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Technology Adoption and Extension Strategies in Mediterranean Agriculture: The Case of Family Farms in Chile

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Abstract: Extension services play a crucial role by improving skills and access to information that result in greater farm level innovations, especially on family farms which are the predominant form of agriculture in the world. This study analyzed the connection between strategies implemented by extension services and technology adoption on family farms. Using the case of the Servicio de Asesoría Técnica (SAT) Program, we developed a bottom-up adoption index (AI) for vegetable and berry farmers in three regions of Central Chile. We implemented 10 focus groups totaling 101 participants, all recipients of technical assistance from private extension companies (PECs) funded by the SAT Program. After the focus group sessions, we surveyed participating farmers to gather information on socio-economic attributes and adopted technologies. Using cluster analysis, we identified three groups of farmers according to their adoption intensity. The results indicate that extension strategies used by PECs have distinct effects on the adoption of new technologies. Higher adoption indexes were positively associated with the duration of the extension visits, the number of group activities, and the use of incentives and credits provided by the Chilean government. The value of production and farm size were positively associated with adoption intensity.

Keywords: adoption index; technology adoption; extension; family farms; Chile

1. Introduction

The development of agriculture depends largely on access to new technologies and information which can be greatly facilitated by extension services [1–3]. Agricultural extension and technical assistance improve skills in production units, especially on family farms, the predominant form of agriculture in the world [4]. Because family farm agriculture (FFA) usually has limited access to markets and services [2,5], the delivery of high-quality extension can be a suitable policy to improve access to information and technology among this group of producers. However, FFA often encounters restricted access to extension services because of the inability or unwillingness to pay for them, the lack of providers, and limited incentives from public institutions. Previous studies have shown that once delivery barriers are overcome, investments in extension yield high rates of return [6]. Prominent reviews of extension programs found that, although overall rates of return to extension varied widely, they exceeded 20 percent in three-quarters of the 81 extension programs examined [2,7]. However, farmers' needs as well as their socioeconomic and agroecological conditions can constrain the adoption of a new technology or practice, even if a suitable extension service exists and gives adequate and timely advice [6]. Hence, identifying the factors that promote or limit the impact of extension services is relevant from the perspective of improving public policy and the efficient allocation of public resources.

Historically, the Chilean agricultural sector has been characterized by a dual system with high land ownership concentrated in a few families and many small and poor farmers [8]. Many efforts have been made since the 1960s to address this inequality; however, the country still has a large number of small holders [9]. In more recent years, the overall economic policy, including the agricultural sector, has moved towards a neoliberal system where small-scale farming faces increasing difficulties to remain competitive [8]. Since 1990, agricultural policies in Chile have centered around three objectives: increasing competitiveness; integrating poorer, less competitive farmers into commercial supply chains; and conservation of natural resources. During the past 20 years, Chile has provided lower trade protection than most OECD countries (Organisation for Economic Co-operation and Development), even though government expenditures have tripled in real terms. About half of this spending has gone to large investments on public goods such as roads, irrigation, and other infrastructure projects. The other half has been spent in making poorer farmers more competitive with programs comprising improved irrigation systems; productivity growth (including preferential credits); rural development; soil recovery; training; and extension [9].

In Chile, FFA represents roughly 260,000 farms which accounts for 90 percent of the total [10]. From a territorial point of view, almost 75 percent of FFA is concentrated between the Maule and Los Lagos regions in Central Chile. Family farms contribute 22 percent of the agricultural gross domestic product (AGDP), owns 25 percent of the agricultural assets and 38 percent of the irrigated area, and it hires 33 percent of agricultural employees, a proportion that increases to more than 60 percent when self-employment is included. Also, FFA accounts for 40 percent of the area devoted to annual crops and for more than 50 percent of the stock of cattle [11]. Most of FFA is carried out by small-scale farmers who are beneficiaries of INDAP (National Institute for Agricultural Development). This Institute defines small farms based on four conditions: (1) household head must work the land directly; (2) farm size must be smaller than 12 equivalent (quality adjusted) hectares; (3) total assets must not exceed 3500 UF (or US$ 130,000); and (4) family income should come primarily from farm activities [12].

In Chile, technical assistance has been provided to FFA by INDAP since its establishment in the 1960s [13]. Before 1978, extension services followed the model created in the 1950s in most Latin American countries, with the participation of US advisors. In 1978, the delivery of extension services for FFA was privatized as part of an overall neoliberal policy designed to limit the participation of the government [13]. Within the 1978 to 2000 period, it is possible to distinguish four stages in the evolution of the Chilean extension service [13,14]. The first period, called maximum liberalization, took place between 1978 and 1983 and replaced the old extension service model carried out by professionals contracted directly by the government with limited services provided by a state agency. The second period, from 1983 to 1990, known as maximum standardization, was based on the training-and-visit (T&V) approach referred to as the Integral Technology Transfer Program (PTTI), which followed World Bank guidelines.

The third period, from 1990 to 1996, was called the Improvement Plan. After 17 years of military rule, the new democratic government gave priority to the poorest sectors of the population, and PTTI coverage was expanded to 47,000 households in 1992. The Improvement Plan was redesigned in 1993–1994 to change the farming strategy from "increase yields" to "diversify and increase yields." During the fourth period, between 1997 and 2000, technical assistance underwent another transformation as the PTTI became the Technical Assistance Service (SAT) with the following adjustments: (1) an increased role for organizations in choosing and evaluating technical assistance; (2) differentiation of services according to farmers' capabilities; (3) greater responsibility of farmers in co-financing extension services; and (4) enhanced competitiveness to increase the participation of small-scale farmers in an open market economy.

Currently, the technical assistance delivered to FFA is administered by INDAP, which pursues the strengthening of the human, social, productive, natural, and cultural capital of small-scale landowners [8]. More than 130,000 farmers receive technical assistance through various programs provided by INDAP that are basically divided into two sub-programs: (1) PRODESAL (Local Development Program) and (2) the SAT Program. The main objective of PRODESAL is to maintain and improve the productive activities for home consumption undertaken by smallholders and their families as well as supporting the incubation or improvement of their own or collaborative ventures. The focus of the SAT Program is the expansion of the capabilities of participating farmers and their families to consolidate and/or diversify their businesses [15]. In 2017, a total of 13,546 farmers were beneficiaries of SAT which had a budget of 10,909 million Chilean pesos (about US$ 1200 per farmer) [16]. For the purposes of this study, our focus was on the SAT Program because it has one of the highest budgets provided by INDAP per farmer and draws on the expertise of several private extension companies (PECs).

According to the "Technical Standards and Operating Procedures" of the SAT Program, small-scale farmers present several constraints, namely: (i) low access to innovation technologies that affects productivity, efficiency, and the quality of products and services; (ii) limited access to financial capital for the incorporation of new technologies, while INDAP funds are insufficient to pay for high-impact technological packages that would enhance production and productivity; (iii) low management performance defined by as the standard use of the prevailing technology; and (iv) restricted access to productive assets and infrastructure which limit the modernization of farming systems [14].

Aiming at overcoming these restrictions, the SAT Program provides extension assistance focused on five areas: development of productive and management capabilities to improve the farm business so as to increase productivity and food quality through technology adoption; commercialization channels and the strengthening of farmers' negotiation abilities in the marketplace; increase the social capital for innovation in rural areas; promote the use of complementary programs from INDAP or other public or private funding agencies (e.g., credit and incentives); and encouragement in the adoption of best management practices that promote the conservation of natural resources [16].

Extension strategies of the SAT Program should be suitable to the local and socioeconomic situation of farmers. In this context, the "Technical Standards and Operating Procedures" suggest a combination of different strategies such as farm visits, group activities, and benchmarking based on information that makes it possible to compare the performance between farmers. Also, the aforementioned strategies can be complemented with one or more of the following: technical tours; demonstration plots; market information; and complementary visits by experts [16].

The objective of this study was to analyze the relationship between the degree of technology adoption by FFA and the strategies implemented by extension providers. Using the case of the SAT Program in Chile, we developed a bottom-up technology adoption index (AI) among vegetable and berry farmers in order to associate the technology adoption outcomes with the strategies implemented by the extension providers. According to the SAT Program, PECs can use diverse strategies related to the frequency and duration of farm visits, group activities, formulation of complementary projects, and group meetings. Our intention is to contribute to the design of policies to improve the overall efficiency of extension programs focusing on promoting technology adoption in Chile.

Technology Adoption and Extension

The potential effect of a new technology depends on whether farmers adopt it and, if they do, whether the adoption is to the degree that can lead to results in a certain period of time. Those results are often evident in increases in productivity, food quality, and the sustainability of farm management [17]. The acceptance of new technology usually passes through four different steps: consciousness, profitability, appraisal, and finally acceptance. At each stage, there are various constraints (social, human, economic, physical, or logistical) for different groups of adopters [18]. The extension literature comprises a large number of studies analyzing farmers' adoption decisions vis-à-vis farm and farmer characteristics such as age, farm size, education, off-farm income, access to credit and extension, among others [19].

Table 1 summarizes the results of several econometric studies that have sought to explain the effect of extension on technology adoption such as the use of chemical fertilizer [1], irrigation technologies [18,20], improved varieties [19,21–24], and conservation agriculture [25–28]. All studies cited in Table 1 include the variable "technical assistance or extension" to refer either to the number of extension contacts or to a dummy variable that captures whether or not the farmer receives such support. These limited definitions give us an opportunity, in this article, to investigate a more refined relationship between the strategies of extension services and the adoption of technologies by beneficiaries.

Table 1. Summary of key features and the association between extension and technology adoption.

Reference	Year	Country	Technology	Variable Type/Effect	Crop(s)
[1]	2016	Ghana	Chemical fertilizer	presence of extensionist/+	Rice
[18]	2016	Chile	Irrigation technologies	presence of extensionist/+	Vineyards
[19]	2017	Ghana	Improved varieties	number of extension contact/+	Rice
[20]	2011	Spain	Irrigation technologies	presence of extensionist /+	Various crops
[21]	2010	Pakistan	Improved varieties	presence of extensionist/+	Cotton
[22]	2015	Zambia	Improved varieties	number of extension contact/+	Maize
[23]	2015	Tanzania	Improved varieties	presence of extensionist/+	Maize
[24]	2012	Philippines	Certified seeds/integrated crop management	presence of extensionist/+	Rice
[25]	2003	Ethiopia	Soil and water conservation	presence of extensionist +	Various crops
[26]	2017	Ethiopia	Conservation Agriculture	number of extension contact/+	Maize
[27]	2014	Ghana	Soil and water conservation	presence of extensionist/+	Rice
[28]	2013	Chile	Soil and water conservation	presence of extensionist/+	Various crops

The rest of the paper is organized as follows: The subsequent section describes the area under study and the data and methods used. We then discuss the results and derive some conclusions for policy formulation.

2. Materials and Methods

The study area covers the O'Higgins, Maule, and Ñuble regions in Central–South Chile (33°50′ and 37°12′ South), which belong to the central valley of the country, the heart of fruit and vegetable production. These three regions accounted for 43 percent of the SAT Program budget and 53 percent of beneficiaries in the country (i.e., 7258 users) in 2017 [16]. The sample consisted of 101 small-scale farmers who grow berries or vegetables. All groups receive technical assistance from a private extension company (PEC) funded by the SAT Program.

The methodology employed consisted of four steps: (1) sessions with focus groups; (2) face-to-face interviews; (3) determination of the technology adoption index; and (4) definition of farmer clusters. In the first step, a total of 10 focus groups were carried out within the study area from December 2017 to July 2018 with the participation of six to 22 farmers from a group per meeting. Focus groups sessions were held in order to identify the most common technologies and practices adopted by farmers. The procedure started with three core questions posed to the farmers for discussion: "production problems"; "technologies or solutions"; and "institutional actors". For the analysis, we used a qualitative method based on a grounded theory procedure [29] that considers a standard comparison of the transcripts generated from the focus groups using an open coding process. The procedure consisted of grouping similar sentences which were then assigned a conceptual code (or category) that allows for a systematic comparison using the software NVivo (version 12). The data related to "production problems" were regrouped into five categories: commercialization; production systems; natural resources; financial structure; and productivity. A similar procedure was used to regroup the "technologies or solutions" into four categories: techniques and productive information; conservation; infrastructure; and certification and technological innovation. The list of practices and categories based on the answers provided by farmers are summarized in Table 2.

Table 2. Weights and adoption rates of various practices: berry and vegetable farmers.

Categories	Practices	Weight *	Adoption	Berries	Vegetables
Techniques and productive information	Information on chemicals dosage	0.71	92%	x	x
	Soil analysis information	0.68	89%	x	x
	Market information	0.65	65%	x	x
	Informal group sales	0.65	44%	x	x
	Price information	0.60	75%	x	x
	Previous formal training—last two years	0.55	67%	x	x
	Internet use for farm decisions	0.74	49%	x	x
	Calibration (nozzles) machinery	0.55	64%	x	x
Conservation	Ridge cultivation	0.65	62%	x	x
	Use of groundwater for irrigation	0.66	42%	x	x
	Use of guano, compost, humus	0.65	45%	x	x
	Crop rotation	0.62	46%	na	x
	Intercropping	0.68	16%	x	x
	Stubble incorporation	0.65	54%	na	x
	Use of mulch	0.66	22%	x	x
	Mechanical weed control	0.63	62%	x	x
	Cleaning irrigation channels	0.65	74%	x	x
	Scheduling irrigation (climatic or soil)	0.74	52%	x	x
Infrastructure and certification	Input storage shed	0.71	78%	x	x
	Packing room (harvesting)	0.80	39%	x	na
	Own transport for products	0.55	58%	x	x
	Good agricultural practice (GAP)	0.73	31%	x	x
Technological innovation	Improved seeds (certified)	0.69	37%	na	x
	Use of Trichoderma	0.60	32%	x	x
	Pressurized irrigation system	0.75	38%	x	x
	Minor mechanization (roto-cultivator, brush cutter, fumigator)	0.74	89%	x	x
	Mechanized harvest	0.62	21%	na	x
	Greenhouse	0.66	25%	na	x
	Improved varieties (from certified plant nursery)	0.63	63%	x	na
	Implements for soil preparation	0.74	71%	x	x
		Total practices		25	28

* Weight assigned by "judge-farmers". x: practice available for berries and/or vegetable farming. na: not available.

Face-to-face interviews (second step) were then administered to farmers who participated in the focus group sessions. The questionnaire used was composed of four different sections. In the first section, farm structure and general demographic information (e.g., age, education, experience) were requested. The second section concerned the identification of farming problems and potential solutions and needed support. The third section included questions on previous experience with technical assistance, detailing the quality and strategies of the service received (e.g., number and duration of visits per year, and field days, among the most relevant). The last section aimed to measure current technology adoption.

The third step in the methodology employed was to generate a technology adoption index (AI). The literature suggests using adoption indexes consistent with local conditions and relevant to the production system being analyzed to summarize the levels of technological implementation [30–34]. Conceptually, indexes are a suitable way to capture the complexity of the adoption process [35], but the challenge is to assign appropriate weights to each technology that reflect the relative impact on the production system. One way to determine the weight of individual practices or technologies is to use a perception scale derived from a panel of "judge-farmers" [36]. Hence, we used information from the focus groups to generate the list of practices. Then, a separate group of 100 farmers were asked to rank each practice according to its productive and economic importance on a scale from 1 (least) to 7 (most). Next, an adoption index (AI) was developed based on the weights attributed to each of the 30 practices applicable to berry and vegetable production. The index, given by the sum of the weighted practices, can be expressed as [35]:

$$\boldsymbol{AI_j} = \boldsymbol{w_i P_{ij}} + \cdots + \boldsymbol{w_n P_{nj}} i = 1,\ 30\ j = 1,\ 101$$

where AI_j is the adoption index of household j; w_i is the weight for the ith practice; and P_{ij} is a binary variable indicating whether the jth household adopted the ith practice. The weight for each practice was generated using the information from the survey of farmers and the focus groups. The AI was standardized to values between 0 and 1. Table 2 shows the weight and adoption rates for all practices used by berry and vegetable farmers in the sample.

Once the AI was calculated for each farmer in the sample, the final methodological step was to identify homogeneous clusters of farmers, using the AI as a grouping variable. The AI was classified by hierarchical clustering (dendrogram) and then homogeneous groups were formed using the K-means algorithm [36]. Having obtained the number of homogeneous groups, the means were compared across groups based on the following variables: number of extensionist visits per year; duration of visits in minutes; number of field days per year attended; number of expert (non-SAT) visits per year; and number of group meetings per year. The analyses were done using STATA version 15.

3. Results

Table 2 shows a list of practices that were organized into four categories according to the results of the qualitative analysis: (1) techniques and production information; (2) conservation; (3) infrastructure and certification; and (4) technological innovation. Overall, farmers' adoption of the practices from all four categories ranged from 12 to 92 percent, although those percentages differed among categories. Regarding the first category, techniques and production information (68 percent overall adoption), we observed that the most adopted practices were "information on chemical dosages" and "soil analysis information". In contrast, "internet use for farm decisions" and "informal group sales" showed lower levels of adoption.

One of the areas where the SAT Program is supposed to provide assistance is on natural resource conservation; however, the category conservation presents the lowest adoption rate with 46 percent on average. The category infrastructure and certification exhibited a 50 percent average adoption rate. The practice "input storage shed" was used by 78 percent of the sample, and this high level is consistent with the direct support provided by INDAP's investment development program (PDI) through a subsidy to co-finance the construction of this type of infrastructure. A similar subsidy for "packing rooms" is of particular relevance to berry producers, but the adoption rate in this case was only 39%. The category *technological innovation* represented a 48 percent average adoption rate, while the practice "minor mechanization" was one of the most adopted (89 percent). The aforementioned technology also received a subsidy from INDAP.

Cluster Analysis

As shown in Table 3, the cluster analysis yielded three different groups using the AI as the grouping variable. A total of 24 producers were classified as "high adopters" with an average AI of 0.88. This cluster showed a high level of adoption for all categories, and the general adoption rate was 75.7 percent. A second group comprising 46 producers, called "intermediate adopters", displayed an average AI of 0.65 and an adoption rate of 52.2 percent. Finally, the third group with 31 producers had a lower AI (0.38) and an adoption rate of 31.9 percent. Table 3 shows Household and Farm characteristics, followed by Extension strategies and Farmer incentives for each cluster. One-way analysis of variance (ANOVA) was used to test the null hypothesis (H_0) that the means of all variables in Table 3 between clusters were equal. If we rejected the null hypothesis then we performed a post-hoc analysis to confirm where the differences occurred. The letters (^{a}, ^{b}, ^{c}) at the bottom of Table 3 indicate significant differences for the variables among clusters, using the Tukey post-hoc ($p < 0.05$) [36].

Table 3. Farmer and extension characteristics for three clusters.

Variables *	Clusters		
	High (n = 24)	Intermediate (n = 46)	Low (n = 31)
Average adoption index (AI)	0.88	0.65	0.38
Average adoption rate (%)	75.7	52.2	31.9
Household characteristics			
Age (years)	54.5 $^{n.s.}$	51.8 $^{n.s.}$	50.8 $^{n.s.}$
Education (years)	8.7 $^{n.s.}$	9.0 $^{n.s.}$	8.9 $^{n.s.}$
Female-headed household (in %)	12.5 $^{n.s.}$	15.2 $^{n.s.}$	15.8 $^{n.s.}$
Household size (number)	4.0 $^{n.s.}$	3.4 $^{n.s.}$	3.3 $^{n.s}$
Years of crop experience (in years)	10.4 $^{n.s.}$.	12.4 $^{n.s.}$	9.9 $^{n.s.}$
Farm characteristics			
Farm size (own land in ha)	4.5 ^{a}	2.9 ^{a}	1.7 ^{b}
Total farm size (owned plus rented land)	4.9 $^{n.s.}$	3.9 $^{n.s.}$	5.3 $^{n.s.}$
Value of production ($US/farm) mean	69,116 ^{a}	21,554 ^{b}	6130 ^{b}
Extension characteristics			
Time as SAT beneficiary (years)	8.2 $^{n.s.}$	8.1 $^{n.s.}$	6.7 $^{n.s.}$
Time with same PEC (years)	5.3 $^{n.s.}$	4.3 $^{n.s.}$	3.9 $^{n.s.}$
Extension strategies			
Visits (number/year)	10.1 $^{n.s.}$	11.0 $^{n.s.}$	12.0 $^{n.s.}$
Duration of visits (minutes)	75.4 ^{a}	57.7 ^{b}	52.7 ^{b}
Field days (days/year)	2.7 ^{a}	2.9 ^{a}	1.3 ^{bc}
Expert consultant visits (number/year)	1.5 ^{a}	0.9 ^{b}	0.1 ^{c}
Group meetings (number/year)	1.6 ^{a}	1.2 ^{a}	0.4 ^{b}
Farmer incentives			
PDI-Investment development program (%)	50.0 $^{n.s.}$	50.0 $^{n.s.}$	54.8 $^{n.s.}$
Soil recovery program (%)	33.3 ^{a}	13.0 ^{ab}	6.5 ^{b}
Irrigation projects (%)	50.0 ^{a}	30.4 ^{a}	9.7 ^{b}
INDAP credits (%)	37.5 $^{n.s.}$	34.7 $^{n.s.}$	22.5 $^{n.s.}$

* Different letters ($^{a, b, c}$) indicate significant differences for the variables among clusters, according to one-way ANOVA and using Tukey's post-hoc test ($p < 0.05$). $^{n.s.}$ = non-significant.

The "high adopter" cluster covered 24 percent of the sample, of which 12.5 percent were women (n = 3). On average, household size was four persons, higher but not significantly so than in the other two groups. The variables age, education, and farm experience showed similar values across the three clusters. Regarding farm characteristics, the variable "Farm size" showed significant differences across clusters. However, if we look at "Total farm size", which includes owned and rented land, the analysis is different, since low adopters cultivate more land (5.3 hectares on average) than high and intermediate adopters (4.9 and 3.9 hectares, respectively). Although the differences are not statistically significant, this finding suggests that renting land increases total area cultivated but not technology adoption.

Production value, given by the sum of the value of individual crops using average prices, is the farm characteristic that presents the major difference among clusters. The average annual value of output for "high adopters" reached US$69,116 per farm and was significantly different from the value for "intermediate adopters" (US$21,554) and "low adopters" (US$6130).

Regarding the variables "Time as SAT beneficiary" and "Time with same PEC", neither variable exhibited statistical significance, although there was a slight positive association between adoption of technologies and years of extension experience and with the same PEC. Relating to extension strategies, we identified five approaches contemplated in the SAT framework. The variable "Visits" (number/year) showed no statistical difference among the clusters, and this is consistent with the SAT stipulation that PECs must conduct 12 farm visits per year. However, the variable "Duration of visits" showed significant differences among the clusters, where longer visits per farm were associated with a higher adoption rate. The remaining strategies (Field days, Expert consultant visits which relates to visits by non-SAT experts, and Group meetings) showed a positive correlation with adoption.

The last group of variables analyzed was the use of farmer incentives provided by INDAP. The "PDI-Investment development program" is an initiative that co-finances investments to foster the modernization of production processes by supporting project design and implementation [37]. The results showed that roughly 50 percent of the sample received help from the PDI across the three clusters. In contrast, the "Soil recovery program" and "Irrigation projects" revealed a significant direct association with technology adoption. Finally, "INDAP credits" showed a positive but not significant association with adoption among the clusters.

4. Discussion

The aim of this study was to understand the association between extension service strategies and the intensity of adoption practices by producers of berries and vegetables in central Chile. Farmers were grouped into clusters using a bottom-up adoption index and data generated from group discussions and individual interviews. As stated in the results section, the category of practices most adopted were techniques and production information, while conservation exhibited the lowest adoption. It is clear that the SAT Program and the PECs involved in providing extension assistance did not pay attention to soil and water conservation practices, even though many traditional agricultural practices contribute to soil degradation [38,39]. Furthermore, technologies designed to improve or conserve soil and water showed limited adoption in the sample, even though their usefulness has been demonstrated [40]. The severity of current degradation has inspired significant efforts to develop and promote the adoption of conservation strategies [41]. Nevertheless, the evidence we present indicates that the SAT Program has neglected this crucial factor for agriculture.

The results of this study reveal high adoption of practices related to improved yields and the value of production. This finding is consistent with evidence showing that producers of annual crops with higher levels of income are more likely to adopt the proposed technology compared with low-income farmers [42]. In Mexico, a cluster analysis of 33 technologies and practices adopted by 104 growers, indicates that the most significant level of adoption is related to higher yields [31].

The international literature is fairly consistent in establishing that extension-related variables have a significant impact on technology adoption [24] when extension is measured as a number of visits by an extensionist or whether a farmer receives this support (References in Table 1). Our results show a positive association among various extension strategies used by PECs under the SAT Program and AI. The findings show that the number of visits by an extensionist per year is directly proportional to the adoption of technologies [43]. Our results regarding the number of visits are inconclusive and in contrast with those of several authors (see Table 1), but we found that the duration of each visit had a significant and positive association with increased technology adoption. A possible policy implication from the latter is that extension visits supported by the SAT Program should be flexible and in line with the specific needs of farmers.

The remaining SAT extension strategies analyzed (field days, expert consultant visits, and group meetings) showed significant differences among the clusters. Farmers who participated in these activities tended to belong to the high and medium adoption clusters. This result is consistent with Reference [19], where it was noted that field days had a significant impact on the adoption of fertilizers and herbicides. These authors also found a synergy between extension visits and field days; therefore, they stress the role of extension services in providing the knowledge and experience needed to change perceptions and attitudes of farmers towards technology adoption. Thus, access to knowledge and information provided by agricultural extension services strengthen the capacity of farmers to innovate [1]. Our results are also consistent with Reference [22], the authors of which show a significant connection between technology adoption and belonging to either a formal or informal farmer association. Along the same line, Reference [19] observed that farmers involved in networks are able to share information regarding new or improved agricultural production technologies.

Concerning the incentives provided by INDAP, we found that subsidies play an important role in increasing the AI. Specifically, our analysis shows that financial incentives contributed significantly to the adoption of soil recovery and irrigation and are important variables in the clustering. This finding is consistent with the fact that both of the aforementioned programs require relatively high investments making the availability of financial capital critical in the adoption decision, and here INDAP plays a leading role in assisting smallholders [28]. Similarly, our study indicates that the number of annual visits by the extensionist is unrelated to the AI. Nevertheless, INDAP and the SAT Program appear to focus on this variable at the expense of other strategies such as the duration of farm visits. In sum, we found a positive connection among extension strategies, and a complementary association between incentive programs and technology adoption. A recommendation for future research is to provide a conceptual framework that allows us to investigate the causal effects between the strategies of the SAT Program and technology adoption.

5. Conclusions

We developed a bottom-up technology adoption index (AI) in order to analyze the connection between the strategies implemented by extension services and the adoption of 30 practices among small-scale farmers in Central Chile. The sample included 101 small-scale farmers growing berries or vegetables who receive technical assistance through private extension companies (PECs) funded by the SAT (Servicio de Asesoría Técnica) Program. The methodology involved four steps: focus groups of six to 22 farmers per group to identify technologies; a survey applied to focus group participants to capture the level of adoption practices; development of an adoption index; and a cluster analysis to characterize different groups of producers according to their level of technology adoption.

The results show that farmers with higher adoption indexes were those that had longer extension visits, a greater number of group activities (i.e., group meetings and field days), and greater use of incentives and credit provided by INDAP. It is important to emphasize that even though the sample comprised small-scale farmers, the variables "value of production" and "farm size" were positively associated with higher levels of adoption. Thus, while incentives and credit were crucial in the adoption of appropriate technologies, the SAT Program should make additional efforts to implement extension strategies that encourage smaller holders to innovate. A promising area for future research is to explore the causal effects between different SAT strategies and technology adoption. It would also be of interest to quantify the intrinsic motivation of farmers to participate in the activities proposed by PECs since successful extension strategies need receptive farmers.

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