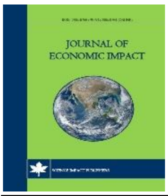

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FARMERS' DECISIONS ON SUSTAINABLE CROP RESIDUE MANAGEMENT: A CASE STUDY FROM PUNJAB PROVINCE, PAKISTAN

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ABSTRACT

The sustainable management of crop residue is termed a win-win strategy for sustainable agriculture production and the abatement of carbon emissions from the agriculture sector. Therefore, it is essential to propose future policies on the promotion of sustainable crop residue management to contribute to a more bio-based circular economy. Nevertheless, there is a lack of understanding about the decision-making processes underlying the use of sustainable crop residue management at the farm level by farmers. The objective of this study is to understand the farmers' decisions in terms of adopting sustainable and alternative crop residue management practices. For this purpose, a survey was conducted from three agro-ecological zones of Punjab, Pakistan, and a multivariate probit approach was employed to analyze factors affecting farmers' decisions on the use of different practices. The results revealed that farmers were becoming more interested in using sustainable crop residue management practices despite a number of challenges. The majority of farmers are currently using crop residue for their animal feed and are willing to use it as a bio-fertilizer, also for energy purposes in bio-gas plants. These results hold true for a wide range of countries with notable spatial variations in livestock density, particularly for those with ambitions to use crop waste more sustainably and effectively. The findings of the study recommend that improving crop residue on-farm use requires a combination of appropriate crop residue management practices, such as a clean energy source, accurate and easily accessible information about the efficacy of crop residue management practices, and proper regulations and enforcement. To improve farmer participation, adequate extension services, training, and credit facilities are necessary to enhance the farmers' capacity in reusing crop residues.

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INTRODUCTION

In developing countries that heavily rely on agriculture, there is an increasing need to reuse and promote timely utilization and valorization techniques in order to reduce pollution and utilize agricultural waste sustainably (Gupta et al., 2016; He et al., 2016; Jiang et al., 2018a). Crop residue is an agricultural waste that can be reused and recycled in a variety of ways, i.e., used as fertilizer, mulching, and helping to reduce waste pollution (Lin et al., 2014; Raza et al., 2019; Zhao et al., 2017). Additionally, it will aid in reducing to reduce soil erosion, smog, threats to biodiversity, water shortage, risks of drought, and agro-ecosystem resilience (Chalak et al., 2017; Jiang et al., 2018b). Moreover, sustainable management of crop residues can involve reducing the greenhouse gas emissions from the open burning of the crop residues (Haider, 2013; Irfan et al., 2015), which are not only impairing the local environment but also a major contributor to global warming.

In recent years, some Asian, European, and African countries have implemented new technologies and sustainable crop residue management practices, such as biogas plants, on-farm use, animal feed, and bio-fertilizers. These innovations have successfully increased farm productivity while significantly reducing pollution (Feiz and Ammenberg, 2017; Jaleta et al., 2013; Sárvári Horváth et al., 2016; Tittonell et al., 2015). Hence, adopting sustainable residue management practices and technologies may help to reduce ecological environmental pollution, and contribute to energy savings and household income.

Few studies have reported the adoption or acceptance of different crop residue management practices in a sustainable and environmentally friendly way by the farmers (Abbas et al., 2017; Norse and Ju, 2015; Shehrawat et al., 2015). On the other hand, a lack of harvesting technology, transportation, and a labor shortage are contributing factors that influence farmers' crop residue retention (Akteruzzaman and Zaman, 2013). Ngwira et al. (2014) discovered in a survey of 524 farmers that membership in a farmer group influenced large landholders' attitudes toward adopting conservation agriculture practices. Mugerwa et al. (2012) surveyed 150 Ugandan farmers and discovered that due to a lack of feeding products, most farmers used crop residues for animal feeds. Pandit (2017) found that young and educated farmers with larger farm sizes are more concerned about the negative effects of burning. Furthermore, lack of knowledge, lack of a market, and ease of collecting biomass were major factors influencing willingness to use crop residue sustainably. Hence, more likely that farmers are willing to understand the adoption of sustainable residue management practices.

The adoption and diffusion of agricultural innovations largely depend on numerous factors, such as the qualities of innovation, farm size, and farmer characteristics, and farmers' behavior towards innovation or broad environmental issues. The impact of these factors on farmers' adoption of new technologies and innovations has been extensively analyzed by various researchers (Chalak et al., 2017; Jallow et al., 2017; Leite et al., 2015; Mastrangelo and Laterra, 2015). Although these factors have been highlighted and briefly explained in the previous studies, the majority of these factors are demand-side factors, e.g., factors affecting the farmers' behavior towards a product or their capacity to use it. However, supply-side factors such as huge distances from the innovation or a lack of infrastructure or equipment can also be hurdles to the adoption (Case et al., 2017), and the current study also incorporates supply-side factors.

Pakistan, which has the second-largest cultivated land area in South Asia, produces approximately 225,000 tons of crop residue each year (Bank, 2016). The majority of the crop residue is managed by open-field burning in order to prepare the field for the next crop (Ahmed et al., 2015a; Irfan et al., 2015). On average, 85% of farmers partially or fully burn residues of their crop (Ahmed et al., 2015b; Haseeb Raza et al., 2022). Therefore, certain legislation and a good understanding of agricultural innovations by farmers and other stakeholders are needed to increase the adoption of sustainable crop residue management practices.

Despite these facts, adoption of the sustainable crop residue management practices and new technologies (i.e., mulching, the conversion of crop into energy, and bio-methanation technology) has been below expectations in Pakistan. These sustainable crop management practices and technologies were introduced many years ago, but still, a large segment of the farming community is reluctant to adopt them due to several economic and technical issues that exist. These issues need to be addressed for the success of these sustainable crop residue management practices.

At present, the literature about the use of crop residue for energy purposes is rich. Nevertheless, from the perspective of the farmers attitude towards the adoption of sustainable residue management practices is very rare in Pakistan. Therefore, successfully achieving targets for increased use of sustainable crop residue management practices depends partially on the assumption that farmers are willing and interested in adopting these practices. Nevertheless, no study has been conducted to investigate farmers' attitudes toward the adoption of sustainable crop residue management practices along with supply-side factors. Further, the result of this study would be helpful in enhancing efforts for a cleaner environment and sustainable agricultural production.

The overall objective of this study is to understand the farmers' decision in terms of adopting sustainable and alternative residue management practices and their interest in sustainable practices in the future. The particular interest is the factors that influence the decision to adopt the sustainable residue management practices that they currently do not use. Specifically, our study has two objectives: 1) to understand the current adoption of farmers in terms of crop residue utilization practices, and 2) to investigate farmers' intention in terms of future adoption of crop residue utilization practices.

METHODOLOGY

The assumption of this study is to start with farmers' perception of environmental pollution, focusing on the consequences of smog and air pollution due to the burning of crop residue over the past few decades. There are some external and internal factors influencing their burning of crop residues. Therefore, understanding the farmer's current adoption practices and perception of future adoption is very important. Consequently, the influence of the socio-economic factors on the current adoption and future willingness needs to be explored and publicized for the betterment of climate change mitigation efforts. For this reason, we selected four currently available (used) residue management practices at the farm level and investigated the influence of the factors on the adoption of these practices. Furthermore, for future adoption, we selected five practices and investigated the impact of socio-economic factors on the farmers' attitude about adoption.

Survey Design

In order to investigate farmers' behavior towards current adoption and future willingness to adopt the SCRMPs, we designed a questionnaire-based survey. The questionnaire was designed after consultation with the experts of the Punjab Agriculture Department and modified with the input gained from local representatives of the extension department and farmers. The questionnaire was divided into six main sections: Demographic, Farmer and farm characteristics, Current management practices, future interest in management practices, and advantages in the adoption of SCRMPs.

Study Area and Sampling Procedure

Due to many reasons, the Punjab province was selected as the main study area. As a larger contributor to the cereal crop production of Pakistan, almost 74% and also makes a significant contribution to the agricultural gross domestic product (GDP) (53%). Further, in the recent past, massive-scale crop residue burning was reported in Punjab province (Ahmed et al., 2015b; Singh and Kaskaoutis, 2014). Most of the crop residue is managed through open-field burning, and some portion is used for domestic cooking purposes (Ghafoor et al., 2016; Irfan et al., 2014). The cross-sectional data were collected for this study. To quantify the variation in the different crop residue practices, Punjab province could be divided into five agro-climatic zones: wheat-rice zone, cotton-wheat zone, mixed cropping zone, barani (arid) zone, and low crop intensity zone (Ahmed et al., 2017; Chaudhry and Rasul, 2004). The study was mainly conducted in these districts: Gujranwala from the rice-wheat zone; Faisalabad from the mixed cropping zone; and Rahim Yar Khan from the Cotton-Wheat-Sugarcane zone. The map of the study area and selected districts is shown in Figure 1.

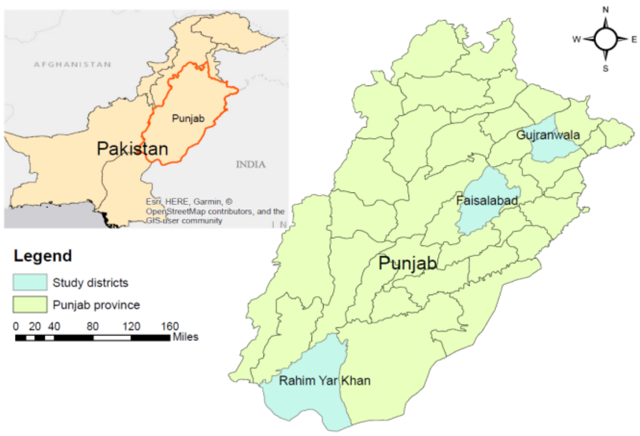

Figure 1. Study area map.

The data was collected through face-to-face interviews with farmers in February-March 2018. Fourteen union councils were selected randomly from each district. With the help of the agriculture department, random farmers were selected. Respondents were asked about the current residue management practices and their future interest in the SCRMPs. For this purpose, we recorded the responses of the farmers about different management practices given in the questionnaire.

Data Analysis

On the basis of the contemporary review of relevant literature, several farm/farmer characteristics such as education, age, annual income, ownership of tube well, tractor trolley, rotavator, Disc plough, Thresher, distance from output market, Distance from the tarred road, access to extension department, weather information, canal water information, Credit access, and the farming area used as independent variables shown in Table 1, as these characteristics can influence farmers' current management practices and future interest in the adoption of agriculture innovation and technology (Manda et al., 2016; Nkomoki et al., 2018). The dependent variables used in the study were current residue management practices, i.e., on-farm use, animal feed, used for residue retention, and bio-fertilizers. The five other dependent variables, i.e., on-farm use, animal feed, used for residue retention, bio-fertilizers, and biogas plants, are of future interest to the farmers.

Following Akhtar et al. (2017), Case et al. (2017), and keeping in view the dichotomous nature of the dependent variables multivariate probit model is used to predict the probability that independent variables influence the output of the dependent variables. For this study, multivariate probit models were used to determine the influence of independent variables on the SCRMPs. The multivariate probit models were run using STATA 15.0.

RESULTS AND DISCUSSION

Descriptive Statistics

In the Table 2 presents the descriptive statistics of the variables used in the analysis. For this study, two types of variables were used such as continuous and discrete choice dummy variables. The results showed that the mean age of the farmers was 44 years, which shows that farmers were middle-aged and with less knowledge. The mean year of education was seven for the respondents, which is within the national level. The average farm size of the sampled farmers was about 13 acres; land holding is comparatively high in the surveyed districts because farmers are mainly dependent on income from farming. The average distance from the main market to the farm is 11 km. Further, we asked about the machinery and extension services available from the farmers.

Table 1. Variable definition.

Variables	Measurement	Definition
Education	Continuous	Number of years
Age	Continuous	years
Income	Continuous	Income in PKR
Farm size	Continuous	Farm size in acres
Tube well ownership	Dummy	1, if yes; 0, otherwise
Tractor Trolley	Dummy	1, if yes; 0, otherwise
Rotavator	Dummy	1, if yes; 0, otherwise
Disc Plough	Dummy	1, if yes; 0, otherwise
Thresher	Dummy	1, if yes; 0, otherwise
Distance output market	Continuous	Number in Km
Tarred Road	Continuous	Number in Km
Member of Farmers' organization	Dummy	1, if yes; 0, otherwise
Extension Services	Dummy	1, if yes; 0, otherwise
Credit	Dummy	1, if yes; 0, otherwise
Weather forecast	Dummy	1, if yes; 0, otherwise
Canal water information	Dummy	1, if yes; 0, otherwise
Gujranwala	Dummy	1, if yes; 0, otherwise
Faisalabad	Dummy	1, if yes; 0, otherwise

Table 2. Descriptive statistics of factors influencing farmers' current and future interest in SCRMPs.

Variables	Mean	Standard deviation
Education	7.019	4.54
Age	44.0	13.04
Income	542445.2	457808.2
Farm size	13.34	16.26
Tube well ownership	0.67	0.94
Tractor Trolley	0.24	0.43
Rotavator	0.23	0.42
Disc Plough	0.38	0.48
Thresher	0.12	0.33
Distance output market	11.14	9.35
Paved Road	2.24	2.70
Member of Farmers' organization	0.05	0.22
Extension Services	0.63	0.48
Credit	0.67	0.47
Weather forecast	0.63	0.48
Canal water information	0.54	0.50
Gujranwala	0.33	0.47
Faisalabad	0.33	0.47

Crop Residue Management Practices Available

Overall, almost 35% of farmers manage their crop residues by using them in on-farm activities. A large number of farmers used crop residue in livestock feed, accounting for nearly 66% of the sample size. Likewise, approximately 29% of the farmers managed residue retention through conservation agricultural practices. Only 5% used their crop residue as a bio-fertilizer mainly the majority of the farmers were likely unaware, and limited local access to bio-fertilizer preparation methods is the main hurdle in the adoption of this practice. In addition to this, crop residue use for biogas production is uncommon in rural areas due to a lack of awareness.

The multivariate probit regression was used in the present study to investigate the factors that affect farmers' current adoption of crop residue management practices. The results (presented in Table 3) demonstrated how socioeconomic factors affected the probability of on-farm use of crop residual management. The education, age, own tube well, and extension services all significantly influence the on-farm use practice. Farmers' education levels were positive and significant at 1% and 10% levels, indicating that more educated farmers adopt on-farm use and livestock feed strategies respectively. The findings of this study are consistent with those of Kumar et al. (2015) and Mugerwa et al. (2012), who reported that educated farmers prefer to use crop residual for livestock over burning.

In cases of on-farm use, the age coefficient was positive and significant at 1%, indicating that older-age farmers prefer the on-farm crop residue strategy over younger-age farmers. However, the age coefficient for residue retention is negative and significant at 5%, indicating that this strategy is used by young farmers. The findings are in line with the results of (Buurma and van der Velden, 2017), young farmers are more inclined to adopt new technologies.

Farmers' income for the crop on-farm use and livestock is negative, indicating that farmers with lower incomes use the residual on-farm and for livestock purposes, while wealthier farmers are more likely to choose residue retention and bio-fertilizers as crop residual management. Farmers with large farm sizes are more likely to choose bio-fertilizers, as crop residual management and income coefficient also support this finding. Income and farm size for the adoption of bio-fertilizer are statistically significant.

A number of farm instruments such as disc plough and thresher were also included in the model, indicating that farmers who owned these farm instruments used various crop residue management strategies, such as tube-well ownership is found to be beneficial and significant for livestock feed, on-farm use, residue retention, and bio-fertilizers, indicating that farmers who own tube wells implement these strategies on their farms more diligently. Tractor trolley is also positive and significant for on-farm use and residue retention. Rotavator was found to be positive and significant for livestock feed and bio-fertilizers. Extension services are positive and significant for livestock feed, residue retention, and bio-fertilizers, revealing that farmers who are taking extension services use crop residue for livestock feed, residue retention, and bio-fertilizers.

Furthermore, analysis was done according to cities, namely, Gujranwala and Faisalabad, and found that farmers of Faisalabad have a negative and significant adoption for livestock feed. The results also revealed that farmers of Gujranwala and Faisalabad are willing to adopt residual retention (coefficient = 0.83, $p < 0.01$) and (coefficient = 0.58, $p < 0.001$) respectively.

Table 3. Model results of available crop residue management practices.

Independent Variable	Dependent Variable			
	On-farm use	Livestock feed	Residue retention	Bio-fertilizer
Education	0.04(0.02) *	0.05(0.01) ***	0.02(0.017)	-0.01(0.031) ***
Age	0.03(0.00) ***	0.00(0.00)	-0.01(0.00) **	0.00(0.01)
Income	-0.00(0.00)	-0.00(0.00)	0.00(0.00)	0.00(0.00)
Farm size	0.00(0.01)	0.00(0.00)	0.002(0.00)	0.02(0.00) ***
Tube well ownership	0.02(0.11) ***	0.10(0.07)	0.09(0.083)	0.37(0.32)
Tractor Trolley	0.25(0.34)	-1.00(0.27) ***	0.53(0.26) **	-1.47(0.44) ***
Rotavator	-0.22(0.37)	1.83(0.34) ***	-0.21(0.28)	0.95(0.44) **
Disc Plough	0.25(0.24)	-0.09(0.18)	0.11(0.18) **	0.37 (0.31)
Thresher	0.74(0.55)	0.55(0.31)	0.39(0.30)	0.50(0.43)
Distance output market	0.01(0.01)	-0.02(0.00) ***	-0.00(0.00)	-0.02(0.015)
Paved Road	0.02(0.03)	-0.00(0.02)	-0.07(0.03) **	0.00(0.04)
Extension Services	-0.69(0.29) **	0.61(0.17) ***	0.90(0.19) ***	0.54(0.43)
Credit	-0.20 (0.22)	-0.37(0.166) **	0.35(0.17) **	0.09(0.29)
Weather forecast	0.03(0.26)	0.10(0.182)	0.43(0.19) **	0.98(0.49) **
Canal water information	-0.15(0.23)	0.08(0.16)	-0.05(0.16)	-0.09(0.29)
Gujranwala	0.31(0.25)	-0.18(0.33)	0.83(0.20) ***	-0.04(0.33)
Faisalabad	0.17(0.26)	-0.56(0.18) ***	0.58(0.19) ***	-0.28(0.37)
Log Likelihood	-109.78	-211.44	-205.19	-57.96
LR chi2(17)	44.60	118.44	70.56	73.63
Prob > chi2	0.00	0.00	0.00	0.00
Pseudo R2	0.1688	0.21	0.15	0.38

Note: ***, **, * significant at, 1% 5%, and 10%.

Crop Residue Management Suggested for the Future

In this section, we wanted to know if the farmer is interested in crop residual management in the future using the given strategy. Table 4 shows the results of the multivariate probit approach for future interest in SCRMPs. For residue retention, bio-fertilizers, and bio-gas plants, the coefficient of education is positive and significant at 1%, 5%, and 10%, indicating that highly educated farmers are more likely to be willing to adopt these practices. Results indicate that the role of educated farmers is vital to the success of environmentally friendly agricultural practices. The findings of our study are consistent with Abid et al. (2015)and He et al. (2016), who reported that young farmers and families were more interested in the adoption of pro-environmental agricultural practices.

Additionally, income is also a very important factor in the adoption of environmentally friendly agricultural practices. The income coefficient for biogas plants has a positive and significant effect at a 5% level, revealing that farmers with high income are more likely to adopt environmentally friendly practices. Habiba et al. (2012) and Arunrat et al. (2017) also confirmed a positive relationship between higher income and eco-friendly agricultural innovation adoption. Additionally, the adoption of bio-fertilizers is highly significant and positively correlated with farm size and tractor ownership. In addition, farm size is also highly significant for biogas plants. According to the findings, farmers with access to credit, a stable financial situation, large farms, and equipment are more likely to adopt agricultural innovation. The literature (Arunrat et al., 2017; Kokoye et al., 2013; Mohamed and Temu, 2008) also demonstrates a positive relationship between farm size, ownership of machinery, access to credit, financial stability, and adoption strategies.

Furthermore, city-wise analysis shows that farmers of Gujranwala continue using on-farm practice for crop residual management (coefficient = 0.32, $p < 0.01$) and (coefficient = 0.31, $p < 0.010$) shows their willingness to adopt a biogas plant for future use to manage crop waste. On the other hand, farmers of Faisalabad city are less inclined to adopt livestock feed as crop residual management practice (coefficient = -0.25, $p < 0.010$) respectively.

Table 4. Multivariate probit results of the crop residue management suggested for the future.

Independent Variable	Dependent Variable				
	On farm use	livestock feed	Residue retention	Bio-fertilizer	Biogas plant
Education	0.04(0.01) **	-0.01(0.01)	0.02(0.01) **	0.04(0.01) **	0.06(0.01) ***
Age	0.01(0.00) **	-0.01(0.00) *	-0.00(0.00)	0.00(0.00)	0.01(0.00) **
Income	0.00(0.00) ***	0.00 (0.00)	-0.00 (0.00)	-0.00 (0.00) ***	0.00(0.00) **
Farm size	0.00(0.00)	-0.00(0.00)	-0.00(0.00)	0.02(0.00) ***	0.01(0.00) **
Tube well ownership	-0.27(0.19)	-0.42(0.15) ***	0.16(0.15)	-0.09(0.20)	-0.32(0.19) **
Tractor Trolley	-0.24(0.25)	-0.38(0.23) *	0.23(0.24)	0.83(0.29) ***	-0.33(0.25)
Rotavator	0.49(0.27)	-0.45(0.26) *	-0.58(0.28) **	0.23(0.30)	0.39(0.27)
Disc Plough	-0.17(0.20)	-0.27(0.16) *	0.51(0.16) ***	-0.21(0.21)	-0.08(0.20)
Thresher	0.48(0.27) ***	1.01(0.26) ***	0.46(0.26) *	-1.07(0.32)	0.72(0.28) ***
Distance output market	-0.00(0.009)	-0.00(0.00) *	-0.00(0.00)	-0.00(0.00) **	0.00(0.00)
Paved Road	-0.05(0.03)	0.09(0.032)	-0.05(0.03)	-0.10(0.05)	-0.03(0.03)
Extension Services	0.24(0.22)	-0.08(0.17)	0.31(0.30) **	0.02(0.23)	0.34(0.22)
Credit	0.35(0.18) ***	-0.13(0.14)	-0.39(0.34)	0.32(0.18)	0.32(0.18) *
Weather forecast	-0.05(0.21)	0.32(0.16) **	-0.16(0.17)	0.24(0.23)	-0.22(0.21)
Canal water information	-0.08(0.18)	0.20(0.15)	-0.13(0.15)	0.32(0.19) *	0.00(0.18)
Gujranwala	0.32(0.21) ***	-0.025(0.17)	0.05(0.17)	0.32(0.22)	0.31(0.21) *
Faisalabad	0.09(0.21)	-0.25(0.16) *	-0.16(0.17)	0.23(0.22)	0.046(0.21)
Log Likelihood	-169.74	-260.72	256.07	-149.46	-169.97
LR chi2(17)	104.63	59.83	34.15	101.25	114
Prob > chi2	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.23	0.10	0.062	0.253	0.25

Note: ***,**, * significant at, 1% 5%, and 10%.

CONCLUSIONS

As environmental pollution is threatening climate mitigation efforts in Pakistan, crop residue burning is the major contributor to environmental pollution. Sustainable management of crop residue has become an important policy option to mitigate the haze during the winter season in Pakistan. Therefore, the timely adoption of these practices is desirable to reduce pollution, environmental degradation, and losses at the farm level. This study analyzes the farmers from Punjab, Pakistan, provides insight into the farmers' perception of their future interests and current management practices. Farmers adopt four measures to manage crop residue without burning. Further, farmers' opinion about their future interest in the practices was also inquired in this study. Analysis reveals that despite several obstacles, farmers are becoming more and more interested in using SCRMPs. These findings apply to a wide range of nations, especially those with ambitions to use crop waste more sustainably and effectively, like Australia and Brazil, and nations with significant spatial variations in livestock density. Southeast Asian nations have also started a variety of programs for the environmentally friendly use of crop waste. These initiatives are primarily concerned with the industrial use of crop waste and its transformation into various products. These programs continue to elicit little interest from the industrial sector, posing a significant problem (Lin et al., 2014). Effective environmental measures should be implemented to address the rapidly growing pollution problem. Our research suggests that a combination of appropriate crop residue management practices, such as a clean source of energy, accurate and easily accessible information about the effectiveness of crop residue management practices, and proper regulations and enforcement, is critical to improving crop residue on-farm use.

This study found that the rate of SCRMP adoption in Pakistan is being constrained by the expense of residue management, limited application times, cost, and labour availability. Therefore, successful policies to enhance farmers' perceptions and adaptive capacity can encourage both the actual and intended adaptation of farmers. Adaptation strategies require the participation of multiple players from all related sectors, engaging with local communities and farmers.

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