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RESEARCH PAPER

Agroforestry Systems as Alternative Land-Use Options in the Arid Zone of Thal, Pakistan

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Abstract Agroforestry offers unique opportunities for increasing biodiversity, preventing land degradation, and alleviating poverty, particularly in developing countries, but factors explaining the adoption by farmers are not well understood. A survey of 524 farm households was conducted in Bhakkar district of Punjab, Pakistan to study factors that determine the adoption of agroforestry on the sand dunes in the resource-deficient region of Thal. Two types of agroforestry systems were studied: intercropping and border cropping (also known as boundary or perimeter planting). Both agroforestry systems included irrigated cultivation of the timber trees *Eucalyptus camaldulensis* (local name: sufeda) and *Tamarix aphylla* (local name: sars) with wheat, chickpeas (*Cicer arietinum*) (local name: chana) or cluster beans (*Cyamous tetragocalobe*) (local name: guars). The majority of the farmers was in favour of intercropping and border cropping. Most farmers reported the protection of nearby crops from dust storms as the most important positive perception about both agroforestry systems. Age, education, and farm to market distance were significant determinants of agroforestry adoption. Older and less-educated farmers, with farms closer to markets were less likely to adopt tree planting or border cropping in Thal. In general, the agroforestry systems examined were more likely to be adopted by farmers who can wait 3–4 years for harvesting crop outputs, but not by poorer farmers who are totally dependent on subsistence agriculture and cannot afford the high initial cost of agroforestry establishment, nor can they wait for crop output for extended periods. Furthermore, the adoption of both agroforestry systems was more likely in remote marginal areas than in areas

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close to markets. To increase agroforestry adoption rates, government policies should strengthen farmers' knowledge of every stage of agroforestry through extension services, focusing particularly among the prime prospects, i.e. farmers who will be most likely to adopt agroforestry. Once the prime prospects have adopted it, the older, less-educated, and poor farmers of the rural population can be also focused on to motivate adoption.

Keywords Border cropping · Farmers' perceptions · Sand dunes · Tree planting

Introduction

Deforestation and land degradation have emerged as issues of global concern, especially where productive forests and fertile land are shrinking at alarming rates (Baig et al. 2008). In Pakistan, deforestation is a serious ecological issue attributed to several factors, including the rapid growth of the population and the expansion of agriculture, market demands, changes in land ownership regimes, and political instability (Rahman et al. 2014). Farmers practise intensive farming methods and often bring highly marginal land under cultivation through conversion of forests on steep slopes. It is believed that almost 39,000 ha of forest are lost every year in Pakistan (Hasan 2007). Agroforestry integrates trees or shrubs into farming systems in ways that create an agro-ecosystem succession similar to that occurring in natural systems, allowing farmers to mimic natural ecosystems in their management of fields. Agroforestry technologies have the potential for improving both productivity and livelihoods of farmers (Garrity 2006; Swallow et al. 2009). About 1.2 billion people in the developing countries rely on agroforestry practices to sustain agricultural productivity and provide income (Chao 2012).

Pakistan is situated in the arid and hyper-arid region of the world and is deficient in natural forest resources of commercial value (Rahman et al. 2014). Only 5% of the country is under forests (Government of Pakistan 2013). In the hot and arid zone of Pakistan, especially in the desert of Thal, agricultural improvement and development is a challenging task for local farmers who practise irrigated and rainfed agriculture. Soils are infertile and of low productivity, and agriculture is subject to uncertainty due to erratic rainfall and drought. Most of the arid zone of Pakistan depends upon monsoon rains for crop production, but crop yields under those conditions are low and uncertain. In the past few years, an emergence of agroforestry in the area of sand dunes motivated several local farmers to adopt agroforestry in Thal. Empirical evidence confirms that agroforestry adoption in the sand dunes provides support to the farming system by conferring stability of income and generating assured income for the local people, since most area of Thal consists of sand dunes. Also, the cultivation of trees in the sand dunes can be useful in fulfilling significant household needs for firewood, expanding timber business in the area and increasing employment opportunities. Despite obvious agroforestry benefits in the Thal desert, a large portion of local farmers continues the cultivation of traditional non-irrigated crops in the sand dunes. It is, therefore, a necessity in the area to clearly understand the reasons of some farmers to adopt agroforestry in the sand dunes and those of others who do not.

There is much information available in the literature regarding factors affecting the adoption of agroforestry practices (Mercer 2004). Theoretical models of agroforestry adoption have primarily utilized a household production framework to model agroforestry adoption as an investment choice based on maximization of expected utility or profit, given various labor and financial constraints (Mercer 2004). Adoption is most likely when the farmer has the available inputs (e.g. land, labor, income) to begin a new agricultural technique (Adesina and Chianu 2002). Education and adoption by neighbors also play a role. Usually, adoption studies have a tendency to look at extrinsic variables, like commodity markets and government policies, when explaining agroforestry uptake. These variables are significant particularly for smallholder farmers in developing countries, including the farmers of this study. Although economic factors are crucial in the adoption process, a wide range of other variables affect the decision as well. Market participation is also correlated with initial conditions related to several characteristics of the household and farm, such as land size, asset ownership, wealth, and the prevailing agro-ecological environment (Amrouk et al. 2013). For example, a study of farmers' decisions to adopt alley farming in Nigeria showed that economic variables as well as farmers' characteristics were significant in explaining adoption decisions (Adesina and Chianu 2002). Similarly, decisions of smallholder farmers for integration of woody plants in Ethiopia were found to rely on resource-based factors such as shortage of land and seedlings, competition with major cash crops, as well as access to infrastructure and support services, including personal characteristics of farmers (Krause et al. 2007). A previous study from Pakistan (Nouman et al. 2006) concluded that farmers were adopting agroforestry practices mainly to meet their fodder and fuelwood needs.

Farmers often adjust the technology and can play an important role in the development and adoption of agroforestry practices (Douthwaite et al. 2002; Thangata and Alavalapati 2003; Ajayi et al. 2003). More recently, several studies have also looked at socio-psychological factors, e.g. farmers' perceptions, to explain adoption behavior. Farmers' perceptions of what they need for adopting agroforestry and which risks are connected with agroforestry adoption can play a major role. Uncertainty inhibits adoption, assuming farmers are often risk averse, given that doubt can drive incorrect predictions of the expected benefits from adoption (Pannell 2003). A study from Pakistan (Irshad et al. 2011) revealed that positive factors affecting the adoption of agroforestry practices in Swat district included farmers' perceptions of agroforestry as a source of income and specific socio-economic characteristics of farmers, such as good education level of the household head and large family size. On the other hand, negative factors for agroforestry adoption were constraints expressed by the farmers, such as poor crop stands, lack of markets, lack of nurseries, damage by animals and humans, and lack of incentives. A study of factors determining tree planting adoption in rural Rwanda (Ndayambaje et al. 2012) found that a large number of household members in informal employment, a large number of meals per day (leading to frequent use of fuelwood for cooking meals), and the selling of tree products on the market had a positive effect on adoption, whereas the male heads of households and the amount of fuelwood from own farms had significant negative effects on the presence of trees on farms.

Obviously, farmers' motivations play an important role in explaining the decision-making process and in shaping adoption behaviors (Ahnström et al. 2009). Understanding farmers' motivations has received substantial attention recently, driven by the efforts of advisors and policy makers to encourage farmers to make changes to improve their status without compromising the environment (Greiner et al. 2009). Studies on agroforestry adoption will provide lessons for guiding the introduction of other agroforestry technologies and will fill important gaps in the adoption of agroforestry technologies in the literature (Adesina and Chianu 2002). Socioeconomic research on agroforestry can identify strengths and weaknesses in the current state of knowledge and provide guidance for investigation and more productive feedback loops between researchers and practitioners (Montambault and Alavalapati 2005). To this end, farmers' surveys are helpful because of their usefulness in setting the research agenda, testing research hypotheses, designing extension strategies, evaluating the effectiveness of projects and development interventions. It should be noted, however, that research on agroforestry is limited in Pakistan.

The aims of this study were to describe the agroforestry system in the area and to determine factors affecting its adoption in the arid zone of the Thal desert in Pakistan. The study is the first of its kind for the area and aims at drawing attention to the potential of agroforestry technologies in the context of specific area of Thal; it is expected to provide a benchmark for future comparisons of agroforestry adoption rates in the area or other areas with similar growers' profile under similar conditions and to support policy development efforts of the local authorities for promoting more effectively the agroforestry adoption decisions of farmers by incorporating knowledge and preferences of the local community.

Materials and Methods

Study Area

The study was carried out in Bhakkar district of Punjab province in Pakistan (Fig. 1). Most of the area in the district lies in the desolate plain of the Thal desert. The Thal desert is a large (the third largest) desert in Pakistan, located in central Punjab; it covers an estimated area of 20,000 km^2. Bhakkar is located between the Indus and Jhelum rivers and meets the foothills of the Salt Range of Potohar Plateau in the northern part of Punjab. The climate of Thal is arid; the area is dominated by rainfed sand dunes and resource-deficient land of marginal quality (Rahim and Hasnain 2010). The average annual rainfall is less than 300 mm and consequently scarcity of water often prevails. Windstorms are a common climatic component, causing severe soil erosion. Due to the harsh environment, the biodiversity in the Thal desert is low.

Fig. 1 Map of the study area

Agriculture and livestock rearing are the major livelihoods in the area. However, variability in climatic conditions often generates serious risks to farming, livestock, and water resources. Climate extremes affect the welfare and livelihood of rural populations (Dasti and Agnew 1994; Shah et al. 2007). Bhakkar district is particularly at risk because of the dominance of rainfed, rather than irrigated, agriculture for food production. The impact of increased temperatures from global warming and reduced or more variable precipitation, resulting from climate change, is expected to depress crop yields, reduce agricultural production, and put further pressure on marginal land holdings. There is no specific cropping system for the entire district. Empirical evidence confirms that the preferred cropping systems largely depend upon soil type and its potential, availability of water resources, distance from the market, and the investment capacity of farmers. Wheat, chickpeas (*Cicer arietinum*) (local name: chana), and cluster beans (*Cyamous tetragocalobe*) (local name: guars) are common crops in the area. However, the production is low due to total dependence on rainfall, which exhibit large cyclic fluctuations (Dasti and Agnew 1994; Shah et al. 2007). Also, the area largely lacks road infrastructure and industrial establishments, and therefore there is high poverty and unemployment.

Bhakkar district includes the largest land area cultivated in the Thal desert. In recent years, many inhabitants in this district turned to agroforestry to increase their incomes. Empirical evidence confirms the cultivation of the timber trees *Eucalyptus camaldulensis* and *Tamarix aphylla* either as pure tree farming or as intercropping in orchards. Bhakkar district has a large timber market. Vegetation from unproductive dry land can be a source of fuelwood and timber for the local community, often seen as an additional source of income for farmers. However, high exploitation pressure by local people to meet basic household energy needs, construction demands, and fuelwood collection has become a great threat to natural forests in arid or semi-arid regions. Thus, it was hypothesized that this district would provide the most relevant and important information about agroforestry adoption. Bhakkar district was chosen for this study also taking into account that agroforestry farming systems have been established in the area. Based on the the deadlines of this project, two tehsils (i.e. sub-districts) out of the four tehsils of Bhakkar district were randomly selected (i.e. Darya Khan and Kaloor Kot). Data were collected from three villages, i.e. two from Darya Khan tehsil and one from the Kaloor Kot tehsil, taking into account the population of each district, using a simple random sampling technique.

Sample Selection

In total, 524 farmers from three villages (Joyia, Raitri, Fazil) participated in the study. All farmers in each village were used as the study sample (census). In total, 197 farmers were from Joyia village and 130 farmers were from Raitri village from the tehsil Darya Khan. From the tehsil Kaloor Kot, 197 farmers were from Fazil village. Lists of farmers were taken from the chief-officer (numbardar) of each village for the data collection. Every farmer in all three villages participated in the study. Due to missing information, four farmers were dropped, so the total sample of the study was finally 520 farmers. Out of these farmers, 39 were practicing border cropping, 182 were practicing orchard intercropping and the remaining were practicing neither. The farmers were grouped based on their adoption of the dominant agroforestry system (the agroforestry system with the greater land use in the sand dunes compared with the other production systems), because most of them were using both types of cropping systems. Dominance was based on farmers' operational area in the sand dunes.

Data Collection

Primary data were collected using open- and closed-ended questions from a fully structured questionnaire through face to face interviews with the farmers. It was preferred to interview the household head. In case the head of the household was not found or was not available for an interview, an adult member of the household was recruited to collect the required information. With reference to farmers' perceptions of intercropping and border cropping, farmers were asked to express their opinion of the advantages and disadvantages of these agroforestry systems with 0 = no or 1 = yes, using both open and closed-ended questions. Open-ended questions were used to better clarify responses to close-ended questions. Simple questions were designed to be easily understood by farmers combined with the binary response format (0 = no, 1 = yes) to facilitate easy and fast processing by the respondents, contributing to less time required for the survey. The binary answer format was found to represent an interesting alternative to the ordinal format, especially when speed of completion is essential (Dolcinar and Grün 2007). High mean values for a specific advantage (or disadvantage) indicate a high proportion of farmers mentioning that advantage (or disadvantage). The final part of the questionnaire included questions about the socio-demographic characteristics of farmers, such as gender, age, education, land tenure, and crops. Furthermore, group discussions with a limited number of farmers and local leaders of each village, were also conducted to collect more information. The main reason for conducting the group discussions was to gain insight into how the groups think about agroforestry as well as into the inconsistencies and variation that exists in the local communities in terms of beliefs and their experiences and practices. Detailed information from the group discussions is not presented; it is only used to better explain our quantitative data in the discussion, where necessary.

Data Analysis

For all data collected, basic descriptive statistics (mean values and standard deviations) were calculated in SPSS version 20. Independent sample t-tests were used to determine significance of differences in the means of socio-demographic variables between adopters and non-adopters of agroforestry (Norman and Streiner 2008). Chi square tests were used to compare differences among farmers' perceptions of agroforestry. Unless otherwise stated, mean differences were declared significant at the 95% confidence level.

Logistic regression was used to determine factors influencing adoption of tree planting or border cropping. Logistic regression is similar to linear regression models, but is suited to situations where the dependent variable is dichotomous (Pampel 2000). Although other models are suitable for this case, the logistic model was selected for reasons of simplicity and ease of interpretation. For logistic regression, the possibility (P) for the dependent variable (y) is determined as the function of independent variables (x_i) as follows:

$$P_i = \frac{e^{b_0 + b_i x_i}}{\mathbf{1} + e^{b_0 + b_i x_i}}$$

where b_i is the coefficient corresponding to the independent variable x_i (Pampel 2000). The model consisted of adoption of tree planting or border cropping as the dependent variable, while certain socio-economic variables, such as age (years), education (years), off-farm monthly income (Pakistan rupees), immediate family members (no.), and land characteristics as well as resource variables, such as the total land under cultivation (ha) and the operational area in the sand dunes (ha), as the independent variables. The independent variables were included on the basis of their theoretic significance commonly derived from past research in adoption studies. The three villages were not considered as independent variables in the regression. If a farmer did tree planting or border cropping, the dependent variable was set to one in both models. In the output in the results section, estimates b for the beta and the value Exp(β) are presented for ease of interpretation. This value, Exp(β), represents the change in the odds that the dependent variable has the value 1, when the respective predictor variable increases by one unit. The variance inflation factor was < 10, signifying that the variables did not show severe multi-collinearity problems (Randolph and Myers 2013). The Omnibus test of model coefficients was used to check the capability of all predictors in the model to predict the response (dependent) variable (Osborne 2014). A finding of significance corresponds to the conclusion that there is adequate fit of the data to the model. The Hosmer and Lemeshow test was used to assess the fit of the predictions and the actual outcomes. Non-significance of the *p* value of this test indicates an acceptable match between the predicted and actual values. The power of the model in explaining data variation was also assessed by −2 log likelihood and pseudo R^2.

Results

Information About Agroforestry Systems Adopted by Farmers

Overall, 39 farmers were practicing border cropping, 182 farmers were practicing orchard intercropping and the remaining farmers were practicing neither. The most frequent method of tree planting on the sand dunes of the Thal desert was the cultivation of the timber trees *Eucalyptus camaldulensis* and *Tamarix aphylla* either in pure tree farming or in orchard intercropping. Wheat, chickpeas (*Cicer arietinum*), and cluster beans (*Cyamous tetragocalobe*) were the major crops in intercropping. There was a trend of cultivating timber trees for sale or commercial purposes, because timber trees provide more income and economic benefit after 3–5 years. Arid chana (chickpeas), arid guars (cluster beans), and arid wheat were the major annual crops in the area. Recently, a shift from these crops to agroforestry systems, such as orchard intercropping or border cropping, was observed among local people of the area. Tree planting was usually established with irrigation, using turbines (by leveling land), hand pumps, or with the help of small tube wells with plastic pipes. These small tube wells with plastic pipes along with the hand pumps are inexpensive and do not require land leveling; therefore, many farmers adopt these irrigation methods for tree planting. Border cropping, however, requires both land leveling and fixing turbines on the sand dunes, which render it a much more expensive irrigation system. This is the reason for which the border cropping method was selected by only a small number of farmers.

Basic Socio-Economic Background of Farmers Implementing Tree Planting

Basic socio-economic characteristics of the farmers implementing tree planting compared to those who are not are shown in Table 1. All farmers were male.

Table 1 Mean values of the variables included in the analysis of tree planting and values of the independent samples t-test

Variable	Adopter	Non-adopter	t-test	Sig.
Age of the household head (years)	40.34	44.71	−3.761	0.000
Education of the household head (years)	5.47	3.90	3.633	0.000
Immediate family members (no.)	6.81	6.80	0.037	0.971
Off-farm monthly income (US$)	70.34	53.09	1.931	0.054
Total land under cultivation (ha)	9.28	10.65	−1.624	0.105
Operational area in the dunes (ha)	4.09	4.74	−1.868	0.063
Farm to market distance (km)	5.47	4.35	3.076	0.002

Women do not have an active role in the selection of the production system. Adopters of tree planting had a mean age of 40.3 years, which was lower than mean age of non-adopters. As for the education, adopters of tree planting had a mean education level of 5.5 years, which was higher than that of non-adopters. Mean number of family members, average off-farm monthly income, and total land under cultivation for the farmers implementing tree planting were 6.8 individuals, 70.3 US$, and 9.3 ha, respectively, without significant differences with the respective values of non-adopters. The average distance from farm to market was significantly greater for adopters than non-adopters of tree planting (Table 1).

Farmers' Perceptions of Tree Planting

Farmers showed variable perceptions of tree planting (Table 2). A large proportion of the farmers, though less than half, felt that tree planting can protect nearby crops from dust storms (mean 0.46) and others thought that tree planting can compact the soil in the dune area, i.e. to improve the soil stability (mean 0.29). Most farmers expressed an intention to increase the cultivated area with tree planting in the future (mean 0.57) (Table 2).

Adoption of Tree Planting

The results of the logistic regression model for adoption of tree planting are shown in Table 3. The Omnibus test for model specification showed that the model containing all the predictors was significant (see model fit statistics in Table 3). With reference to the personal characteristics, the age of the household head had a negative and significant impact (p value < 0.01) on adoption of tree planting with an odds ratio of 0.968. This value signifies that holding other factors constant, an increase in the age of the household head by 1 year reduces the likelihood of adopting agroforestry by 0.968. On the other hand, the education level of the

Table 2 Farmers' perceptions of tree planting

Perception of tree planting	Mean	SD
Compacting the soil in the dunes area	0.29	0.456
Protecting nearby crops from dust storms	0.46	0.500
Source of grazing for farm animals	0.03	0.164
Additional source of income in the dunes	0.23	0.423
Collateral security for the times of need	0.14	0.346
Increasing the fertility of the dunes land	0.15	0.363
Increasing the natural beauty of the land	0.09	0.285
Preventing soil erosion in the area	0.09	0.285
Land utilization in all seasons	0.07	0.259
Intending to increase the tree planting area in the future	0.57	0.497

Mean values represent percentages of farmers having each specific perception; Chi square = 172.493, df = 9, $p < 0.001$

Table 3 Logistic regression analysis of tree planting adoption

Variable	Beta (β)	SE	Wald	Sig.	Exp(β)
Constant	0.90300	0.667000	1.831	0.176	2.467
Age of the household head	−0.03200***	0.012000	6.908	0.009	0.968
Education of the household head	0.05800*	0.034000	2.954	0.086	1.060
Immediate family members	−0.00800	0.039000	0.046	0.830	0.992
Off-farm monthly income	0.00003**	0.000015	4.014	0.045	1.000
Total land under cultivation	−0.00700	0.013000	0.243	0.622	0.993
Operational area in the dunes	−0.03000	0.032000	0.865	0.352	0.970
Farm to market distance	0.13900***	0.038000	13.506	0.000	1.149
Cox and Snell R-square	0.113				
Nagelkerke R-square	0.151				
Hosmer–Lemeshow test	0.595				
−2 log likelihood	432.931				
Omnibus test of model coefficients					
Chi square	41.281				
Degrees of freedom	7				
Significance	0.000				
Correct prediction (%)	63.8				

* Significant at $p < 0.1$; ** significant at $p < 0.05$; *** significant at $p < 0.01$; *SE* standard error

household head had a positive and significant impact (p value < 0.1) on adoption of tree planting with an odds ratio of 1.060. Off-farm monthly income had a positive and significant impact (p value < 0.05) on adoption of tree planting with an odds ratio of 1.000. Also, the farm to market distance had a positive and significant impact (p value < 0.01) on adoption of tree planting with an odds ratio of 1.149. This value implies that an increase in farm to market distance by one km increases the likelihood of adopting agroforestry by 1.149.

Basic Socio-Economic Background of Farmers Implementing Border Cropping

Basic socio-economic characteristics of the farmers implementing border cropping are shown in Table 4. All farmers were male. Mean age of adopters of border cropping was 38.3 years, which was lower than that of non-adopters. Adopters of border cropping had a mean education level of 6.0 years, which was higher than that of non-adopters. Farmers implementing tree planting had total land under cultivation of 8.5 ha, which was less than that of non-adopters. Mean family members and off-farm monthly income for the farmers implementing tree planting were 6.3 individuals and 63.8 US$, respectively, without significant differences with the respective values of non-adopters. Similarly, the distance from farm to market did not differ significantly between adopters and non-adopters of border cropping (Table 4).

Table 4 Mean values of the variables included in the analysis of border cropping and values of the independent samples t-test

Variable	Adopter	Non-adopter	t-test	Sig.
Age of the household head (years)	38.28	44.71	−2.934	0.005
Education of the household head (years)	6.03	3.90	2.582	0.013
Immediate family members (no.)	6.33	6.80	−1.172	0.245
Off-farm monthly income (US$)	63.84	53.09	0.860	0.394
Total land under cultivation (ha)	8.51	10.65	−2.144	0.035
Operational area in the dunes (ha)	4.07	4.74	−1.500	0.138
Farm to market distance (km)	5.30	4.35	1.663	0.102

Farmers' Perceptions of Border Cropping

Farmers had variable perceptions of border cropping (Table 5). A large proportion of farmers thought that border cropping can protect nearby crops from dust storms (mean 0.59), whereas some farmers thought that the *Eucalyptus* trees used for border cropping in the area use too much water and harm other crops (mean 0.26). However, the majority of the farmers expressed an intention to increase the area under border cropping in the future (mean 0.59).

Adoption of Border Cropping

The results of the logistic regression model for the adoption of border cropping are shown in Table 6. The Omnibus test for model specification indicated that the model with all the predictors was significant (see model fit statistics in Table 6). Regarding personal characteristics, the age of the household head had a negative and significant impact (p value < 0.01) on adoption of border cropping with an odds ratio of 0.957. This value means that holding other factors constant, an increase in the age of household head by 1 year reduces the likelihood of adopting border

Table 5 Farmers' perceptions of border cropping

Perception of border cropping	Mean	SD
Providing higher profit	0.31	0.468
Protecting nearby crops from dust storms	0.59	0.498
Collateral security for the times of need	0.13	0.339
Increasing the natural beauty of the land	0.08	0.270
Preventing soil erosion in the area	0.05	0.223
Eucalyptus trees use much water and harm other crops	0.26	0.442
Intending to increase the border cropping area in the future	0.59	0.498

Mean values represent percentages of farmers having each specific perception; Chi square = 150.735, df = 6, $p < 0.001$

cropping by 0.957. On the contrary, the education level of the household head had a positive and significant impact (p value < 0.01) on adoption of border cropping with an odds ratio of 1.124. Also, the distance of farm to market had a positive and significant impact (p value < 0.01) on adoption of border cropping with an odds ratio of 1.139. This value implies that an increase in farm to market distance by one km increases the likelihood of adopting agroforestry by 1.139.

Discussion

Most farmers in this study had quite positive opinions of tree planting and border cropping; the majority of them expressed intention to increase tree planting and border cropping in the future. This behavior may play an important role in the fate of agroforestry in the area because the adoption rates often depend on farmers' perceptions of risks and uncertainties and not so much on the actual risks and uncertainties (Meijer et al. 2015). Farmers make land-use decisions not only in a business context (i.e. product prices and input costs), but also in a personal context (Pannel et al. 2006), as also confirmed through the group discussions of this study. Therefore, farmers' perceptions play an important role in explaining the decision-making process and in shaping adoption behaviors (Greiner et al. 2009). Because farmers' perceptions may affect behavior (Damalas and Hashemi 2010; Hashemi et al. 2012), lack of adequate information about farmers' perceptions has been a

Table 6 Logistic regression analysis of adoption of border cropping

Variable	Beta (β)	SE	Wald	Sig.	Exp(β)
Constant	−0.133000	1.110000	0.014	0.905	0.875
Age of the household head	−0.044000***	0.020000	4.577	0.032	0.957
Education of the household head	0.117000***	0.055000	4.593	0.032	1.124
Immediate family members	−0.057000	0.076000	0.563	0.453	0.944
Off-farm monthly income	0.000015	0.000031	0.240	0.624	1.000
Total land under cultivation	−0.038000	0.030000	1.568	0.211	0.963
Operational area in the dunes	0.047000	0.065000	0.517	0.472	1.048
Farm to market distance	0.130000***	0.057000	5.184	0.023	1.139
Cox and Snell R-square	0.115				
Nagelkerke R-square	0.184				
Hosmer–Lemeshow test	0.205				
−2 log likelihood	172.902				
Omnibus test of model coefficients					
Chi square	24.455				
Degrees of freedom	7				
Significance	0.001				
Correct prediction (%)	83.0				

* Significant at $p < 0.1$; ** significant at $p < 0.05$; *** significant at $p < 0.01$; *SE* standard error

significant constraint upon establishing effective approaches, principally for smallholder farmers.

The likelihood of adoption of tree planting or border cropping decreased with the age of the household head. This finding means that the older farmers were not as likely to adopt tree planting or border cropping in the sand dunes, and they preferred conventional farming. There are several possible explanations for this behavior in the literature. The older farmers are not of an age considered to be highly productive in farming (Anim 2011). This issue is important in the sense that growing trees is a labor intensive job. Compared to a farmer of advanced age, a younger farmer may be energetic enough and may want to make more money from ventures other than traditional agriculture (Donkor and Owusu 2014). As confirmed through the group discussions of this study, the result may also imply that most of the young people in the area cannot get formal employment, while business activities are also limited, which means that these farmers are more likely to supplement household income by on farm tree production. Another possible explanation for this comportment may be related with the risk-taking behavior of farmers (Roe 2015). Risk preferences are important constraints that keep farmers from reaching their productive potential particularly in the developing countries (De Brauw and Eozenou 2014). Despite the yield improvements generally associated with the adoption of new farming technologies and modern inputs, technology diffusion among small-scale farmers in the developing countries is slow (Brick and Visser 2015). This is not surprising, given that most farmers in the developing world operate in extraordinarily risky environments and face several risks in production, such as climate variability (Hazell et al. 2010). Although component elements of risk taking include several factors that can be considered predisposing factors, it is generally accepted that risk aversion increases as we age (Morin and Suarez 1983). Thus, young individuals are often risk lovers, i.e. they are willing to take more risks while investing to earn high returns. On the other hand, older individuals are often risk averters, i.e. they fear the consequences of a wrong decision or action—not realizing that not making a decision or taking action also has consequences. Findings from sub-Saharan Africa showed that food secure farmers may act as entrepreneurially inclined ‘opportunity seekers’ and venture into agroforestry, whereas being ‘food imperative’ makes it more difficult for agroforestry to take root among the ‘poorest of the poor’ who act as ‘risk evaders’ (Jerneck and Olsson 2014). Despite the fact that risk aversion was not measured in this study, evidence from the group discussions confirmed this assertion to a great extent. It should be noted, however, that despite the fact that the difference in mean age is significant due to the model, this difference should be treated with caution from a practical point of view, unless the life expectancy is short.

The likelihood of adoption of tree planting or border cropping increased with education of the household head. Thus, education had a significant contribution to the adoption of agroforestry in the area. The level of formal education is an important socio-economic factor in transforming lives of individuals. Education makes farmers knowledgeable of and more comfortable with innovative, improved, and profitable farming practices. Furthermore, educated farmers have more frequent contacts with extension services, thereby becoming more open in the adoption of innovative practices. Moreover, a high education leads to a better understanding of the new technology when reviewing the different extension materials. Dhakal et al. (2015) found that education was a significant determinant of the adoption of agroforestry-based land management practices in Nepal. Similarly, Gibreel (2013) found that farmers with higher education were more likely to practice the traditional gum Arabic agroforestry system in western Sudan. Education was also found to be a major determinant for adoption of agroforestry systems in areas of Brazil (Do Pompeu et al. 2012).

The farm to market distance had a positive and significant impact on the adoption of the tree planting and border cropping. Thus, the higher the distance between the farm and the market place, the greater the likelihood of adoption for the agroforestry technology will be. Although the result seems paradoxical at first glance, similar results can be traced in the literature. For example, Zerihun et al. (2014) reported that the distance from the nearest market positively affected the adoption of agroforestry technology in South Africa. In the present study, this result means that agroforestry is more likely to be adopted in remote marginal areas than in areas close to towns and markets. Obviously, farmers prefer to adopt both technologies in dune areas that were largely abandoned in the past, i.e. in non-operational sand dunes.

This study provides insights into factors affecting adoption of agroforestry systems as alternative land-use options in the Thal area of Pakistan. There are, however, inherent limitations in such kind of studies that should be kept in mind. First, individual surveys generally cannot provide strong evidence of cause and effect; thus, the results are mainly of a descriptive nature and do not provide definite information about cause-and-effect relationships. Second, careful crafting of the survey questions is essential in studies of this kind, because even slight variations in wording can have a significant impact on how people respond. This is the reason for selecting simple questions with a binary response format to facilitate easy and fast processing by the respondents. Thus, even though that in-depth information may have not been collected, the general trends of farmers' perceptions in the area were correctly depicted.

Conclusions

This study provides a description of the agroforestry system in the Thal area of Punjab province, Pakistan and the factors affecting its adoption. Factors that impact the adoption of agroforestry in the Thal area were found to be: age, education level of the household head, and farm to market distance. In general, agroforestry was more likely to be adopted by farmers who can wait 3–4 years for harvesting the crop, but not by poor farmers who are totally dependent on subsistence agriculture and they cannot afford the high initial cost of agroforestry establishment nor can they wait for crop outputs for an extended period of time. Case studies on agroforestry adoption in developing countries provide useful information for identifying factors facilitating and impeding adoption. Such studies also offer the opportunity to enrich more traditional approaches to assessing interventions, helping to explain why some interventions are unsuccessful, or why they seem to work effectively in some contexts, but not in others. Given that studies on this topic do not exist in Pakistan, the current study provides a benchmark for future comparisons of agroforestry adoption rates in the area or other areas with similar growers' profile and highlights possible points of intervention for the management of the behavior of farmers. By identifying barriers of agroforestry adoption in the Thal area, this research has provided a first assessment of the agroforestry systems adoption in the area, highlighting that the adoption of agroforestry needs to be sensitive not only to the characteristics of the technology, but also to the socioeconomic conditions, which often are not given due attention. Future research could focus on different agroforestry systems to study the profitability of each system with the aim to provide the most suitable crop and tree combinations for the study area as well as on the role of risk and uncertainty in the intensity of adoption.

The government should facilitate farmers by providing extension services with scientific-based practices and information on every stage of agroforestry (e.g. personal assessment, biophysical site assessment, agroforestry system selection, practice design, and marketing strategies), focusing particularly among the prime prospects, i.e. farmers who will be most likely to adopt agroforestry. Once the prime prospects have adopted it, the older, less-educated, and poor farmers of the rural population can be also focused on to motivate adoption. Focusing attention on people who seem unlikely to adopt agroforestry systems may provide the required information to change attitudes and create willingness in those people to eventually adopt new production systems. In addition, a strong and stable advocacy is needed to ensure the conditions necessary for technology adoption and also the application to real needs is crucial to its integration beyond the innovators and early adopters. Agroforestry adoption can be increased, if the government provides some financial incentives to farmers. Above all, however, it clearly appears that the government needs to put more effort into improving economic well-being and supporting formal education in rural agricultural communities. An important criterion for the success of agroforestry programs in the area is the physical and mental involvement of the local population at various tiers of the community. Local farmers have to play a fundamental role in identifying the needs which could fit harmoniously to their socioeconomics, land ownership, and sustainable life spectrum, leading to prosperity in the long run.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Research Ethics Participants were fully briefed, verbally, in their own language, on the nature and purpose of the research. Verbal consent to participate was obtained without pressure.

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