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Synergies and Determinants of Sustainable Intensification Practices in Pakistani Agriculture

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Abstract: Sustainable intensification practices (SIPs) involve a process to produce high yields for existing land without affecting the environment. The significance and relevance of SIPs in a Pakistani context demands an investigation. Hence, this study takes the initiative to investigate the determinants regarding the adoption of these practices. Based on the evidence, we selected five SIPs, namely, improved seeds, organic manure, crop rotation, intercropping, and low tillage. Furthermore, this study analyzes the adoption of SIPs with randomly collected data from 612 farmers through multistage sampling. A multivariate probit model (MVP) is employed to analyze the mutually dependent adoption decisions and identify the factors associated with them. The results revealed that education, the area under cultivation, access to information, extension access, social participation, rainfall variability, and temperature increase significantly predict the adoption of SIPs. The adoption of organic manure and crop rotation was highest between all the ecological zones, whereas low tillage was the least adopted practice. Adoption intensity in mixed cropping zones was slightly higher than the other ecological zones. Moreover, the findings also reveal the important synergies amid natural resource management and input-based SIPs. Hence, the study highlights the perseverance and importance of social groups and recommends the government to formulate comprehensive policies to facilitate institutional access and elevate the adoption level amongst the farming community.

Keywords: sustainable intensification practices; multivariate probit; adoption; synergies; Pakistan

1. Introduction

Asian agriculture is going through a tough period, as attaining an optimum level of production has become a difficult task. Ever-increasing population, urbanization, and climatic uncertainties are continuously posing threats to regional food security. Moreover, agriculture is a mainstay of people's livelihoods, as the majority of the working class are associated with agriculture.

The same is true in Pakistan's case, with a 19% contribution to the GDP and the engagement of 38.5% of the labor force working in agriculture, occupying a pivotal position in Pakistan's economy [1,2]. Besides farming, most of the farmers are also engaged in livestock ventures, which make Pakistan one of the top global milk producers. Despite being a vital part of Pakistan's economy, agriculture remains a backward sector, and a continuous slump in its performance is an open fact. The country's population is expected to surpass 229 million by 2022, and to feed the continually increasing population looks like a difficult task. Apart from the population pressure, the climate and land-use change continue to stress the fragile agriculture production system of Pakistan [3–5]. Corresponding to the emerging countries benchmark of 4%, the current agriculture growth rate of Pakistan is 2.8%, which is way below the baseline. This gap will continue to widen unless the country does not respond to the challenges [6,7]. A plethora of literature suggests the adoption of sustainable agriculture as a measure to combat environment adversaries and improve production [8–12]. The sustainable intensification of agriculture involves the enhancement of the agricultural production of existing farmland without leading to environmental damage [13]. This notion has received considerable attention since the late 1990s [11,12,14–17]. Sustainability assures high yields, even in the presence of climatic shocks, and promotes environmentally friendly practices. Sustainability requires the integration of multiple practices on a long-term basis, although there are no clear outlines on how the different activities should be combined in sustainable intensification to achieve desired environmental and agricultural outcomes.

Sustainable intensification contains natural resource management and the input of intensive practices. Natural resource management consists of reduced tillage, organic manure, intercropping, and crop rotation, and the input consists of improved seeds here. The rationale behind the adoption of these practices is to ensure sustainable soil fertility through an improvement in soil structure [18]. These benefits come with the promise of a substantial reduction in production costs [19]. The existing literature reports that sustainable intensification practices (SIPs) have supported many communities in refining their resources and enhancing production [20]. The diffusion and adoption of modern sustainable agriculture practices among developing countries still stay lower than the desired levels [8,21–25]. Multiple authors have conducted studies to investigate the underlying reasons for the low adoptions. Those studies associate the low adoption with multiple factors such as demographic variables, farm-location characteristics, financial resources, information access, and the occurrence of climate shocks [26–29]; certainly, the results from previous studies are inconstant and vary from location to location [30–32]. Consequently, it becomes necessary to design a specific location-based study to have a better understanding of the impediments and factors that hinder the technology adoption decisions of the farming community. Considering this, further empirical evidence is still required to understand what stimulates the farmers to adopt certain agricultural practices. Evidence shows the presence of different SIP components in Pakistan's cereal-based farming system [33–35]. However, the extent of SIP integration and the factors behind SIP adoption are an unexplored phenomenon. Apart from this phenomenon, agriculture in this region is diverse and characterized by multifaceted problems, such as a lack of infrastructure, a poor financial system, lack of access to modern agricultural technologies, low productivity per hectare, and land degradation, which demands a study to address these issues.

Cereal production holds considerable importance due to its potential in offering food security to the whole country, but the current production level is quite far from what the potential level is [33,36]. Factors such as the non-availability of seeds, climate change, inefficient fertilizer use, water shortages, and weed infestation are considered to be responsible for this yield gap [36]. The Punjab region is considered to be the "breadbasket" for the whole country and is responsible for the majority of cereal production, but even this region suffers from food shortages [36]. Nearly 40% of the districts in Punjab produce surplus food, which was 61% five years ago. The situation is much worse if we look at the other provinces, as the food sufficiency level is 26% in Sindh and, horrifyingly, is 4% in Khyber Pakhtunkhwa (KPK) and Baluchistan. These statistics put an enormous amount of pressure on Punjab to feed the whole country [36,37]. As the availability of cultivatable land is almost zero, the adoption of the latest technologies and conservation methods provides an answer to low productivity.

Consequently, it is necessary to understand the adoption intensity of SIPs and elements, inducing their adoption for the sake of reaching a viable way to intensify cereal production in Pakistan in a sustainable manner. Keeping the local context and problems in mind, following the mentioned interconnected SIPs, such as crop rotation, intercropping, organic manure, improved varieties, and low tillage, are considered here [38]. To date, the literature on the conservation of agriculture in Pakistan is completely limited. Certainly, no study has been conducted on the factors related to SIP adoption. Hence, this study takes the initiative to fill the existing research gap in Pakistan by investigating the determinants of SIP adoption. The research aims to identify the main determinants of SIP adoption with the adoption intensity between multiple ecological zones in the Punjab region and further explore the synergies and substitutability among the adopted SIPs. This study seeks to answer the following questions: (i) What is the extent of SIP adoption among different ecological zones of Pakistan's Punjab province? (ii) What are the determinants of SIP adoption? (iii) Do any of these SIPs substitute or complement each other?

2. Theoretical and Conceptual Frameworks

2.1. Sustainable Intensification Practices Selected for the Study

This study is based on the data collected from the recent survey and contains 612 responses. As Pakistan's crop production has remained static since the last decade and pressure on land is increasing day by day, the intensification practices promise more productivity with less land usage.

Keeping this background in mind, we selected specific SIPs in our study. Selection for these practices was made cautiously, and a comprehensive literature review was carried out to avoid any bias [33,34,37–41]. Based on prevalence and necessity, we selected five SIPs for our study, namely, intercropping, crop rotation, organic manure, low tillage, and improved varieties. All of these practices were taken as dummy variables, and data were collected as 0 or 1, where if a farmer adopted any of these practices, then the variable would be equal to 1, otherwise 0. Intercropping involves sowing two crops in the same field, and in our study, 28% (Table 1) of farmers were found to practice intercropping [42]. Researchers have reported multiple cereal-based intercropping patterns, such as rice with mung beans, maize with mash, and wheat with mash and brassica plants [40,43–45]. Crop rotation involves the cultivation of any two crops in sequence over the year in the same field. Intercropping and rotation generate higher yields, with the addition of building soil resilience, which benefits both the people and the environment.

Table 1. Description and descriptive statistics of surveyed farmers (n = 612).

Sustainable Intensification Practices (SIPs)	Description		Percentage
Crop rotation	Farmer is practicing crop rotation	(1 = yes; 0 = no)	0.74
Intercropping	Farmer is practicing intercropping	(1 = yes; 0 = no)	0.28
improved seeds	Farmers using improved seeds	(1 = yes; 0 = no)	0.34
Low tillage	Farmers using low tillage practices	(1 = yes; 0 = no)	0.20
Organic manure	Farmers using organic manure	(1 = yes; 0 = no)	0.69

Organic fertilizer consists of animal manure, crop residues, and household wastes. The application of organic manure improves soil structure and quality by giving organic matter back to the soil, which, as a consequence, enhances land fertility and productivity [46]. Improved plant varieties possess high yield capabilities while bearing weather-related extremities such as salinity tolerance, high-temperature tolerance, drought tolerance, and flood tolerance. Consequently, Singh et al. (2015) suggested that varieties with stress tolerance attributes can provide a sustainable answer to weather-related shocks [47]. Further, it has been stated that a considerable level of improved plant variety adoption exists in all the provinces of Pakistan [39].

The practices, as mentioned earlier, are expected to boost income and provide sustainability to farm households, even in the presence of climatic uncertainties. Low tillage practices contain tillage operations without unsettling the top layer of soil. These tillage practices come with some shortcomings, such as overdependence on herbicides and expensive nature of applicability. However, such methods are often described as an option to enhance yield sustainably [35]. Low tillage practices are prevalent among Pakistani farmers but on a smaller extent [33]. Similarly, in our study, low tillage was the least adopted practice, as only 20% (Table 1) of farmers were associated with it.

2.2. Explanatory Variables for Multivariate Probit Model

The study has employed a multivariable probit model with a dependent variable (SIPs adoption) against the explanatory variables consisting of household characteristics, assets endowment, and environmental characteristics to assess their effects on the adoption decisions. The data set used in the study includes both the continuous and categorical variables. Apart from education, most of the categorical variables were binary. Household characteristics were used in the model, controlling for the level of education, household size, farming experience, household type, and risk willingness. All of these demographic variables have also been used in earlier studies to define decision making in the adoption of agricultural technologies [26,48,49].

On the part of education, the factor was categorized into five categories and each category was assigned a distinct value such as 0 = illiterate, 1 = primary, 2 = eighth standard, 3 = matric, 4 = intermediate, whereas, the farming experience was defined as the number of years working as a farmer. The family size count is the number of adult members in a household, while the family type indicates the nature of the household, which can be either joint or nuclear. Risk attitude deals with the farmer's willingness to adopt technology after evaluating the positive and negative sides of a certain practice.

Land ownership, the area under cultivation, and livestock ownership were taken as household asset endowments in our study. The area under cultivation counts for the number of acres currently being cultivated by the farmer. Land tenure deals with the ownership rights of the farmer and the responses on the land tenure consist of if a farmer owns the land or not. Livestock holdings elevate the incomes of farmers, which increase the chances of adopting SIPs. Livestock ownership was defined as having single cattle.

Adequate social networking has always been an essential factor in determining the adoption of the latest innovations. Social capital enables farmers to gain information regarding the latest happenings in the field of agriculture, which facilitate farmers to access inputs and credit [26]. This study has taken social participation, access to credit, access to information, urban linkage, and extension access as institutional variables. In our case, social capital was defined as a household's participation in a farmer's group or village committee. The responses on the variable of access to credit consist of whether the farmer had received any credit in the past 12 months or not, whereas access to extension was defined as the farmer having received any advisories in the past 12 months from agriculture department or not. The environmental characteristics were defined as whether or not, in the past five years, the farmers had experienced the rainfall variability, increase in pest attacks, and temperature increase.

2.3. Empirical Model

A multivariate probit (MVP) model was used here to analyze the decision-making process of farmers regarding the adoption of SIPs. This initiative was taken to understand the farmer's choices to adopt multiple SIPs rather than a single practice. The MVP model eases the understanding of the interconnectedness of multiple SIPs via correlations, whereas a univariate model tends to ignore the possible correlation of error terms in adoption equations [26]. This weakness of univariate models may lead to biased estimates [50]. Relevant factors were chosen to observe their influence on adoption-related decisions.

A multivariate model of our study contains four interrelated equations. Each equation is linked to one of the five SIPs mentioned earlier. To elaborate on the MVP model, we let each SIP represent a random variable, having values of 1, ..., 5 for a positive integer.

It was supposed in our study that each farmer may adopt a group of SIPs. Moreover, it was also assumed that the decision would depend on factors such as the demographic, socio-economic, and institutional characteristics, besides other factors (X). The MVP model for this study can be described as follows:

$$SIP^{*}_{ij} = \beta'_j x_{ij} + I_{ij} \; (j = 1, \ldots, 5) \tag{1}$$

This equation represents all of the SIPs in our case, as X is taken as a set of conditioning variables. Thus, the SIP^*_{ij} is a latent variable linked with an individual I-value and technology (SIP).

$$SIP^*_{ij} = \begin{cases} 1 \ \ if \ \ SIP_{ij} > 0 \\ 0 \quad otherwise \end{cases} \tag{2}$$

where SIP^*_{ij} is a latent variable, while β'_j is the vector of a parameter to be assessed. It assumes that a rational household has a latent variable, SIP^*_{ij}, which captures the disregarded inclinations with multiple SIPs. The latent variable is supposed to have a linear combination with the institutional and household characteristics (x_{ij}) that are perceived to influence the simultaneous selection of SIPs, besides unobserved characteristics. The stochastic error is termed as I_{ij} here.

3. Materials and Methods

3.1. Study Area

The study was conducted in the Punjab province Figure 1, which is the largest province in terms of population [37]. The total geographical area of Punjab is 20.63 million hectares, out of which 59% is used for cultivation. The rationale behind the selection of Punjab includes its share in the GDP and agricultural yield of Pakistan. It contributes to 54% of the GDP, while it represents 62% of the agriculture sector [51–53]. Cereal cultivation is an essential part of Punjab's farming system, as a major portion of farmers are associated with it. Besides agriculture, Punjab holds the largest livestock population and represents nearly 67% of the milk production in Pakistan [2]. The average temperature in Punjab varies from a minimum of 16.52 °C to a maximum of 32.75 °C. The monsoon season is responsible for nearly 75% of rainfall in Punjab, which continues from June to September. The average rainfall varies between districts, for instance, the average rainfall in the Vehari district fluctuates from 72.5 to 462.1 mm annually. The second district from the mixed cropping zone receives a minimum rainfall of 219 mm to a maximum of 718 mm annually. The rainfall in the Gujrat district varies from 697 to 1401 mm annually [54]. Based on the rainfall variability and geographic diversity, three ecological zones were selected from the whole province.

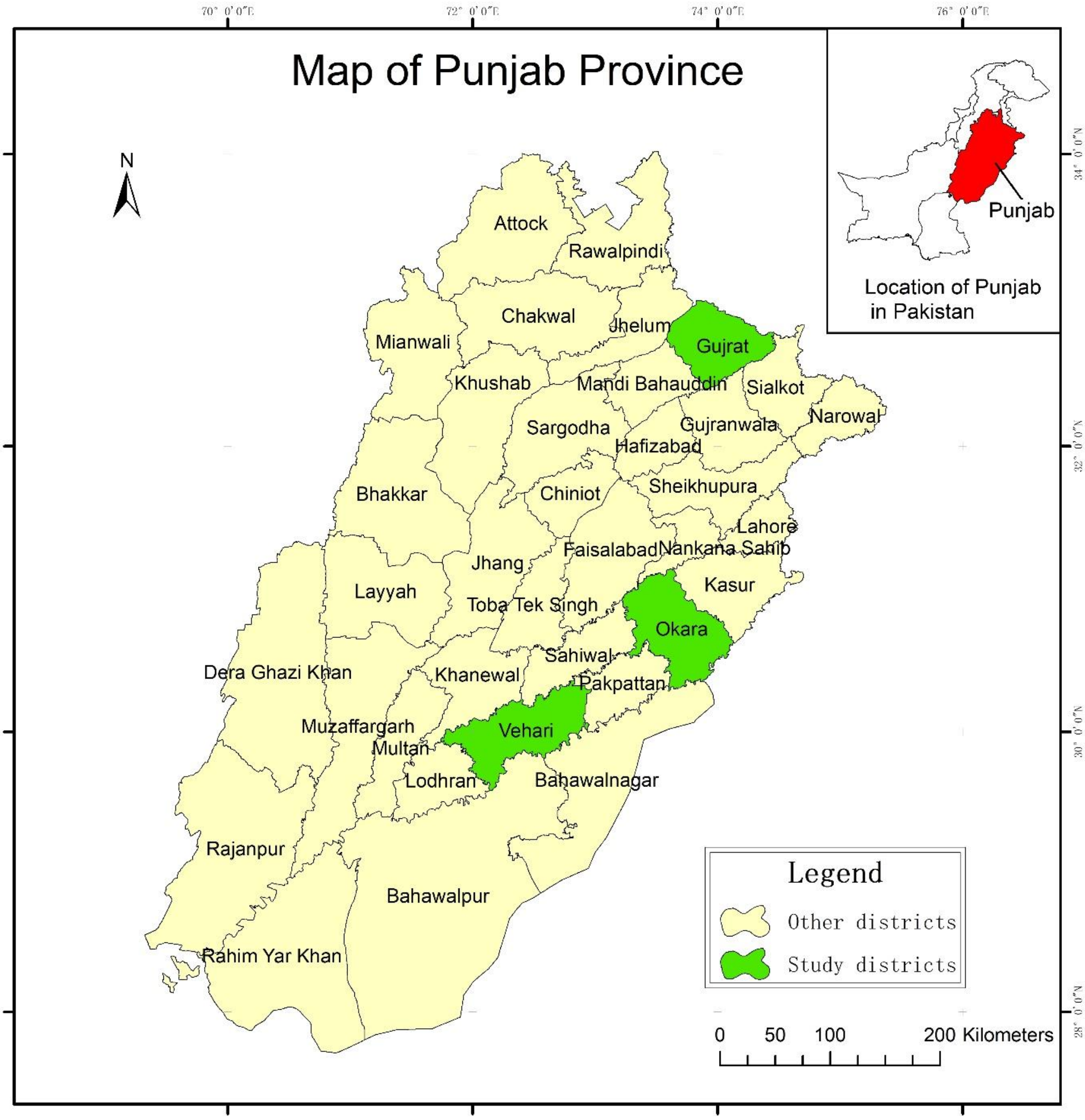

Figure 1. Map of the study area.

3.2. Data Collection

In contrast with previous studies, our quantitative study used a survey approach and employed multi-stage stratified random sampling to collect the primary data from a sample of 612 farmers, determined through Cochran's formula [37,55–57]. A well-designed structured questionnaire was used to collect the data through interviews with the farmers. As shown in Figure 2, due to agriculture significance and ecological diversity, the Punjab region was selected at the first stage.

$$n_0 = \frac{z^2 pq}{e^2} 666 = \frac{(2.58)^2 (0.5)(0.5)}{(0.05)^2} \quad (3)$$

Based on Pinckney's categorization, the Punjab region consists of five agro-ecological zones, i.e., the rain-fed zone, mixed cropping zone, low-intensity zone, cotton-wheat zone, and rice-wheat zone [58].

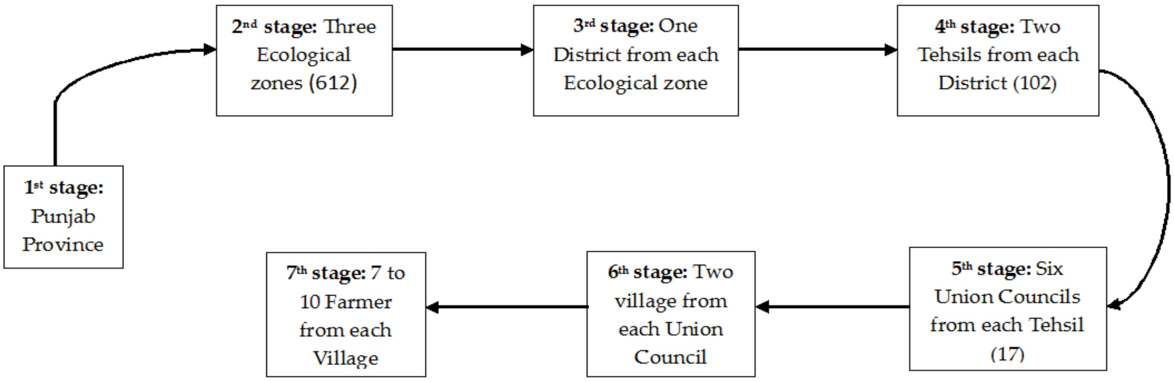

Figure 2. Sampling framework.

Considering the climatic variability and cropping patterns, three regional agro-ecological zones were selected randomly in the second stage. At the third stage, we selected one district from each zone. Then, at the fourth stage, two cities (tehsils) were chosen randomly from each of the districts. In the next stage, six union councils were selected from each of the tehsils for the research purpose here. According to the administrative set-up of the Punjab province, each union council consists of multiple villages. Consequently, in the sixth stage, three to four villages were selected from each union council, and, at the seventh stage, nine to ten farmers were chosen randomly from the chosen villages. As mentioned in Table 1, a combined number of 612 farmers were selected, with equal distribution of 204 farmers for each district (Note: initially, 222 farmers were allocated to each district but during survey, due to incomplete responses at the initial stage, the sample size was restricted to 204 farmers).

3.3. Socioeconomic and Demographic Profile of Respondent

Appendix A presents the descriptive statistics of explanatory variables. Most of the farmers had primary-level education (primary education), with an average of 1.28, which indicates that most of the farmers could read and write. As shown in Table A1, the average farming experience in this study was 20.57, ranging from 2 to 65 years. Moreover, the average family size was 5.4 people per household, with 86% of people living in a joint family system. About 45% of farmers were inclined to avoid risk by not adopting new technology.

In our study, 80%, farmers had ownership status, and the area under cultivation was of medium size as the average plot size was 11 acres. Moreover, 86% of farmers had at least one livestock animal. Coming to institutional characteristics, nearly 58% of the farmers had received credits in the past 12 months, whereas 58% of the farmers did not receive any agricultural advisory during the past year. About 54% of farmers reported an urban linkage with having at least one relative or friend in a metropolitan area. The average distance from the village to town was 6.3 kilometer. Moreover, 55% of farmers participated in agricultural-related social activities.

In our study, 41% of the farmers experienced an increase in the temperature, and 39% of the farmers reported a rainfall variability in recent years. Besides that, 59% of the farmers have noticed a rise in pest attacks in past years.

4. Results

4.1. The Extent of the Adoption and Intensities

Adoption intensity consists of the number of intensification practices adopted jointly by farm households, ranging from one to five. Legends represent the number of practices adopted together, such as one SIP counts for a single practice, two SIPs count for double practices, three SIPs counts for three practices adopted together, and the same pattern continues for all the legends. The overall results (Figure 3) indicate that the adoption of two practices together was highest among others, and this trend was the same in all the studied zones. Nearly 15% to 17% of farmers combined two practices in all three zones, followed by three practices, representing almost 9% in all zones. At most, 3% to 4% of farmers from each zone practiced four SIPs, whereas only the smallest proportion of farmers adopted all five SIPs across all zones.

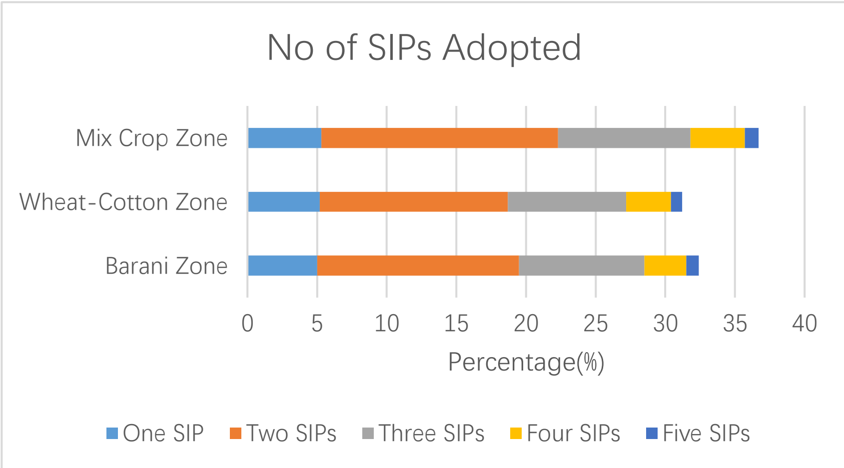

Figure 3. The number of sustainable intensification practices (SIPs) adopted in each zone.

Adoption intensities in the mixed cropping zone were slightly higher than in other zones, which indicates that cereal production in this zone is done through SIPs more than the different zones. A mixed cropping zone exists in the heart of Punjab and contains major urban centers of Pakistan. Apart from infrastructure, the mixed cropping zone features the most fertile land of the region, which gives this zone a central position in all of the agricultural policies of this province. Hence, as a result, farmers from this zone are more privileged than other zones.

4.2. Complementarities and Substitutability

The alternative hypothesis of mutual interdependence among SIPs was statistically significant. The likelihood ratio test (Table 2) shows that the independence of SIPs as alternative hypotheses of mutual independence is significant (χ^2 (10) = 25.0091, prob > chi-squared value = 0.005). These results support the selection of the multivariate probit model in this research study.

Table 2. Correlation coefficients of the adoption of SIPs.

	Organic Manure	Intercropping	Low Tillage	Crop Rotation
Intercropping	0.1864 **			
Low Tillage	0.0621	0.1059 **		
Crop Rotation	0.0743 *	0.0784 *	0.0406	
Improved Seeds	0.0765	0.2786 **	0.0344	0.0785 *
(χ^2 (10) = 25.0091 prob > chi-squared value = 0.005)				

** and * indicate significance at $p \leq 0.05$ and $p \leq 0.1$, respectively.

The literature suggests that more than one technology can be adopted simultaneously as they are not mutually exclusive. The strengths and associations between the dependent variables are presented in Table 2. Furthermore, six out of eight correlation coefficients were significantly correlated, reflecting that most SIPs complement or substitute each other. Low tillage practice did not feature any significant relationship with organic manure and improved seeds. The relationship between crop rotation and organic manure was substantial. Similarly, there was a significant relationship between improved varieties, organic manure, and crop rotation.

4.3. Drivers and Barriers of Adoption of SIPs

The results of the multivariate probit model are displayed in Table 3. The results indicate that the data of the model fit well, as the statistically significant chi-square test asserts that the four types of explanatory variables had a different effect on the adoption decisions of SIPs. Moreover, these variables significantly explained the variability in the adoption of the five SIPs taken in our study (Wald χ^2 (100) = 286.44, p = 0.000). Concerning household characteristics, households with a lower number of members were more likely to exercise and invest in SIPs, as the findings revealed a negative relationship between family size and SIP adoption [27]. Meanwhile, as expected, the experience of farmers was significantly associated with organic manure. Moreover, a household's education level was an important determinant of intercropping and low tillage [59]. Farmers' willingness to take risks affected the adoption of intercropping significantly and positively. Plot size remained an essential factor. It significantly affected the approval of most SIPs. Hence, the increase in the size of the plot increased the chance of SIP adoption. In our case, it significantly predicted the adoption of improved seeds and intercropping. These results are consistent with previous studies [26,60].

Table 3. Parameter estimates from the multivariate probit (MVP) model for estimating determinants of the adoption of SIPs.

Explanatory Variables	Improved Seed		Low Tillage		Organic Manure		Intercropping		Crop Rotation	
	Coef.	SD	Coef.	SD	Coef.	SD	Coef.	SD	Coef.	SD
Household Characteristics										
Farming Experience	0.001	0.003	0.005	0.004	0.010 **	0.004	0.006	0.004	0.005	0.004
Education	0.109	0.100	0.254 **	0.108	−0.068	0.106	0.413 ***	0.113	−0.078	0.106
Family size	−0.09 ***	0.025	−0.001	0.028	−0.012 *	0.026	0.018	0.028	0.072 **	0.027
Family type	−0.197	0.194	−0.479 **	0.198	−0.375	0.206	−0.444 **	0.199	0.563 ***	0.193
Risk willingness	0.111	0.114	0.180	0.124	−0.144	0.114	0.56 ***	0.131	0.192	0.117
Assets Endowment										
Area under cultivation	0.226 ***	0.062	0.041	0.067	0.048	0.063	0.099	0.066	0.120 *	0.066
Land tenure	−0.142	0.143	0.062	0.159	−0.074	0.148	0.228	0.160	−0.216	0.157
Livestock Ownership	−0.244	0.162	−0.056	0.179	−0.015	0.167	−0.534 **	0.178	0.221	0.169
Institutional Characteristics										
Access to credit	0.109	0.232	0.370	0.239	−0.098	0.280	−0.239	0.243	−0.115	0.261
Social participation	0.278 *	0.146	0.179	0.159	0.132	0.149	0.293 *	0.162	0.265 *	0.152
Urban linkage	0.001	0.153	0.176	0.168	0.239	0.158	0.036	0.170	−0.077	0.162
Access to information	0.332 ***	0.118	−0.011	0.128	0.317 **	0.115	0.380 ***	0.133	0.141	0.121
Extension access	0.247 **	0.114	0.261 *	0.123	0.058	0.115	0.141	0.129	0.119	0.119
Distance to market	−0.012	0.032	−0.017	0.035	−0.000	0.033	−0.003	0.036	0.021	0.033
Environmental Characteristics										
Rainfall Variability	0.011	0.118	−0.012	0.127	0.250 **	0.120	0.229 *	0.130	−0.269 **	0.123
Crop pest attack	−0.010	0.222	−0.159	0.227	0.001	0.270	−0.253	0.232	0.094	0.252
Increase in temperature	0.316 **	0.114	0.134	0.124	0.35 ***	0. 117	0.76 ***	0.127	0.364 ***	0.121
Location Dummies										
Cotton wheat Zone	0.081	0.135	−0.259 **	0.149	−0.004	0.132	0.013	0.155	−0.099	0.139
Mixed crop zone	0.220	0.141	−0.055	0.151	0.059	0.141	0.61 ***	0.156	0.006	0.146
Constants	−0.801 *	0.423	−1.32 ***	0.460	0.259	0.438	−0.54 **	0.178	0.221	0.169
Number of observations					612					
Log pseudo–likelihood					−1283.60					
Wald chi–square (100)					286.4 ***					

***, **, and * indicate significance at $p \leq 0.005$, $p \leq 0.05$, and $p \leq 0.1$, respectively.

Likewise, access to information and farmers' groups on the latest agriculture technologies significantly determined the adoption of improved seeds. Besides, farmers' groups had a strong influence on intercropping and crop rotation, while access to information significantly predicted organic manure and intercropping. These findings were consistent with earlier studies, such as [61], which suggested that farmers organized in a group are more likely to adopt organic fertilizer. Meanwhile, extension access emerged as a strong predictor and predicted low tillage and improved seeds positively and significantly. Our results suggest a significant and robust correlation between rainfall variability and SIPs, but with mixed signs. For instance, unusual rainfall increased the likelihood of organic manure and intercropping, whereas it decreased the probability of crop rotation. These results highlight the importance of temporal dynamics in technology adoption [62,63]. Expectedly high temperatures significantly predicted improved seeds, organic manure, intercropping, and crop rotation [49,64,65]. On the part of the location, the results showed a positive and significant relationship between the mixed cropping zones and intercropping.

5. Discussion

Based on the large sample size across the Punjab region in Pakistan, from the perspective of household socioeconomics, institutional, environmental characteristics, and SIP adoption, the current research has constructed multivariate probit models to identify the determinants related to the approval of SIPs. Moreover, adoption intensity among different ecological zones and synergies among these practices was also part of the investigation. The findings of the study are aligned with the empirical evidence here.

5.1. Synergies and Adoption Intensities of SIPs

The findings disclose the synergies between SIPs. Specifically, the results have identified some vital synergies between natural resource management (reduced tillage, organic manure) and input-based (improved seed) SIPs. The findings are consistent with recent studies, which also report a homogenous result [66,67]. Hence, based on the earlier evidence, our research has taken the initiative to contest against the widespread confusion that both types of practices are not compatible. Indeed, farmers apply both methods concerning their needs and experience. Consequently, the findings here have highlighted positive correlations among the two types of SIPs among Pakistani farmers. The results entail that a mix of input-intensive and conservation agriculture practices can yield beneficial synergies. In addition to synergies, the study has also explored the adoption intensities among agro-ecological zones of the region considered here. The mixed crop zone was the highest adopter among the other ecological zones. The differences in adoption intensities are attributed to numerous factors, such as access to information, access to credit, and better infrastructure. Having the most fertile land of the region makes this zone a center of attraction for agriculture policymakers. Apart from government agencies, the private sector could design many products specifically for the farmers of this zone. Hence, due to all these factors, the farmers of this area may receive many farm inputs at subsidized rates.

5.2. Determinants of SIPs Adoption

Household characteristics have always been a significant influencer of technology adoption. Our findings also support this notion and report a significant association between household characteristics and SIP adoption (Table 3).

With growing years of experience, a person deals with several shocks and climatic variations, which helps them to choose the right combination of technologies [27,68]. Hence, the farming experience can be termed as a knowledge index, which keeps the records of past misadventures and allows farmers to search for sustainable solutions. In contrast with previous studies, i.e., [69,70], our results have revealed a positive and significant relationship between farming experience and the adoption of organic manure.

On account of family size and family type, both variables negatively influenced the adoption decisions of low tillage, improved seeds, and intercropping. The findings disclose that households with a smaller number of people are more likely to adopt SIPs. Hence, the capital-intensive nature of SIPs seems to influence the adoption decisions of households. Numerous studies [10,27,71] support this finding and report the negative relationship between household size and SIP adoption.

The results indicate that farmers with higher education tend to adopt these SIPs more than lower education farmers. Hence, awareness plays a crucial role in stimulating adoption-related decisions. Based on risk aversion, mostly farmers value benefits over cost when accepting a specific technology [71]. In our case, risk willingness significantly predicted intercropping, which entails the riskiness and implication associated with the adoption of intercropping due to its higher cost. Similarly, a study conducted by Kurgat et al. [71] also found a positive relationship between risk willingness and SIP adoption. Thus, farmers who seek higher economic benefits are more likely to invest in intercropping who seek higher economic benefits.

Land size also plays a crucial part when it comes to taking up a modern practice. The results have revealed the significance of land size, as it predicted most of the SIP adoption here. A larger plot size seems to be convenient in day-to-day operations. For example, smaller plots pose difficulty in using a tractor for plowing [26,27,60]. However, livestock ownership discourages adoption decisions. Looking through an entrepreneurial view may communicate this point more comprehensively. The Punjab province produces almost 36.23 million liters of milk per year and is responsible for 67% of Pakistan's milk production [2].

Multiple studies have also supported this finding and reported the negative impact of livestock ownership on technology adoption decisions. So, it appears that most of the farmers keep livestock for a business point of view as livestock promises high incentives. Thus, they allocate more resources to animals than investing in intensification practices.

Access to information, extension access, and the social networks of farmers cohesively shape the acceptance of the latest innovations in farming systems [72–74]. All of these factors have a positive impact on the adoption of improved seeds (Table 3).

Farmers with a big social sphere are more likely to adopt the latest agriculture practices, as social connections work as an information source and improve the knowledge regarding the newest agriculture innovations. A farmer cooperative is a viable option when it comes to disseminating information related to key changes and the latest agricultural technologies [61]. Therefore, it suggests that active involvement in social networking may improve the knowledge of farmers regarding choices for the adoption of different SIPs in combination rather than separately.

Climate uncertainty is a reality in Pakistan's farming system and is responsible for most of the natural disasters that concern agriculture [39]. The adoption of SIPs works as a defensive measure, which is also reflected in our findings. Environmental factors were found to have a positive relationship with the approval of SIPs, as rainfall variability and temperature increase significantly predicted organic manure and intercropping. The results reveal that environmental characteristics emerged as the strongest predictor of SIP adoption, which mirrors farmers' apprehension about natural catastrophes [71,75]. The findings are in contrast to numerous reports which cite Pakistan as one of the most disaster-prone countries of South Asia.

The location serves as an essential determinant in SIPs adoption, and logically so. The results show that the cotton-wheat zone hurts the adoption of low tillage. The findings seem rational, as the cotton–wheat zone lies in the southern part of the province, which is the least developed part of the Punjab province and lacks many aspects, such as education and infrastructure. Hence, these shortcomings seem to hinder SIP adoption. Contrary to that, the mixed crop zone significantly influenced intercropping adoption (Table 3). The mixed cropping zone is located on the central part of Punjab province, which carries the best education and infrastructure facilities compared to the rest of the region.

Hence, the above discussion links the role of socioeconomic and institutional characteristics in creating the awareness of climatic uncertainties and technological solutions. Moreover, it concludes with the non-negotiable role of climatic factors in shaping the adoption of the latest agricultural technologies.

6. Conclusions

This research employs an MVP model and descriptive statistical analysis to identify the main determinants of SIPs adoption among Pakistani farmers. The results discovered that education, the area under cultivation, access to information, extension access, social participation, rainfall variability, and temperature increase significantly predict the adoption of SIPs. Apart from the determinants, this research further discusses the integration of SIPs among Pakistani farmers. The findings have revealed that crop rotation and organic manure are the most adopted practices across the Punjab province, whereas intercropping and low tillage were among the least adopted practices. The study found positive signs for trade-offs and synergies between SIPs. Specifically, the research highlighted positive synergies between natural resource management practices and modern inputs amid Pakistani farmers. Hence, our findings certainly add to the evolving evidence [65] that challenges the misperception about the incompatibility of both practices. The results embrace the fact that farmers do exercise the combination of both practices to achieve sustainable outcomes. The extent of integration depends on the skill and experience level of farmers. Hence, it is proposed that when SIPs complement each other, farmers should be stimulated to adopt SIPs. It is assumed that a variety of SIPs may work more efficiently together and elevate production levels, simultaneously avoiding environmental hazards. The results also emphasize the promotion of these policies through native institutions, such as farmer groups or cooperatives. Farmers groups or associations can undoubtedly enhance the adoption of SIPs. Furthermore, there is an urgent need to establish extension services and research institutes to depict farm trials based on modern agriculture technologies as a means to create awareness regarding SIPs. The findings recommend that SIPs need to be promoted in a well-planned manner with a target to improve the financial base of households. This research provides support for future studies as it has explored the factors of SIP adoption in a Pakistani context. In contrast, the potential economic and environmental advantages of these practices demand attention in order to formulate comprehensive policies and set guidelines for the Pakistani farming community.

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Appendix A

Table A1. Description and descriptive statistics of the surveyed farmers (n = 612). SD: standard deviation.

Variables	Description	Mean	SD
Household Characteristics			
Farming Experience	Farming experience of household head in years	20.57	14.39
Family Size	Total adult members of family	5.40	2.37
Family Type	0 = single family, 1 = joint family	0.86	0.33

Table A1. *Cont.*

Variables	Description	Mean	SD
Education	The education level of the household head, 0 = illiterate, 1 = primary, 2 = 8th standard, 3 = 10th standard, 4 = intermediate	1.28	0.56
Risk Willingness	Household head is willing to take risk, 1 = yes, 0 = otherwise	0.55	0.49
Assets Endowment			
Plot Size	Area size under cultivation in acres	11.04	14.99
Land Tenure	Households ownership status, 0 = tenant, 1 = owner	0.80	0.39
Livestock Ownership	1 = farmer owns livestock, 0 = otherwise	0.86	0.47
Institutional Characteristics			
Access to Credit	1 = household has access to credit, 0 = otherwise	0.58	0.48
Access to Information on New Agriculture Technologies	1 = household has access to information on new agricultural technologies, 0 = otherwise	0.58	0.50
Urban Linkage	1 = household has friends or relatives living in urban areas, 0 = otherwise	0.54	0.49
Extension Access	1 = household has access to extension services, 0 = otherwise	0.42	0.47
Social Participation	1 = household head is a member of any farmer cooperative or village committee, 0 = otherwise	0.55	0.48
Distance to Market	Distance to nearest market in kilometers	6.34	1.91
Environmental Characteristics			
Increase in Temperature	1 = farmer has experienced a change in temperature in recent years, 0 = otherwise	0.41	0.46
Rainfall Variability	1 = farmer has experienced unusual rain in recent years, 0 = otherwise	0.39	0.45
Crop Pest Attack	1 = farmers has experienced an increase in crop pest attack in recent years, 0 = otherwise	0.59	0.49
Locational Dummies			
Mixed Crop Zone	1 = If household is from mixed crop zone, 0 = otherwise	0.33	0.47
Wheat Cotton Zone	1 = If household is from wheat cotton zone, 0 = otherwise	0.33	0.47

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