing private services as well.

- How many companies are registered for providing UAVs services to farmers.
  a. No company is officially registered to date. However, some companies are providing services locally.

****National Agricultural Research Center, Atomic Energy Commission, Ayyub Agricultural Research Center, and Agricultural Universities in Punjab (University of Agriculture, Faisalabad. MANSUA, Multan)****

1. Use of UAVs in Operations:
   - What do you say about the potential of UAVs in agriculture?

   a. UAVs play a very important role in agriculture.
   b. In plant protection, when there is pest control for disease, sometimes it is not possible to do it manually or with a tractor or any big machine.
   c. Drone is a very good equipment that can spray uniformly.
   d. Weed and disease management in tall crop such as Maize or Sugarcane.
   e. Orchard spraying
   f. Time savings and timely spraying
   g. Cost effectiveness

   - Are you currently utilizing UAVs in your operations?

   a. Drones donated by different countries are operational in NARC, UAF, and ARID.
   b. Some drones are locally purchased as well
   c. Used to conduct limited scale studies basically ofr R&D purposes

2. Experience with UAVs:
   - What has been your experience using UAVs?

   a. Effective time management and less laborious
   b. Better and uniform spray coverage compared to other methods.
   c. Non-destructive method of spraying
   d. Proper training is required to operate drones.
   e. Proper agriculture knowledge is necessary in terms of agrochemicals and crop types.

   - What are the impacts of using UAVs on plant growth and productivity?
     a. Preliminary studies conducted at ARID, UAF, and NARC have showed positive results in different cropping systems.
     b. Saving of agrochemicals between 5 to 20%.

c. Large scale testing is required for proper insights.

3. Cost-Benefit Analysis:
- Have you conducted a cost-benefit analysis of using UAVs?

a. Only a few studies conducted on cost-benefit analysis.
b. ROI of 2 to 5 years for more than 500 acres farms
c. Benefits in terms of labor savings and time saving between 10 to 40% depending on the sprayed acreage (large acreage results in more savings)

4. Constraints:
- What legal, technical, and operational challenges do you face?

a. Not been allowed by the Government of Pakistan yet.
b. No large-scale implementation due to unavailability of commercial drones
c. Publications are not easy due to above mentioned reasons.
d. Lack of proper trained staff to operate drones
e. Lack of data for drone testing in each crop
f. Data interpretation skills for UAV related data
g. Proper maintenance training to repair and maintain drones
h. Safety training and SOPs for operating UAVs

- What is the role or potential role of NARC in developing/implementing UAVs policy?

a. PARC is a Federal Institution
b. Provide feedback to MoST on drone policy development and implementation in agriculture
c. Safety guidelines
d. Feasibility studies on drone use for cost effective crop management

****Agriculture Department Punjab (Extension Department, Engineering Department)****

1. Role in UAV Deployment:
- What is your department's role concerning UAVs?

a. Conduct feasibility studies for agricultural land management
b. 3D modelling of soils
c. Demonstration plots for farmers in different districts of Punjab
d. Provide technical and awareness documentation to farmers
e. No current use due to unavailability of drones' policy

2. Limitations:

- What are the limitations regarding UAVs, including skill sets and the availability of trained experts?

a. The biggest limitation is non availability of skilled workers. All the people working in the field areas are agronomists.
b. Lack of basic engineering knowledge
c. No training program for developing skill sets to operate drones.

- What are the limitations of staff regarding highlighting the importance of UAVs among farmers?

a. Lack of trust to adopt innovative technologies
b. All the field workers who are working in the field, no one is given drone training.

3. Market Development Potential:

- If your department were to lead the development of the UAV market, what potential do you see?

a. There is a lot of potential. There are 28 offices across Punjab. From Potohar to Rajanpur, the network is very strong. There are 15 to 20 staff in each office. Whether they are assistant directors, deputy directors, or director level, they are all further distributed.
b. Engineering and extension department should play a role where there is a lot of potential to cover large area and rapid technology transfer
c. Rental spaces for service providers
d. Proper training of service providers at Department's regional offices
e. Large network of farmers allows better knowledge sharing

APPENDIX B: FARMERS SURVEY QUESTIONNAIRE

PART 1. A: Data on Socio-Economic Variables:

District		**Tehsil**		**Union Council**		**Village**	
Name (Respondent)			**Contact No.**			**HH GPS code**	**N:** **E:**
HH Members	**Gender**	**Age**	**Education**	**Marital Status**	**Occupation**		**State if primary occupation is:**
Relation with HH 1*	**M=1, F=2**	**Years**	**2***	**3***	**Principal Means of Livelihood 4***	**Secondary Means of Livelihood 4***	**1. Outside village** **2. In urban area**
Household Head 1							
Family Size							

1* Self [1]; Wife/husband [2]; son/daughter [3]; son/daughter in law [4]; Grandson/daughter [5]; Mother/father [6]; Brother/sister [7]; other relatives [8]; other non-relatives [9]
2* Read & write [1]; primary [2]; middle [3]; Matriculation [4]; intermediate [5]; graduate [6]; masters [7]; illiterate [8]
3* Married [1]; Single [2]; Divorced [3]; Widow/er [4]
4* Farming [1]; private employee (e.g. small business/ shop) [2]; Government employee (e.g. teacher, peon)[3]; daily wage earner [4]; Fishing [5]; Other _____[6]

B: Tenure Arrangements:

Land information		Total Cultivated Area (Acres)	Own Land (Acres)	Land Rented In (Acres)	Land Rented Out (Acres)	Fallow Land (Acres)
Season	Rabi					
	Kharif					
Distance from field to home (1-way km)						
Quality of Soil. (1. Low; 2 Medium, 3. High)						
How many years have you continuously used this plot?						
Rent paid/ received if plot is leased? (PKR / year)						

C: Agricultural Products: Outputs, and Prices: [seasons: Kharif (May - September); Rabi (Oct - April)

Season	Crop	Area	Planting Date	Harvesting Date	Average Production in the previous year	Average Production in the current year	Post - Harvest losses	Quantity Sold	Price
		Acres	Day-Month		(PKR/ Maund)				
Rabi									
Kharif									

*** 1. How far is it to the market where you purchase your inputs? One way distance _____(km)**

2. What kind of transport do you mostly use to bring input from the market? _____ (walk, bicycle, motorcycle, local bus, rented vehicle, push cart)

3. One way cost for a visit _____(PKR) (Not to be filled if farmer receives delivery of inputs by a middleman etc.

D: Agricultural Products: Inputs, and Prices

Crop	Seed			UREA			DAP			Nitrophas		
	Quantity Kgs	Cost per Kg, PKR	Source*	Quantity (Bags)	Cost per Bag (PKR)	Source*	Quantity (Bags)	Cost per Bag (PKR)	Source*	Quantity (Bags)	Cost per Bag (PKR)	Source*
Rabi												
Kharif												
Season	**S.O.P**			**Others ( )**			**Manure**			**Herbicide / Weedicide**		
	Quantity (Bags)	Cost per Bag (PKR)	Source*	Quantity (Bags)	Cost per Bag (PKR)	Source*	Quantity (trolleys)	Cost per trolley (PKR)	Source*	Quantity Liters	Cost per Liter, PKR	Source

Rabi												
Kharif												

Season	**Pesticides**			**Usage of Water**								
	Quantity	Cost	Source	Source	Canal Water Applications		Tube Well Applications		Who owns tube well?	Fuel expense	Rent If Borrowed	Method to water your farm?
	Liters	1Liter/PKR		*1	Nos	Hours / application	Nos	Hours / application	*2	PKR / Hour	PKR / Hour	*3
Rabi												
Kharif												

* On cash payment from market/ local dealer (1); on credit from market/ local dealer (2); on cash from Middleman (3); On credit from Middleman (4); free from middleman (5); free from Landlord (6); on credit from land owner (7); Government (8); NGO/agricultural extension (9); other, pls. specify _____ (10)

*1. Canal (1); Tubewell (2); Rain fed (3); Other (specify_) (4)

*2.Personal (1); rented from neighbor (2); rented commercially (3); free/ subsidized rate from landlord (4)

*3. Drip Irrigation (1); Flood irrigation (2); Sprinkler irrigation (3); Furrow irrigation (4); other (specify) (5)

UAVS/DRONES USE AND WILLINGNESS TO USE

1. Do you know about UAVs? Yes No
2. How did you know about UAVs?

A) Word of Mouth (B) Youtube (C) Facebook/Whatsapp (D) Newpaper (E) Extension work (F) Agriculture Exhibitions (G) Any other _____

3. Are you currently using UAVs? Yes No

If yes, tick all relevant 1) for spraying 2) for monitoring (3) (4)

4. Do you know using UAVs reduced the cost of production by---- percent? Yes No
5. Do you know using UAVs reduced Labor costs by----- percent? Yes No
6. Do you know using UAVs reduced the spray cost by----- percent? Yes No
7. Do you know using UAVs in the spray cost by----- percent? Yes No

Scenario Description: Imagine a service that uses drones for crop spraying in your area. This service would cost Rs. 500 per acre per season. Would you be willing to pay this amount for the drone service?

a. Yes No

8. Payment Willingness: What is the maximum amount you would be willing to pay for the drone service per acre per season? Please specify an amount in Rs.

9. Reason for Your Decision: If you answered 'No' to the previous question, please indicate your reason for not being willing to pay

A) Cost (B) lack of perceived benefit (C) alternative methods available

10. Likelihood of Adoption: If the drone service is available at your preferred price, how likely are you to adopt it?

1. Very likely somewhat likely Not likely

11. Benefit Perception: How beneficial do you believe drone technology would be for your farming?

a. Very beneficial somewhat beneficial Not beneficial

12. Frequency of Use: If you were to use drone technology, how frequently would you use it?

a. Once a season Twice a season Monthly Weekly

13. Preference Ranking: Please rank the following attributes in order of importance when choosing a drone service for agricultural use (1 being the most important):

Cost_____ Spray Efficiency _____ Monitoring Frequency_____ Support Services_____

14. Have you attended any training sessions or workshops on UAV technology? Yes No

If yes, who organized the training/workshop?

a. Government NGO Private Organization Other (Specify) _____

15. Would you be interested in training on drone usage for agriculture? Yes No

16. What is your preferred method for learning about UAVs?

a. Online Tutorials In-person Training Printed Manuals Demonstration in Fields

17. Do you use any of the following technologies?

a. GPS-enabled equipment Variable Rate Applicators Remote Sensing Devices

b. Mobile-based agricultural apps IoT sensors for soil and water monitoring

18. How frequently do you adopt new technologies in your farming practices?

a. Every season Once a year Rarely

19. Which factors prevent you from adopting advanced technologies?

a. High Cost Lack of Awareness Lack of Technical Support Other (Specify)

20. Are you aware of how UAVs can reduce the environmental impact of farming (e.g., reduced pesticide runoff)?

i. Yes No

21. What steps do you take to ensure sustainable farming?

a. Organic Farming Efficient Water Use Integrated Pest Management

b. Soil Health Monitoring Other (Specify)_____

22. Which payment model would you prefer for UAV services?

a. Pay-per-use (per acre/per season) Subscription (Monthly/Yearly) Revenue-sharing Model (Based on increased yield)

23. Would you be interested in government-subsidized UAV services? Yes No

Heavy Machinery: (Enter cost in PKR/Acre, in case of rental machinery Enter rental cost in PKR/Acre)

Season	**Crop**	Plough	Rotor weigh	Leveler	Ridges	Cultivator	Reaper	Thresher
Rabi								
Kharif								

*1 Personal (1); landlord (free) (2), land lord rented (3), middleman/trader free (4), middleman rented (5) Rented from markeT **Labor Composition:** No of family member involved in farm work _____

Stages	**Seasons**	**Rabi 2023-24**	**Kharif 2023-24**	**Rabi 2022-23**	**Kharif 2022-23**
	Crop				
Land Preparation and Sowing	Nos				
	Days				
	Type				
Field Management (Irrigation, Fertilizer, Weeding, Water and Pesticides)	Nos				
	Days				
	Type				
Harvesting	Nos				
	Days				
	Type				
Post Harvesting	Nos				
	Days				
	Type				

1. Family 2. Hired 3. Mix

E: Information Related to Household Assets Owned; Quantity and Value

Type of Assets		Owned Quantity	Approx. Value Rs. / Unit	Getting Dairy Products Yes = 1, No = 0	**Type of Assets**	Owned Quantity	Approx. Value Rs. / Unit	Getting Dairy Products Yes = 1, No = 0
Land (Acres)				N/A				
Livestock	Cows				Goats			
	Buffalos				Sheeps			
	Poultry				Other Birds			
Agricultural Equipment	Plough			N/A	Cultivator			N/A
	Rotor weigh			N/A	Reaper			N/A
	Leveler			N/A	Thresher			N/A
	Ridges			N/A	Tractor			N/A
	Generator			N/A	Loader			N/A
	Trolley			N/A	Cart			N/A
Electronic Appliance	TV			N/A	Computer			N/A
	Radio			N/A	Other			N/A
Communication	Telephone (PTCL)			N/A	Mobile Phone			N/A
	Internet			N/A				N/A
Domestic Appliances	Washing Machine			N/A	Fridge			N/A
	Refrigerator			N/A	Others			N/A
Motorized Transportation	Bike			N/A	Car			N/A
	Truck			N/A				N/A

Thank you for your time and cooperation