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Socioeconomic Determinants and Perceptions of Smallholder Farmers towards Agroforestry Adoption in Northern Irrigated Plain, Pakistan

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Abstract: Amid the epoch of global overpopulation, the agroforestry system can intervene as a novel practice that can safeguard agricultural sustainability, provide a means of livelihood, yield ecological benefits, and contribute to household food security. However, the adoption of sustained agroforestry practices requires an understanding of both farmers' personal characteristics and perceived statuses, constituting a difficult task to anticipate, analyze, and visualize. To this end, it is crucial to understand and identify the most significant factors driving the adoption of agroforestry. This research attempts to examine the determinants and psychological drivers of smallholder farmers' intention to plant trees on farmland and the factors that may discourage them from doing so. The conceptual framework of the study was developed based on the theory of planned behavior. We draw on survey data from 400 smallholder farmers in a northern irrigated plain of Pakistan. A binary logistic regression model was employed to explore how socio-psychological drivers influence farmers' decision to adopt agroforestry practices. The study results reveal that 60.5% of the respondents prefer to adopt agroforestry practices. The results from a logit estimation showed that socio-economic variables such as family size, land ownership, subsidies, livestock rearing, sources of energy, and total income had a significant positive influence on the planting of trees on farmland, while age had a negative influence. Moreover, runoff control and the control of heat significantly affect the perceptions of farmers regarding the adoption of agroforestry. The findings suggest that implementing policies that enhance the delivery of robust agricultural extension services and training programs for farmers could disseminate the agroforestry system countrywide, which might offer substantial benefits for farmers in the long term while maintaining environmental integrity.

Keywords: agroforestry adoption; farmers' perception; logit regression model; northern irrigated plain; Pakistan

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1. Introduction

Over the past few decades, the international community has made significant efforts through policy interventions to increase the number of farmers adopting sustainable agricultural practices in order to combat global poverty and hunger while preserving the environment [1]. Despite the modest success thus far, the world is still confronted with the challenge of a higher demand for food and low levels of agricultural production, which have been exacerbated by an increasing population, changing climate patterns, and land degradation [2]. Millions of farmers in the world's most food-insecure regions can barely feed their families, and an estimated 3 billion people worldwide lack the financial means to purchase the products required for a healthy diet [3]. Agriculture accounts for 4% of global GDP and more than 25% in some developing countries [4].

As a predominantly agrarian economy, Pakistan's rural development and food security depend heavily on its agricultural sector. An estimated 37.4 percent of the labor force is directly or indirectly employed by this sector, which contributes to 22.7 percent of the country's GDP [5]. Approximately 64.6 percent of Pakistanis live in rural areas, and 58 percent of them are smallholder farmers with less than 2 hectares of land [6]. Despite their importance to the Pakistani economy, they are particularly vulnerable to climate change due to their reliance on rain-fed agriculture combined with subsistence agriculture [7]. With these environmental vulnerabilities, the agricultural land in this region renders lower yields, resulting in farmers' inability to raise money [8]. According to the 2018 Asian Development Bank report, 21.9 percent of Pakistan's population lives below the national poverty line [9]. This makes its people highly dependent on natural resources such as forests for fuelwood and timber extraction as an alternative source of income [10]. Pakistan's increasing population and high rate of deforestation have compounded the threat posed to its natural environment [11]. A recent study analyzing Pakistan's National Forest Reference Emission Level (FREL) reported that the country has 4.786 million hectares (5.45%) of forest cover [12]. In the past decade, Pakistan lost an average of 8400 km^2 of forest land, which constituted 33.2 percent of its forest cover between 1990 and 2010 and amounted to a total mean annual loss of 420 km^2 (1.66%) [13]. In addition, the rapidly growing population of Pakistan (224.78 million in 2021), with a growth rate of 1.8 percent annually, relies on the limited forest wood resources provided within this 4.78-million-hectare area. Thus, the per capita area of the forest is only 0.0208 hectares as opposed to the world average of one hectare [5]. Of this entire forested area, only 1/3rd is productive, whereas the majority consists of land with protective and environmental value [14]. Under these conditions, meeting the rising population's demand for fodder, fuelwood, agricultural supplies, and raw materials required by wood-based industries becomes increasingly difficult [15]. The demand for wood in Pakistan is higher than the total amount produced annually. Farmlands account for 60% of total timber production and 90% of total fuelwood production. In this case, farm forestry substantially fulfils the requirement for timber. In addition, it was estimated that 10 percent of domestic farmlands could be conveniently converted to forest cover without affecting agricultural crops. Therefore, agroforestry constitutes a reliable option whose adoption can fulfill the increasing demand for wood products [16].

In the late 1970s, the planting of trees on farmlands, commonly known as agroforestry, received global recognition and emerged as an improved and modern land use system for developing countries [17]. Unlike traditional agriculture and forestry, agroforestry acts as an interface between agriculture and forestry and encompasses not only the physical and biological sciences but also the social sciences [18]. Agroforestry (AF) is an integrated sustainable agriculture system that involves the management of crops, trees, and livestock on the same ground, which is temporally and spatially arranged [19]. Numerous studies have confirmed the advantages offered by agroforestry. Tree planting, a major component of an agroforestry system, promotes food diversity and food security and reduces poverty by providing a source of income [20]. Agroforestry tends to be capable of conserving biodiversity and providing rural livelihood alternatives [21,22]. Around the world, agroforestry practices are adopted to derive social, ecological, and economic benefits. For instance, its adoption can lead to the production of additional marketable goods and improve soil fertility, act as a shield from wind for standing crops, conserve deteriorated land, reduce wind and soil erosion, improve water quality, and limit pest attacks [23]. As part of an agroforestry system, smallholder farmers in developing countries frequently plant trees on their fields [24]. Agroforestry systems constitute the best strategy with which to help rural people adapt to environmental changes and play a role in improving their livelihoods, agrobiodiversity, and economic stability [25]. Furthermore, agroforestry is a sustainable and environmentally friendly method that helps farmers meet their financial requirements [26]. Approximately 1.8 billion people directly or indirectly make use of agroforestry products and services for their livelihood [27].

The area where this study was conducted is the most populated province of Pakistan and contributes the largest share to this country's national agricultural production level. It was also noted that agroforestry in Pakistan's northern irrigated plain considerably increased in late 1995 when the Punjab Forest Department provided various financial subsidies and incentives and transferred technology. A study conducted by [28] highlighted that compared to cropping, where farmers face various constraints, such as natural hazards, poor access to credit, and little support from local authorities (Punjab Agricultural Department and the Forest Wildlife and Fisheries Department), governmental support can bring about change in farmers' perceptions and attitudes, resulting in increased motivation for the adoption of agroforestry [28]. Despite the fact that the planting of trees on farmlands provides diversified livelihood benefits and improves the resilience of local farming systems, there is little empirical evidence revealing the factors affecting smallholder farmers' tree-planting practices on farmland in the northern irrigated plain of Pakistan. Previous research conducted by [29,30] in the study area provided a comparison of livelihood and ecological impacts between agroforestry and conventional farming. However, these studies did not address the determinants and drivers influencing the adoption of agroforestry. Farmers' perceived statuses, which influence their decisions regarding the planting of trees and its ecosystem services, are still largely unexplored [31,32]. Additionally, smallholder farmers in Pakistan currently lack a comprehensive model that incorporates various social, economic, ecological, and farmer-related factors governing the adoption of agroforestry practices. To date, there are no known adoption studies concerning agroforestry that include an analysis of these variables in the study region. Thus, the present study aims to address this knowledge gap and provide new strategies for adopting agroforestry. Scientific research on the determinants and perceptions of smallholder farmers is required to determine how they influence farmers' adoption of agroforestry and their willingness to plant trees on their farmland. The process of adopting agroforestry can be better understood by analyzing relevant socioeconomic and ecological conditions, which can be valuable for developing targeted agricultural management strategies and policies.

To the best of our knowledge, this study is a novel contribution to the existing literature as it is the first study to examine the factors influencing the adoption of agroforestry in Pakistan by employing a unique, comprehensive framework and a dataset that incorporates a variety of variables specific to smallholder farmers. Moreover, this study discusses and analyzes its results using a Logistic regression model and a Probit model to acquire robust findings. This study is also ethnobotanical as it investigates the potential of agroforestry and the reasons why indigenous farmers in the northern irrigated plain of Pakistan are willing to adopt agroforestry practices. In addition, the findings of this study may help determine and address the needs and demands of smallholder farmers. This study will reveal the significant factors that either facilitate or impede the adoption of agroforestry in the study area, which will contribute to the improvement of existing agroforestry policies in Pakistan. Agricultural extension agents, researchers, policymakers, development experts, and other concerned stockholders may benefit from it. Furthermore, although this study focuses on Pakistan, its outcomes can be applied to other countries with similar socioeconomic and ecological backgrounds.

2. Theoretical Background

Empirical evidence from several studies has highlighted that tree planting on farmlands is beneficial to the provision of a wide range of wood varieties, wood products [29], fodder, and fuelwood [32,33]; improves household income [32]; maintains the domestication of woody species [34]; and increases the supply of forest functions, including the sequestration of carbon and the improvement of soil properties and biodiversity conservation [35].

The theoretical literature offers some justifications for why specific conditions may have a major impact on farmers' decision to grow trees on their farmlands. Some findings agreed that one must look beyond quantitative metrics of income to comprehend the multidimensionality of rural farmers [36,37]. Accordingly, if farmers make rational judgments, given their resource endowments, they will be influenced by their farm households' knowledge base and other variables [38]. The adoption of agroforestry may be dependent on intrinsic factors, such as attitudes, perceptions, and knowledge, as much as it is dependent on extrinsic factors, such as the characteristics of a farmer or the external environment [39]. However, the effect of these variables on a farmer's acceptance and adoption varies by location. For instance, in most developing Asian and African nations, socioeconomic factors such as the gender of the household head, level of education, family size, household income, a farmer's experience, land tenure security, the distance to the market, the agro-ecological zone, contact with extension workers, and membership in farmers' associations were the main reasons why smallholder farmers adopted agroforestry [40,41]. Inhabitants of rural areas are often far from urban centers, which limits their access to the market economy and minimizes their opportunities to attain off-farm income. As a result, remote rural areas have limited market access and services, thereby hampering small farmers' ability to improve their economic situation. On the other hand, the increasing demand for forest products in urban areas of developing countries has influenced farmers' choice to grow trees alongside crops on their farms to supplement their income, while also promoting the conservation and management of natural resources [42]. Therefore, rural areas near urban markets can affect the adoption of agroforestry and rural livelihoods. However, in developed countries in Europe, protecting the soil, contributing to climate change adaptation and mitigation, enhancing biodiversity, and improving the overall condition of a landscape were considered to be prime factors governing the adoption of agroforestry [43]. After reviewing more than one hundred articles on the adoption of agricultural and forestry practices by farmers, Pattanayak, et al. [44] found that agroforestry mainly depends on five factors, namely, market incentives, preferences, resource endowments, biophysical factors, and uncertainty and risk.

The existing agroforestry literature has highlighted various frameworks and approaches for analyzing the factors that influence the adoption of agroforestry [45,46]. Most of these frameworks are based on farmer-first and sustainable livelihood principles, but they have been expanded to include key components from numerous theories and practical realities. Two theories that are frequently used to describe the factors influencing farmers' decisions to accept new technology are the Theory of Planned Behavior [47] and the Technology Acceptance Model [48]. These two theories allow for the prediction of a person's actions based on their attitudes and perceptions and external influences such as the socioeconomic status of their homes and neighborhood.

The main element of the Theory of Planned Behavior (TPB) is behavioral intention, which is influenced by behavioral attitudes, subjective norms, and perceived behavioral control [47]. The TPB has been used in a variety of disciplines to understand individual compliance. The TPB has emerged as a preeminent guiding principle in studies examining people's adherence to health-related advice and regulations [49,50]. The TPB has also been used to examine individual compliance with policies [51], environmental protection [52], taxation [53], infrastructure, and transportation. More pertinently, the TPB has been applied to delineate the willingness to comply with the planting of trees in home gardens, urban areas, and roadsides. For instance, Meijer, et al. [39] in Malawi and Amare, et al. [54] in Ethiopia used the theory of planned behavior as a conceptual framework to examine farmers' attitudes toward tree planting on farms.

Given the extensive research on agroforestry, it has been confirmed that the adoption of agroforestry (behavioral intention) is positively and significantly related to the acceptance of support from family and friends (subjective norms), having a positive viewpoint (attitude), and believing in one's own ability to engage in this practice (perceived behavioral control) [55]. In the context of adopting agroforestry, it is essential to comprehend agroforestry farmers' decision-making processes. The elements that attract farmers to or dissuade them from planting trees on their fields will have a significant impact on how agroforestry programs and activities are adopted. Farmers' decisions are influenced by their perceptions about the pros and cons of agroforestry practices as well as the opinions and actions of relevant third parties in their environment and the actual opportunities they have to practice agroforestry [47]. Following several previous studies [54,56–60] that were developed based on the theory of planned behavior, this study defines farmers' perceptions of the ecological impact of agroforestry as their preferences, which may drive their decision-making processes; thus, the conceptual framework shown in Figure 1 was developed accordingly. As shown in the figure, a wide range of extrinsic and intrinsic factors, such as individual and household socioeconomic characteristics, influence farmers' perceptions [30,56,61].

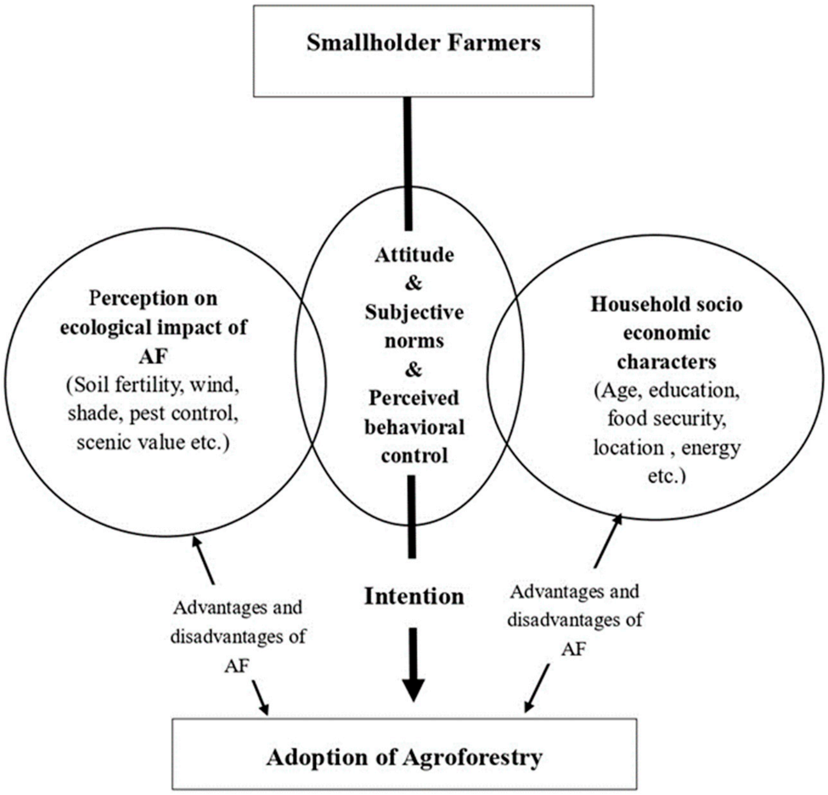

Figure 1. Conceptual framework.

3. Materials and Methods

3.1. Description of the Study Area

There are ten agro-ecological zones in Pakistan, and these zones are established on the basis of their geography, climate, natural resources, and agricultural land use [62]. The northern irrigated plain zone (Zone IV-A), which is one of its agro-ecological zones, was selected for the case study. This zone falls in Pakistan's second-largest province, Punjab. There are limited forest resources in Pakistan, especially in Punjab. In comparison with the state-owned forest, more than 90 percent of fuelwood and approximately 72 percent of timber are obtained by private farmlands through agroforestry, community forestry, and social forestry. It is suggested that trees should be planted alongside agricultural crops on private farms [63]. On a tour of the Punjab province, one can encounter numerous trees on the boundaries of private farms used for windbreaks and shades. It is also evident that there are many more that can be appropriated for tree plantations. Even though there is no proper method followed by farmers, farmlands contribute four times more timber and nine times more fuelwood than the state-owned forests [64]. This province is considered the "food basket" of the country due to the high agricultural productivity of Rabi and Kharif crops. Two districts were purposefully selected from the northern irrigated plain, namely, Gujranwala district and Hafizabad district (shown in Figure 2). The main reason these two districts were chosen is that they are located between the Jhelum and Sutlej Rivers, which are among the world's largest canal-based irrigation systems and are used to irrigate large areas of agricultural land. The geographical coordinates of Hafizabad district are 32°4′0″ N and 73°41′0″ E, while those of Gujranwala district are 32°9′24″ N and 74°11′24″ E. The maximum mean annual temperature of the study area is 39.4 °C, and the minimum mean annual temperature is 6 °C. The area's mean annual rainfall ranges between 300 mm and 500 mm. The major agricultural activities in the region are wheat and rice farming, sugarcane cultivation, and mixed farming. This region is highly important from an agricultural perspective as it earns foreign currency by growing basmati rice on its large tracts of land. The major cash crops grown in the study area are wheat (*Triticum aestivum*); maize (*Zea mays*); rice (*Oryza sativa*); millet (*Eleusine coracana*); barley (*Hordeum vulgare*); and sugarcane (*Saccharum officinarum*). The high-value tree species in the area, such as eucalyptus (*Eucalyptus camaldulensis*), phulai (*Acacia modesta*), gum arabic tree (*Acacia nilotica*), athel (*Tamarix aphylla*), jujube (*Zizyphus nummularia*), jandi (*Prosopis cineraria*), and sheesham (*Dalbergia sissoo*), are grown in agroforestry lands and used for construction material, fuelwood, and fodder for livestock [63].

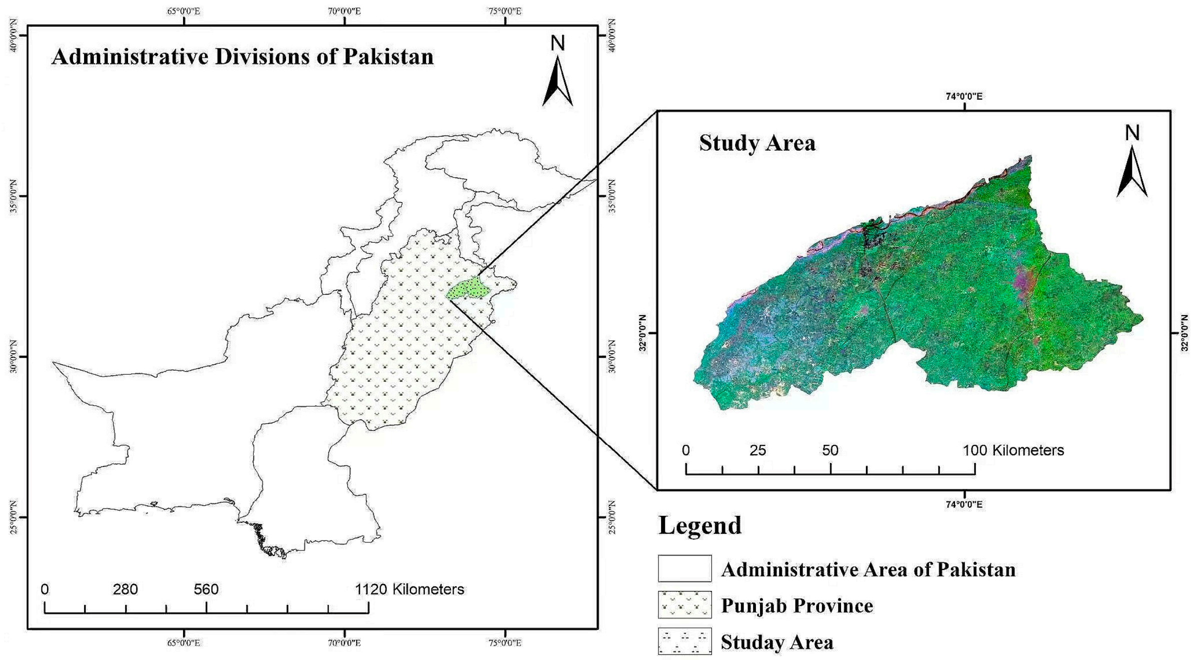

Figure 2. Map of the research area (Gujranwala and Hafizabad districts).

3.2. Data Collection

A household survey of farmers in northern irrigated agro-ecological zones (Province of Punjab) was conducted to ascertain the factors affecting their adoption of agroforestry in their fields. The two districts used in this study were selected to represent the levels of socioeconomic and geographical variation in the province of Punjab. Twenty villages were randomly selected from each district. A total of 40 villages were used for the study. The Tehsil office provided a list of households in the 40 villages that were surveyed. Then, from the list of households collected from each village, we randomly selected 10 individual households. One family member aged 18 or over was interviewed in each household. A total of 400 households were chosen for data collection. No households declined to participate in the survey. During the survey, data were collected in Urdu, the local and national language, and then translated into English. Interviews were conducted at a time that was convenient for the farmers.

3.3. Selection of Variables, Model Development, and Adequacy

3.3.1. Selection of Variables

For the data collection questionnaire, data were collected using a two-section-structured questionnaire. The respondents' socioeconomic statuses were examined first. Then, the second section analyzed the farmers' perceptions of the potential of agroforestry. The conceptual structure is the most critical criterion to consider when choosing independent variables. In addition, we employed a forward and backward selection methods as a stepwise variable addition and elimination method to produce the best-fitting model. This automated methods selects the best-fitted independent variable and adds it to the model. Variable selection begins with the null model; then, the most significant variables are added. At each step, variables with non-significant values ($p > 0.05$) are eliminated. In the final phase, a variable with statistically significant value ($p < 0.05$) is added. Variables must also be rational, and the outcomes must be interpreted to see whether they are consistent with reality or whether they can be obtained by chance in one specific sample [65]. Moreover, multicollinearity is a serious issue, and the greater the number of variables in the model, the greater the risk. For this reason, the multicollinearity test was performed to determine the degree of correlation between multiple independent variables by using a variance inflation factor (VIF) with Pearson's r (cut-off value > 0.9). The results show that the VIF cutoff values are less than 5%. Therefore, the number of variables depends on their independence. Hence, by considering these factors and following the studies conducted by [60,66–70], the present study took the following socio-economic and perceptional independent variables, which were used to assess the factors affecting farmers' adoption of agroforestry, into account: farmers' age, farmers' education, area of house, household members, land ownership, landholding, distance to market, location of farmland, government subsidies, livestock rearing, source of energy, annual income, water availability, agri-based programs, food security, need for windbreak, need for shade, soil fertility, soil erosion, pest control, scenic beauty, heat control, runoff, and water volume. A brief summary of all independent variables (socio-economic aspects and perception of respondents), the related literature, expected outcome, and hypothesis is provided in Appendix A.

3.3.2. Model Development and Adequacy

Descriptive statistics and econometric analysis were applied to assess the data. Descriptive statistics were used to summarize and present the data related to farmers' socioeconomic details and their perception of agroforestry. STATA version 15 was used to perform econometric regressions.

A binary logistic regression model was used to analyze and predict the factors influencing the adoption of agroforestry by smallholder farmers. The logit model's binary output indicates the probability that a decision maker will choose a certain option, for which the outcomes are either adopt (1) or not (0) [71]. This model is a generally powerful statistical tool used to analyze the functional relationship between dichotomous dependent variables and predictor variables of any type. Moreover, it also offers techniques with which to ensure that the model performs more efficient estimations with multiple categorical variables (either nominal or ordinal) [72]. Overall, it is applicable for agroforestry adoption research because the dependent variable of interest is typically whether or not a farmer has adopted agroforestry practices. In this study, farmers were considered adopters if they continued to engage in agroforestry and/or planted at least one tree in the last year, and they were non-adopters if they quit the program and did not plant any trees. The agroforestry farmers who adopted these practices and planted and maintained trees on their farmlands were assigned the value of 1, while those who did not were assigned the value of 0. Therefore, this study's objectives and data suggested that a logistic regression model should be employed. Furthermore, a probit model was estimated for a robustness test corresponding to the logit model [73].

The log likelihood chi-square test and Hosmer–Lemeshow test statistic were used to evaluate the goodness of fit of logistic regression model. Our binary logistic model results and log likelihood chi-square test value indicated that the model's results are entirely statistically significant ($p < 0.001$). The value of the Hosmer–Lemeshow test was insignificant (p-value of $0.218 > 0.05$) according to its chi-square distribution with 8 degrees of freedom, which indicates a good fit of the model with respect to predicting the effect of the independent variables on the dependent variable, and it has been reasonably well adapted, as recommended by [74,75]. Furthermore, a classification table was used to assess the accuracy of the logistic model by comparing the predicted and observed values for the dependent outcome. It shows the percentage of all cases correctly predicted by the model. The correct classification rate in our study was estimated to be 74.25%.

3.4. Defining the Model Parameters

The probability of the adoption of agroforestry is as follows:

$$\text{Logit}[p] = ln[\text{odds}(Y = 1)] = ln(P/(1-P)) = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots\ldots\ldots + \beta_n X_n + \varepsilon_i \quad (1)$$

where Y is respondents' decision to adopt agroforestry (1 = yes, and 0 = otherwise), while the log odds ratio is denoted as $ln[P/1-P]$. The remaining variables are described below:

α_0 is the intercept;
X_1–X_n are independent variables (socioeconomic and perception factors);
β_1–β_n are the coefficients of explanatory variables;
ε_1 is the normally distributed error term.

4. Results

4.1. Descriptive Statistics on Socioeconomic Characteristics and Perceived Status of Respondents

The socioeconomic characteristics of the respondents are presented in Table 1. The results show that 60.5% of the respondents adopted agroforestry (Figure 3). As shown in Table 1, the respondents' average age was 42 years. Their education levels were categorized as illiterate, primary, ordinary level, intermediate level, and university education. In these categories, 35.75% of the respondents had attained an ordinary level of education, around 24.25% had an intermediate level of education, 22.75% attained a primary level of education, and 9.25% had achieved a higher level of education, including technical college and university. About 8% of the respondents were illiterate (could not read or write). Most of the households surveyed had an average of 6 members.

Table 1. Descriptive statistics of household socio-economic status and perceptions of the respondents.

Description	Description	Mean or Proportion	SD	Min	Max
Adoption of agroforestry	Adopter (%) + Non-adopter (%) + Dummy (Yes = 1, No = 0)	60.5 39.5		0	1
Socio-economic status					
Age	Respondents average age	42.23	11.224	19	73
Education	Level of education 1 = Illiterate (%) + 2 = Primary (%) + 3 = Ordinary level (%) + 4 = Intermediate (%) + 5 = Higher education (%) +	8 22.75 35.75 24.25 9.25	1.077	1	5
House size	Size of house (Square meters)	202.12	43.451	107	352
Family size	Household members (Average)	6.75	1.734	3	14
Landholding	Landholding in HH (Hectares)	2.04	0.712	0.3	4.5
Ownership	Private (%) + Another private owner (%) + Dummy (Yes = 1, No = 0)	94.5 5.5	0.228	0	1
Distance	Distance from market (Kilometers)	6.6	2.918	0	16
Subsidies	Receiver (%) + Non-Receiver (%) + Dummy (Yes = 1, No = 0)	19 81	0.392	0	1

Table 1. *Cont.*

Description	Description	Mean or Proportion	SD	Min	Max
Livestock	Livestock rearing (%) + Does not rear livestock (%) + Dummy (Yes = 1, No = 0)	37.5 62.5	0.484	0	1
Energy	Cooking with fuelwood (%) + Cooking with other energy sources (%) + Dummy (Fuelwood = 1, Other energy source = 0)	38 62	0.485	0	1
Location	Near water channel (%) + Far from water channel (%) + Dummy (Near = 1, Far = 0)	62 38	0.485	0	1
Water	Water availability for Agriculture (months)	6.45	1.416	0	10
Program	Participates in Agri-based community development program (%) + Does not participate in agri-based community development program (%) + Dummy (Yes = 1, No = 0)	17 83	0.376	0	1
Food security	Has enough food (%) + Does not have enough food (%) + Dummy (Yes = 1, No = 0)	80 20	0.400	0	1
Income	Annual income (PKR)	1,105,954	405,347.4	309,741	2,264,781
Farmers' Perceptions and Intention					
Windbreak	Suitable for use as Windbreak (%) + Not Suitable for use as Windbreak (%) + Dummy (Yes = 1, No = 0	37.5 62.5	0.484	0	1
Shade	Suitable for use as shade (%) + Not Suitable for use as shade (%) + Dummy (Yes = 1, No = 0)	37.5 62.5	0.485	0	1
Fertility	Improves land fertility (%) + Does not improve land fertility (%) + Dummy (Yes = 1, No = 0)	11.75 88.25	0.322	0	1
Erosion	Controls soil erosion (%) + Does not control soil erosion (%) + Dummy (Yes = 1, No = 0)	86.5 13.5	0.342	0	1
Pest control	Controls pest problems (%) + Does not control pest problems (%) + Dummy (Yes = 1, No = 0)	67.5 32.5	0.468	0	1
Scenic	Used for scenic value (%) + Is not used for scenic value (%) + Dummy (Yes = 1, No = 0)	73.25 26.75	0.443	0	1
Heat	Controls heat (%) + Does not control heat (%) + Dummy (Yes = 1, No = 0)	39.5 60.5	0.489	0	1
Runoff	Runoff control (%) + Does not control runoff (%) + Dummy (Yes = 1, No = 0)	73.75 26.25	0.440	0	1
Water Volume	Improves water volume of stream (%) + Does not improve water volume of stream (%) + Dummy (Yes = 1, No = 0)	42.25 57.75	0.494	0	1

+ Percentage of households.

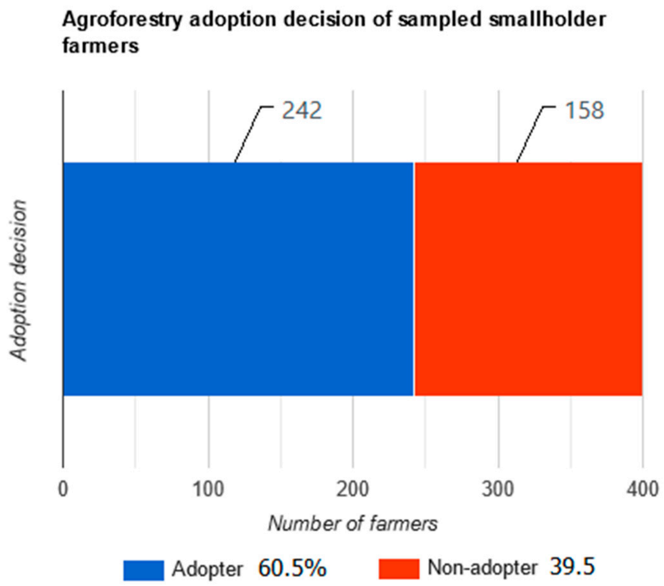

Figure 3. Adoption decisions of smallholder farmers.

The mean house size of the respondents was about 202 square meters, and the average HH landholding was 2.04 hectares (ha), with a maximum of 4.5 (ha) and a minimum of 0.3 (ha). A larger portion of the respondents—nearly 94.5 percent of them—were the owners of their agricultural lands, while the remaining 5.5% cultivated the rented or leased land of other private owners. Regarding the economic support provided to the farmers' households, the survey illustrated that 19% of the farmers receive subsidies from the government. However, the results indicated that the majority of the farmers (81%) do not participate in any kind of agri-based program. Our study results suggested that farmers living in the northern irrigated plane used gas (LP gas) as their main energy source for cooking. Electric energy (electricity) ranked second place while fuelwood ranked third. According to our survey, we found that only 38% of farmers used fuelwood, especially efficient fuelwood stoves, for cooking purposes. Moreover, 80% of the farmers claimed to have a sufficient amount of food throughout the year, thereby demonstrating food security and stability. However, 20% of the respondents said that they do not have enough food throughout the year.

On average, our study sample resides about 6.6 km away from the market. The respondents reported that 62% of their farmlands are near water channels, whereas 38% of farmlands were reported to be far away from water channels. In addition, they reported that, due to reduced water flow in the winter, the availability of water for agricultural practices is limited to six months. The survey illustrated that the average annual household income is around PKR 1105954. Conventional agricultural income, agroforestry income, off-farm income, and livestock income are the four main income sources in the two districts. Around 37.5% of the farmers' rear livestock. According to our observations, we found that the farmers prefer to raise more than one kind of livestock on their farms. These include cattle, buffalo, goats, and poultry.

Table 1 presents the percentage of households that answered Yes or No to each indicator question belonging to an ecological impact concept. According to the results, a nearly equal number of respondents answered that agroforestry is suitable for use as a windbreak (37.5%), use as a shade (37.5%), controlling heat (39.5%), or improving water volume (42.2%). Around three-fourths of the respondents (73.2%) answered that agroforestry is used for improving scenic value and runoff control. Moreover, 86.5% of the respondents said that agroforestry is used to control soil erosion, and more than half of the respondents (65%) thought that agroforestry is effective for controlling pest problems. However, 88% of the respondents, including both agroforestry and non-agroforestry farmers, stated that agroforestry has no effect on land fertility.

4.2. Factors Affecting to Adopt Agroforestry Practices

Table 2 summarizes the outputs of the logit and probit models. The probit model produced results similar to those of the logit model, and the results of the robustness test were in line with our main estimates. Thus, the robustness of the results obtained from both models is supported [73]. Therefore, the discussion below focuses on the logit model, while the probit model's findings are reported as a point of reference. The analyses show mixed results regarding the socio-economic variables of the local people's willingness to adopt agroforestry practices. According to the study, these socio-economic variables, including education, house size, type of landholding, distance to market, location of farmland, water availability, opportunity to participate in agri-based programs, and food security, have no significant influence on individuals' decision to adopt agroforestry.

Table 2. Estimated coefficients and marginal effects of the factors influencing farmers' to adopt agroforestry practices.

Explanatory Variable	Logit		Probit	
	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Socio-economic variables				
Age	−0.1017 *** (0.0178)	−0.0229 (0.0040)	−0.0604 *** (0.0103)	−0.0222 (0.00379)
Education	−0.1307 (0.1232)	−0.0294 (0.0277)	−0.0806 (0.0728)	−0.0297 (0.0268)
Size of house	−0.0060 (0.0031)	−0.0013 (0.0007)	−0.0036 (0.0019)	−0.0013 (0.0007)
Family size	0.2940 *** (0.0865)	0.0662 (0.0194)	0.1785 *** (0.0512)	0.0657 (0.0188)
Land holding	0.6152 (0.3369)	0.1386 (0.0758)	0.3162 (0.1938)	0.1164 (0.0714)
Land ownership	1.8164 ** (0.5745)	0.4231 (0.1106)	1.0532 ** (0.3322)	0.4006 (0.1116)
Distance to market	−0.0629 (0.0531)	−0.0141 (0.0119)	−0.0304 (0.0293)	−0.0112 (0.0107)
Subsidies	0.91402 * (0.3981)	0.1836 (0.0689)	0.5600 * (0.2316)	0.1878 (0.0684)
Livestock rearing	1.1092 *** (0.3368)	0.2347 (0.0654)	0.6911 *** (0.2000)	0.2412 (0.0645)
Energy	1.0455 ** (0.3247)	0.2226 (0.0636)	0.6326 ** (0.1941)	0.2225 (0.0635)
Location of farmland	−0.1574 (0.2796)	−0.0352 (0.0621)	−0.1143 (0.1653)	−0.0418 (0.0601)
Water availability	−0.1005 (0.0981)	−0.0226 (0.0220)	−0.0596 (0.0569)	−0.0219 (0.0209)
Program	−0.5811 (0.3535)	−0.1370 (0.0858)	−0.3362 (0.2080)	−0.1280 (0.0810)
Food security	−0.3888 (0.3747)	−0.0840 (0.0772)	−0.2132 (0.2168)	−0.0762 (0.0750)
Total income	1.282×10^{-6} ** (4.89×10^{-7})	2.89×10^{-7} (0.0000)	8.14×10^{-7} ** (2.93×10^{-7})	3.00×10^{-7} (0.0000)

Table 2. *Cont.*

Explanatory Variable	Logit		Probit	
	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Perceptions and Intention				
Windbreak	0.1495 (0.3269)	0.0334 (0.0726)	0.0965 (0.1931)	0.0353 (0.0703)
Shade	0.0368 (0.3222)	0.0082 (0.0723)	0.01522 (0.1922)	0.0056 (0.0707)
Fertility	0.1571 (0.4093)	0.0360 (0.0953)	0.0990 (0.2403)	0.0369 (0.0909)
Erosion	−0.2308 (0.4121)	−0.0505 (0.0874)	−0.1376 (0.2440)	−0.0495 (0.0858)
Pest control	0.3023 (0.2791)	0.0691 (0.0645)	0.1750 (0.1656)	0.0651 (0.0622)
Scenic	0.3956 (0.3501)	0.0913 (0.0825)	0.2264 (0.2048)	0.0849 (0.0779)
Heat	0.6648 * (0.2690)	0.1454 (0.0565)	0.3845 * (0.1580)	0.1385 (0.0552)
Runoff	0.6463 * (0.3055)	0.1509 (0.0727)	0.3963 * (0.1814)	0.1500 (0.0697)
Water Volume	0.0583 (0.2649)	0.0131 (0.0595)	0.0259 (0.1561)	0.0095 (0.0574)
_cons	−0.4934 (1.1937)		−0.2777 (0.7026)	
	$LRchi^2$ (24) = 137.09 Prob > chi^2 = 0.0000 Pseudo R^2 = 0.2554 Log likelihood = −199.826 Number of observations = 400		$LRchi^2$ (24) = 138.67 Prob > chi^2 = 0.0000 Pseudo R^2 = 0.2584 Log likelihood = −199.037 Number of observations = 400	
Prediction statistics (correctly classified) = 74.25% Hosmer and Lemeshow test = 0.218				

Note: significance—* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

This study's results show a significant ($p < 0.001$) negative correlation between age and adopting agroforestry practices. The result regarding the average marginal effect show that farmers' decision of adopting agroforestry practices decreased by 2 percentage points as their age increased by one level. On the other hand, the influence of the respondents' family size ($p < 0.001$) and land ownership ($p < 0.01$) on adopting agroforestry shows a significant positive correlation. Notably, a larger number of family members in a farmer's HH significantly increased the likelihood, i.e., by 6 percentage points, of a villager adopting agroforestry practices. In addition, farmers with family-owned land or privately owned land were 42% more likely to engage in agroforestry.

Regarding the other socio-economic variables, subsidies ($p < 0.05$) and total income ($p < 0.01$) showed a significant positive correlation with adopting agroforestry practices. This indicates that receiving subsidies from the government and a higher total income render farmers more likely to adopt agroforestry practices. Moreover, it was shown that the usage of fuelwood as a source of energy for cooking ($p < 0.01$) and raising livestock ($p < 0.001$) had a significant positive influence on adopting agroforestry practices. The results regarding marginal effects indicated that an individual's decision of adopting agroforestry practices increases by 22% and 23% points as their use of fuelwood for energy and raising livestock increases by one level, respectively.

In terms of perception, we found that adopting agroforestry has a significant positive correlation with a villager's perception of its suitability for controlling heat and runoff ($p < 0.05$). Participants who answered the question about whether agroforestry is suitable for heat control and runoff control affirmatively are more likely to adopt agroforestry than others. The average marginal effect results show that increasing the perceived status of suitability for heat control by one level increases individuals' decision of adopting agroforestry practices by 14%. Furthermore, the decision of adopting agroforestry practices increases by 15% when a farmer's perception of these practices' use for runoff control increases by one level. The rest of the perceptional variables do not show a significant influence on adopting agroforestry. However, aside from the erosion variable, the positive correlations of the other variables indicated that individuals who positively responded to (i.e., who answered yes) the perceptional question are more likely to engage in agroforestry than those who did not.

5. Discussion

Although the majority of the farmers in this area have traditional knowledge of agroforestry [76], the percentage of farmers engaging in agroforestry corresponds to nearly half of the population (60.5%). The farmers in this area planted trees either on bunds and boundaries (sequentially with crops) or planted them such that they were intercropped on irrigated land traditionally used for cereal production. Unlike cereal crops, trees take a long time to mature before they can be used for agricultural purposes. Accordingly, this is also a long time for a single farmer to wait for a potential profit. This is often the case when small farmers from developing countries such as Pakistan do not engage in agroforestry. Similar to our findings, a study conducted in East Java, Indonesia, also reported that 58.7% of the respondents adopted agroforestry practices [77]. However, a study conducted in Tanzania in 2021 reported a comparatively lower percentage of farmers (only 10.19% of farmers) adopting agroforestry or planting at least one new tree on their lands [60].

The logit regression model developed in this study reveals that socio-economic factors such as education, the size of one's house, land holding, distance to market, the location of farmland, water availability, and the opportunity to participate in food security and agri-based training programs do not have a significant influence on the adoption of agroforestry. Previous research found similarities and differences between our findings regarding socioeconomic variables.

Considering our findings on education, Thangata and Alavalapati [68] conducted a study in Malawi and discovered a similar result, wherein agroforestry adoption decisions are less dependent on the education level of the household head and more dependent on the farmer's contact with an extension agent. Conversely, Muneer, [78] concluded that farmers' levels of formal education had a significant positive impact on adopting agroforestry. Our result related to the size of farmers' houses indicated a negative correlation with adopting agroforestry. This shows that farmers who have larger houses do not adopt agroforestry practices. The key cause for this phenomenon is that the main energy source for a small-sized house in rural Pakistan is usually fuelwood. To fulfill their daily energy requirements, villagers in this area are willing to plant woody trees in their home gardens and on their farmland.

Our study results also indicated that farmers' landholding size had no significant influence on adopting agroforestry. In Pakistan, those who live in the northern irrigated plain zones are mainly conventional agricultural small farmers with fewer than 5 acres of land, which is primarily used to cultivate rice and wheat crops [11]. Therefore, a farmer's landholding has no significant impact on their choice to adopt an agroforestry system in the study area. In addition, Moronge and Nyamweya, [79] found that if the plot or farm sizes of a farmer's landholdings are small, then certain agroforestry systems cannot be economically or practically feasible. Hence, it is expected that owners of large tracts of land are more likely to practice agroforestry. Moreover, our finding on the distance to market shows a negative correlation but not a significant influence on farmers' willingness to practice agroforestry. However, [44] reported that the distance to market was statistically significant in his studies, for which there was a negative correlation with adopting agroforestry.

Water is the main environmental factor that influences crop agriculture. Farmers' crop selection decisions are primarily influenced by the availability of water. For example, sugarcane and rice consume more water than perennial crops, such as fruit trees, which remain in the field for many years [80]. Therefore, if farmland has been established in the nearby bunds of irrigation channels, the farmers will be more willing to plant crops than trees for agroforestry. In the study area, farmlands near irrigation channels were devoted to growing cash crops, especially wheat and rice. The current study's results also indicated that the location of land and water availability were negatively correlated but had no significant influence on farmers' decision to adopt agroforestry. However, in contrast to our findings, a study conducted by [81] found that farmers were more willing to adopt the agroforestry system if there is a greater degree of availability of irrigation for the cultivation of wheat, paddy, vegetables, sugarcane, and fruit trees.

The benefits of participation in agri-based training programs, especially non-formal education programs such as income generation programs, are often considered to improve governance, including the increased potential impact of the information superhighway. However, our study revealed that the opportunity to participate in governmental programs does not have a significant impact on adopting agroforestry. This latter finding was due to the fact that the objectives of the majority of government programs initiated in this area concern an agricultural sector modernization project carried out to support an increase in agricultural productivity through monoculture farming and improving the market [82]. Moreover, agricultural extension agents focused on growing crops and raising livestock, whereas forest extension agents only engaged in tree-planting efforts. The types of trees and shrubs that could be used in an agroforestry system are unfamiliar to many agricultural extension workers. The propagation, management, and ecology of agroforestry trees are not well understood by these extension agents with agricultural backgrounds. Consider the forestry extension specialists: they frequently overlook the demands and limitations mentioned by farmers in favor of seeing tree species solely from a "forestry" perspective. Contrary to our findings, a study conducted in Rwanda highlighted that the opportunity to participate in regular training programs increases the level of agroforestry's adoption [83].

Regarding food security, our results indicated a finding that was unlike what we expected. The results show that farmers who are facing food insecurity are more willing to adopt agroforestry than those who have sufficient food storage throughout the year. It seems that food-insecure farmers grow trees on their land as a substantial source of income and to support their daily food requirements. For example, fruit trees are major agroforestry components in their farmlands. In addition, nearly all agroforestry systems offered food security through diverse food production schemes and increasing the economic income of rural poor people [84]. Therefore, people who are poor and do not have enough income to purchase enough food are willing to plant trees on their lands. Even though previous research supported our findings [85,86], numerous studies have shown that households suffering from food insecurity may prioritize short-term or immediate needs over longer-term needs (agroforestry is a long-term method) to increase the production level of the limited land they have [77,87].

This study also revealed that several of farmers' socio-economic characteristics significantly influenced their adoption of agroforestry. However, of these socioeconomic variables, only the age of a farmer negatively affected their adoption rate. Moreover, Islam, et al. [88] reported that age had a significant influence on farmers' attitudes regarding conservation and intention to practice agroforestry. Furthermore, Zubair, [89] highlighted that young farmers and landowners are more likely to plant trees than tenants, older farmers, and those with off-farm employment. In contrast to our findings, [90] reported that younger farmers will perceive that agroforestry's benefits and market responses yield results too slowly. Therefore, older farmers are expected to be more willing to practice agroforestry.

Considering the variables that have a significant positive influence on adopting agroforestry, the estimation results show that family size, land ownership, subsidies, livestock rearing, energy, and total household income have a significant influence on farmers' decisions.

Farmers with larger families are expected to adopt agroforestry practices more frequently than farmers with smaller families because agroforestry is labor-intensive. AS stated in our hypothesis (Table A1), farmers with more family members are more willing to adopt agroforestry. However, a study by [91] revealed that having fewer or more household members had no influence on adopting agroforestry. Even though it was expected that a larger household with more family members would be concentrated in labor-intensive farming, the authors discovered no difference in the farming system explained by family size. On the other hand, the findings of [46] suggested that more household members could help increase the availability and division of labor and the management of time; therefore, the implementation of agroforestry was expected to have a positive impact. The findings of [81,92,93] are also in line with our results.

Farm subsidies associated with fertilizer and seeds result in an increased use of inputs, higher agricultural yields, and increased income among farmers. The study results revealed that subsidies from the government promote the adoption of agroforestry in the study area. The respondents said that providing subsidies to establish tree nurseries would induce their willingness to adopt agroforestry on their farmland. In addition, they highlighted that the majority of farmers are willing to receive seedlings of timber trees as their subsidies. They claimed that seedlings potted in polythene pots were more convenient to handle and less costly than those they produced themselves. Moreover, Matata, Nicli, et al. [94,95] reported that access to government microcredits and subsidies facilitated farmers' acquisition of the initial inputs for farming and thus the successful adoption of agroforestry.

Moreover, the findings regarding the influence of total income indicated that farmers' total income has a significant positive influence on adopting agroforestry. As we expected, the studied farmers indicated that low-income farmers subject to economic risks were biased against the adoption of agroforestry and that, instead, the adoption of agroforestry greatly favored higher-income farmers. As a result of having more purchasing power for inputs, higher-income farmers adopt agroforestry more than lower-income farmers. Similarly, studies have indicated that agroforestry may be more acceptable to farmers with higher incomes due to their superior access to resources, time, and labor money. Consequently, the income required to adopt agroforestry becomes easier to develop and thus agroforestry yields positive results [60,96–98].

Moreover, as we expected, land ownership positively correlated with adoption. Sebukyu and Mosango, [99] reported that land ownership had a significant positive influence on famers' willingness to adopt agroforestry. If land is owned by a farmer and his or her property rights are protected, then a farmer seems to be more willing to adopt agroforestry. Land ownership demonstrates the long-term viability and support for agroforestry as a future agricultural practice. In addition, Mwase et al. (2015) [100] indicated that some agroforestry practices are difficult to adopt under conditions of insecure land tenure and communal land ownership.

In rural Pakistan, the raising of livestock is a very common and widely practiced activity that is undertaken to provide daily necessities such as dairy products and income [101]. In this study area, fast growing woody species are used as fodder for livestock. During the dry season, this fodder offers dairy cows and goats a crucial supplement. Farmers mentioned that high-yielding tree fodder is also a solution for coping with the pressure applied to smaller land holdings brought about by population growth. This constitutes a step toward zero grazing, in which animals are always housed and fed in pens or sheds. Hence, farmers who raise livestock have a significant positive influence on adopting agroforestry. Similar to our study, studies conducted in Colombia by [102], Nepal by [103], and Zimbabwe by [104] highlighted that the decision to adopt agroforestry practices was influenced by the livestock system that the farmers' implemented.

As we hypothesized, our results indicated a positive correlation between cooking with fuelwood and adopting agroforestry. In Pakistan, the use of logs and timber products to produce wood fuels can account for up to 51% of total energy consumption, and estimates suggest that 65–75% of Pakistani households meet their commercial and domestic energy demands by burning fuelwood. A study conducted in 2001 revealed that, annually, 635 metric tons of fuelwood come from farm woodlots [105]. In the province of Punjab, where this study was conducted, about 90 percent of the demand for fuelwood is satisfied by trees growing on private farmland via agroforestry approaches. Accordingly, farmers who use fuelwood as their energy source grow more trees on their farmlands than those who use other energy sources such as electricity and LP gas. The optimal and most desired fuel species in the study area are *Tamarix aphylla*, *Acacia nilotica*, and *Sueda fruticosa*. In addition, Rahim and Hasnain, [63] also discovered that households that require fuelwood are more likely to plant trees in their farmlands. Moreover, a study conducted in Kenya also highlighted that agroforestry is being more frequently adopted in the country to deal with fuelwood shortage problems [106].

Regarding the relationship between farmers' perceptions of the ecological impact of agroforestry and adopting agroforestry, it was gleaned that the perception of the suitability of the use of agroforestry to control heat and runoff had a significant influence on adopting agroforestry. A study conducted in northeast Missouri by [107] highlighted that an agroforestry system reduced the runoff of land 11% more than corn and soybean rotation. The study results obtained by [108] were consistent with our study results regarding the variables related to heat control. The authors observed that planting trees on farms increases social capital and provides a cool location (heat control) for human beings and animals, especially when the weather is hot, thereby significantly influencing their perceived behavior towards agroforestry. Another study conducted in Indonesia indicated that agroforestry can protect farmland from weather extremes such as heat waves [109].

Even though the relationships between adopting agroforestry and other perceptional variables were not significant, aside from soil erosion, all other variables showed positive correlations. This finding indicates that when farmers have a positive perception of the suitability of agroforestry for the provision of a windbreak and/or shade, controlling pests, improving soil fertility, providing scenic value, and improving the water volume of streams, such a perception may have an influence on their adoption of agroforestry. Likewise, a study in Europe conducted by [110] found that when trees are used as windbreaks in farms, they modify the microclimate, minimize wind erosion, decrease high evaporation rates, and protect the crops from wind. These effects provide an ideal balance of crop and tree morphology that will enhance the growth and productivity of farms, which, ultimately, positively affects growers' interest in adopting an agroforestry system. In addition, Sanou, et al. [46] also found a significant association between the need for shade and practicing agroforestry in Burkina Faso, a Sudanian savanna zone. Moreover, the need for shade is among the important factors influencing a farmer's decision to incorporate trees into their farmlands. However, some negative impacts of the growing of trees were recognized by [108], as some farmers believed farmland tree shade reduces the yield of annual crops, create hurdles in agricultural operations, and provides a refuge for insects and pests, which eventually damage crops.

Another study conducted in Indonesia by the Center for International Forestry Research (2012) found that farmers living in Ngantang, Malang area, practice agroforestry to improve soil fertility in their farmlands [111]. Akin to what was shown in our study, studies conducted in Kenya [112] and Malaysia [113] indicated that farmers are more likely to adopt agroforestry because of its support for plant protection through decreasing the number of pests and increasing the quantity of the natural predators of pests.

In terms of the global use of groundwater for irrigation, Pakistan ranks third. More than 90% of the total groundwater extracted in Pakistan is used in the Punjab province. However, overexploitation has caused groundwater levels to drop below 6 m [114]. This has reduced the water volume of groundwater wells and degraded groundwater quality. Even though we expected a negative result, the farmers in the study area perceived that the trees planted via agroforestry would help improve the water volume of such groundwater wells. Several other studies also highlighted that agroforestry improves water volume by increasing the infiltration rate and reducing the amount of water lost as surface runoff [115,116].

Considering the soil erosion variable, our results indicated interesting findings in contrast to what we hypothesized and the findings of many other previous studies. The farmers' perceived status of the suitability of agroforestry to controlling soil erosion presented a negative correlation because the farmland located in the study area had flat terrain. Therefore, soil erosion caused by rain is not a significant factor on flat land. Thus, farmers do not want to adopt agroforestry on the basis of controlling erosion.

6. Conclusions

Agroforestry has a long history in Pakistan, and it generates multiple economic and non-economic benefits. In the province of Punjab, where this study was conducted, about 60.5% of households were inclined toward adopting agroforestry practices. The study revealed that both socio-economic and perceptional factors affect a farmer's decision to adopt agroforestry.

Socioeconomic factors such as age, family size, land ownership, subsidies, livestock rearing, energy sources, and total household income have a significant influence on farmers' adoption of agroforestry. On the other hand, individuals' perceptions of the suitability of trees for controlling heat and runoff also influenced their decision to adopt agroforestry on their farmlands. Moreover, the perception-based result of this study shows that individuals' perceptions of the ecological and environmental benefits of agroforestry have a positive influence on their adoption of agroforestry.

Our findings are in line with those of previous studies, and we also observed some disparities. For instance, we expected that agri-based training programs initiated by the government may positively influence farmers' decision to adopt agroforestry. However, our result indicated a negative influence, although not a significant one.

Our findings have a number of implications for programs designed to encourage agroforestry among Pakistani farmers. The adoption or rejection of a technology depends on a variety of socioeconomic factors, and policymakers require accurate information on these consequences. Government policies should encourage farmers' engagement in the agroforestry system and develop their capacity through extension programs in order to ensure that smallholder farmers adopt agroforestry more successfully. An effective extension service must offer farmers a concrete platform from which to access agroforestry-based information. The primary inputs for agroforestry are seeds and seedlings, which should be properly identified and distributed to farmers based on the local environmental conditions and their practical relevance for the region. Additionally, it is necessary to maintain quality while stabilizing economic and social viability.

Land ownership significantly influences farmers' agroforestry rights and decisions regarding adoption. Therefore, the assurance of farmers' rights regarding land for agroforestry should be executed conjointly with agroforestry and policy measures. Additionally, they should be provided with better information about and should increase their comprehension of these rights.

Subjective norms or perceived social pressure to engage or not to engage in AF practices are also influenced by cultural factors such as religion. Pakistan is a Muslim majority country, and this study sample totally consisted of Muslims. Therefore, we found that the lack of cultural differences in the study sample was a limiting factor of this study.

Accordingly, the evidence and determinants applied in this study may differ from place to place based on different socioeconomic, ecological, and geographic statuses. However, they are crucial for the successful implementation of a productive agroforestry plan and could be used in adoption studies in the developing world.

Author Contributions: S.A. analyzed the data, performed the experiments, and reviewed drafts of the paper. H.X. supervised, conceived, and designed the experiments; reviewed drafts of the paper; and approved the final draft. E.M.B.P.E. analyzed the data, reviewed drafts, and prepared the figures and tables. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy concerns.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. A summary of all independent variables (socio-economic and perceptions of respondents), the related literature, expected outcomes, and hypotheses.

Symbol	Variables	Hypothesis	Expected Results	References
Socio-economic status				
X_1	Age	Agroforestry requires long-term commitments and investments. Young farmers find that agroforestry yields benefits too slowly; therefore, they may prioritize short-term economic gains over long-term benefits. Hence, it is expected that agroforestry is adopted by elderly farmers familiar with its long-term benefits and possessing the ability to wait patiently.	Positive	[117,118]
X_2	Education	Education improves the ability to find, decipher, and evaluate agricultural production information. Hence, there is a positive relationship between education level and the adoption of agroforestry.	Positive	[90,119]
X_3	House size	House size indicates the area of the house as a measure of wealth. If a farmer's house is small, it represents their weak economic condition.	Positive	[120]
X_4	Family size	Most agroforestry technologies require additional labor. Thus, the adoption of agroforestry is positively related to large family size.	Positive	[81,121]
X_5	Land holding	Agroforestry might not always be profitable on small farmlands. Therefore, the possession of a large landholding makes it easier to plant trees and crops simultaneously.	Positive	[122]
X_6	Ownership	A farmer with strong land rights is more likely to practice agroforestry, whereas rented or borrowed lands hinder the adoption of agroforestry. Therefore, we expect a significant positive relation between land ownership and the adoption of agroforestry practices.	Positive	[123]
X_7	Distance	Distance denotes the distance between farmland and market. The presence of markets nearby enables farmers to easily market their harvest and gain access to inputs and other agricultural information, thereby encouraging the adoption of agroforestry.	Negative	[124]
X_8	Subsidies	Farmers may be more likely to adopt agroforestry if they have access to agricultural subsidies such as cash payments, public funds, and microcredits.	Positive	[83,125]

Table A1. *Cont.*

Symbol	Variables	Hypothesis	Expected Results	References
X_9	Livestock	Livestock rearing requires fodder trees, shrubs, and grazing lands in order to feed domesticated livestock. Therefore, engagement in livestock rearing increases the likelihood of adopting agroforestry systems.	Positive	[102]
X_{10}	Energy	Fuelwood obtained from agroforestry is a common source of energy for cooking in rural areas. Therefore, the need for fuelwood positively impacts their willingness to adopt agroforestry.	Positive	[126]
X_{11}	Location	Location indicates a farmland's distance from a water channel. A greater ease of access to irrigation water increases the efficiency of agroforestry systems. Some farmers may be reluctant to adopt agroforestry due to their limited access to water.	Negative	[127]
X_{12}	Water	Water availability indicates the total number of months that water is available for agroforestry. Integrated agriculture systems including trees and crops, such as the cultivation of paddies and wheat, require additional water. Farmers for whom irrigation water is readily available may be more likely to adopt agroforestry.	Positive	[81]
X_{13}	Program	Agri-based training programs initiated by the government to raise awareness among farmers about the advantages of agroforestry may positively influence their willingness to adopt agroforestry.	Positive	[128]
X_{14}	Food security	Food-insecure households grow trees on their land as a substantial source of income and to support their daily food requirements; therefore, farmers who are facing food insecurity are more willing to adopt agroforestry. Thus, the adoption of agroforestry is positively related to food security.	Positive	[84]
X_{15}	Income	The agroforestry system is most profitable for the lowest-income group, who use it to earn income by collecting timber, firewood, and harvesting fruits that are either sold or used for personal consumption. However, agroforestry requires substantial investments in terms of money, time, and labor. Hence, farmers with better financial resources and higher income are more likely to adopt it.	Positive	[7,96]
Farmers' Perceptions and Intention				
X_{16}	Windbreak	Windbreaks or shelterbelts are created by planting trees between the rows of crops or around a field to block wind. Farmers may adopt agroforestry to protect their crops from wind erosion.	Positive	[129]
X_{17}	Shade	Trees provide shade for animals, enhance social capital by encouraging farmers to interact with one another, and promote the healthy growth of cocoa-related crops. Thus, a positive association between farmers who plant trees for shade and the adoption of agroforestry is expected.	Positive	[130,131]
X_{18}	Fertility	Agroforestry can increase or maintain soil moisture retention and soil fertility by generating soil organic matter. If their farmland is fertile, farmers are more inclined to adopt agroforestry.	Positive	[132]
X_{19}	Erosion	Agroforestry improves soil structure, reduces soil erosion, and decreases the velocity of runoff water. Farmers who perceive a decline in soil fertility and intend to increase land fertility may be more likely to adopt agroforestry.	Positive	[133]
X_{20}	Pest control	Agroforestry is advantageous for pest management. Farmers are more inclined to adopt agroforestry as it helps safeguard their crops from pests.	Positive	[134]

Table A1. *Cont.*

Symbol	Variables	Hypothesis	Expected Results	References
X_{21}	Scenic	The planting of trees on farmlands increases the scenic beauty of rural landscapes and facilitates recreational activities. Farmers who intend to increase their land's recreational value by planting trees are more likely to adopt agroforestry.	Positive	[135,136]
X_{22}	Heat	Heat control: trees' canopies protect crops from heat stress and reduce moisture loss through excessive evaporation. Therefore, since the effects of heat can be minimized through the planting of trees, heat control likely has a positive relationship with the adoption of agroforestry.	Positive	[137]
X_{23}	Runoff	Agroforestry decelerates runoff, nutrient loss, water erosion, and flooding; hence, farmers' perception of the threat posed by runoff may positively influence their willingness to adopt agroforestry.	Positive	[107]
X_{24}	Water Volume	Intermediate tree cover and suitable tree species help conserve water and improve groundwater resources. Improper management and the selection of inappropriate tree species cause competition in the acquisition of tree and crop groundwater. Hence, farmers' perceptions of the condition of the groundwater volume on their farmland may negatively influence their willingness to adopt agroforestry.	Negative	[138]

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