FARMER, LEARNING AND TEACHING: A CLUSTER ANALYSIS OF TECHNOLOGY ADOPTERS IN AVOCADO FARMING IN COLOMBIA †

[AGRICULTOR, APRENDIZAJE Y ENSEÑANZA: UN ANÁLISIS DE CLUSTERS DE ADOPTADORES DE TECNOLOGÍA EN EL CULTIVO DE AGUACATE EN COLOMBIA]

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SUMMARY

Background. The current challenges of agrifood chains make it necessary for them to be efficient from the point of view of production. This demands greater attention to the farmer's technological adoption process and to some aspects that may affect it. **Objective.** In this study a multivariate cluster analysis method was used, with the aim of identifying the influence of a farmer’s profile and their teaching–learning environment on the adoption of technology in avocado farming. **Methodology**. The investigation was conducted with 94 farmers in two rural municipalities, located in the same rural region. The questionnaire that was used included profile variables, learning styles, farmer learning preferences, and extension agent teaching methods. **Results.** Three clusters of adopters were formed and the technology adoption index was analyzed in seven categories, including 37 technologies and technological practices. The case study showed that the high adoption cluster included profiles of older farmers with experience and membership to producer organizations; this cluster was also the only group comprising a combination of farmers’ learning styles and preferences. However, the disconnection between an extension agent's teaching methods and the farmers’ learning is evident in all clusters. **Implications**. Our results provide important evidence regarding the importance of linking the profile, style, and learning preference in contextualized teaching methods, allowing for better development of farmers’ capacities for the adoption of technologies and practices. **Conclusions**. The analysis of clusters of adopters allowed farmers to be classified into high, medium and low rates of adoption of technology and technological practices. Each cluster presented certain differences in terms of learning styles and preferences, as well as a disconnection in the teaching-learning relationship.
Key Words: Extension methods; farmer's learning; farmers profile; multivariate analysis; technology adoption

RESUMEN

Antecedentes. Los desafíos actuales de las cadenas agroalimentarias hace necesario que estas sean eficientes en la producción. Ello demanda mayor atención al proceso de adopción tecnológica del agricultor y de algunos aspectos que pueden incidir en ello. **Objetivo**. Este estudio empleó un método multivariante de análisis de clúster, con el fin de identificar la influencia del perfil del agricultor y su entorno de enseñanza y aprendizaje, en la adopción de tecnología en el cultivo de aguacate. **Metodología.** El estudio fue llevado a cabo con 94 agricultores en dos municipios rurales, ubicados en una misma región rural. Se aplicaron cuestionarios que contenían variables del perfil, estilos de aprendizaje, preferencias de aprendizaje del agricultor y métodos de enseñanza del extensionista. **Resultados**. Se conformaron tres conglomerados (clúster) de adoptadores y se analizó el índice de adopción de tecnología (INAT), en siete categorías e incluyendo 37 tecnologías y prácticas. El estudio de caso mostró que el grupo de alta adopción incluía perfiles de agricultores mayores con experiencia y membresía en organizaciones de productores; fue el único grupo que comprendía una combinación de estilos y preferencias de aprendizaje de los agricultores. Sin embargo, la desconexión entre los métodos de enseñanza de un extensionista y el aprendizaje de los agricultores es evidente en todos los conglomerados. **Implicaciones.** Nuestros resultados brindan evidencia importante sobre la importancia de vincular el perfil, el estilo y la preferencia de aprendizaje en métodos de enseñanza contextualizados, lo que permite un mejor desarrollo de las capacidades de los agricultores para la adopción de tecnologías y prácticas. **Conclusión**. El análisis de clusters

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de adoptantes permitió clasificar a los agricultores en tasas altas, medias y bajas de adopción de tecnología y prácticas tecnológicas. Cada clúster presentó ciertas diferencias frente a estilos y preferencias de aprendizaje, así como una desconexión en la relación enseñanza-aprendizaje.
Palabras clave: Métodos de extensión; aprendizaje del agricultor; perfil del agricultor; análisis multivariado; adopción de tecnología.

INTRODUCTION

Numerous studies have suggested that low levels of productivity and agricultural competitiveness are associated with low rates of technology adoption by farmers, and this has generated several analysis frameworks for the better understanding of this rural phenomenon (Ramírez-Gómez and Rodriguez-Espinosa, 2022; Ramírez-Gómez, Velasquez and Aguilar-Avila, 2020). The adoption of agricultural technology has been approached from different standpoints. In this sense, technology adoption depends on a wide range of personal, social, and cultural characteristics, economic factors, and the innovation aspects (Pannell *et al.*, 2006). Previous studies have identified various socio-psychological aspects, such as intentions, attitudes and social pressure (Martínez-garcía *et al.*, 2016), trust among people in participatory approaches (Takahashi *et al.*, 2015), the effects of social networks (Gamboa *et al*., 2010), the impact of interpersonal communication (Unay *et al.*, 2015), and the effects of capital and social interaction (Micheels and Nolan, 2016).

In this study, we emphasize the approach of aspects such as farmer profile, teaching–learning methods, and dynamics, which have shown a certain relationship with technology adoption in literature. In fact, studies that have concentrated on farmer profiles have considered variables such as level of education, age, experience, economic motivation, farm size, and risk orientation (Mittal and Mehar, 2016; Swathi Lekshmi *et al.*, 2005). Furthermore, other studies have found that a farmer's membership to producer organizations also has an effect on technology adoption (Wossen *et al.*, 2017). In addition, several other specific adoption approaches exist based on farmers teaching methods, such as methodological tools that allow skills and knowledge to be created to promote technological and personal changes (Duveskog *et al*., 2011). With regard to this, on-farm demonstrations (Roo *et al*., 2017), the formation of discussion groups and participatory approaches (Prager and Creaney, 2017), and field schools for farmers stand out as mechanisms for promoting adoption of technology. On the other hand, the relationship between farmer learning and technology adoption has barely been addressed in literature, generating research opportunities in various fields. The work of Marra *et al*. (2003) is important because it initially determined that identification of farmers' learning dynamics is an important factor in the technology adoption process. This explains the emergence of approaches such as the type of farmers' experiential learning and its impact on technology adoption, practical and on-hand learning at the farm level (Mariano *et al.*, 2012), farmer social learning (Morgan, 2011), learning from observation and reflection (Ingram, 2010), and the type of learning classified as active, passive, and reflective (Crawford *et al*., 2007). However, a gap in knowledge and a discrepancy still exists regarding the relationship of the teaching and farmers' learning in literature, where the most effective method for rural extension agents for intervention in communities comes into consideration (Franz and Westbrook, 2010). With regards to this, establishing that farmers can effectively have their own styles, as mentioned above, and have specific learning preferences is important (Franz and Westbrook, 2010). Although farmers can be influenced by various aspects, such as cultural aspects, they could considerably be related by specific characteristics, that is, the farmers' profile itself (Kilpatrick and Johns, 2003).

In fact, these discrepancies in the teaching–learning relationship, beyond the farmers' learning style, also recognize the existence of a learning preference, such as discussion groups, on-farm demonstrations and demonstration plots (Maertens *et al.,* 2018), or field days (Fabregas *et al*., 2017). This, of course, is in contrast to the discussion related to the teaching styles adopted by extension agents, and the way in which they somehow manage to respond to how farmers learn based on their styles and preferences (Franz *et al*., 2010). Within this context, the topic related to the farmers' teaching–learning environment, within the framework of a profile with specific characteristics, is an approach that is not yet sufficiently studied in literature, precisely because these topics have usually been studied separately. Thus, the research question is: ¿Which is relationship between agricultural technology adoption and extension services' teaching methodologies and farmers' learning preferences and styles? Therefore, this study aims to identify the influence of farmers' profile and their teaching–learning environment on the adoption of technology in avocado farming for export using a multivariate method. The farmers are grouped into clusters and their levels of technology adoption are analyzed in seven categories; this contributes to broadening the discussion around the planning of better rural extension models.

MATERIAL AND METHODS

We integrate our analytical framework in our quest to link new relationships between concepts. We briefly introduce the concept of preferences and learning styles, rural extension methods, and the adoption of agricultural technology**.**

Farmer learning theory and extension methods

Farmer learning has been supported by various theories, many of which have been adapted over time. For example, in experiential learning theory, it is argued that learning is the process by which knowledge is created through experiential experience. In addition, from experiential learning, the importance of effective feedback is recognized that allows reflection, agreement and disagreement in the construction of learning among the people involved (Baker, Robinson and Kolb, 2012). One of the main approaches adapted from this theory is based on transformative learning (Cooreman *et al*., 2021), based on the impact that collective group action and community relations can have on the process of technological change in farmers (Duveskog *et al*., 2011). Farmer field schools have also emerged from this approach, seen as a strategy to promote experiential learning, when the farmer finds shared cultural affinities, norms and values with their peers (Palis, 2006), facilitating exchanges between farmers, positively influencing technology adoption (Alene and Manyong, 2006). On the other hand, another of the outstanding theories is based on social learning. This theory, centered on psychology, still does not have enough consensus in the literature (Muro and Jeffrey, 2008). This approach assumes an iterative feedback between the learners and their environment, the learner changing the environment, and these changes affecting the learner (Pahl-Wostl *et al.,* 2008). Therefore, social learning arises from interactions between people when social actors change mindset, towards critical thoughts and dialogue with others (Schneider *et al.,* 2009). Based on this approach, communities of practice have also emerged as learning dynamics where farmers share cultural identities and social practices, generating spaces for communicative action that promote learning (Tran *at al.*, 2018).

These theories and approaches raised have also been associated with the preferences and learning styles of farmers, but also with teaching methodologies by extension agents. For example, visual, auditory, reading-writing and kinesthetic preferences constitute certain characteristics of farmers that are also related to certain consistent teaching methods. From this perspective, it is affirmed that farmers can learn better from images, or through heard information, information represented in words, experience and practice (Pouratashi and Iravani, 2012). Learning styles and preferences have also been associated with practice carried out through direct demonstration; farm visits, highlighting visual styles of farmers; field days, in which farmers have greater opportunities for interaction with various actors; discussion panels, where it is possible to strengthen social learning (Franz *et al*., 2010).

Agricultural technology adoption

The adoption of technology and innovations is a process by which an individual, or a production unit, begins to have a first knowledge about the innovation, until its adoption or rejection, so it is a process that involves knowledge, persuasion, decision, implementation and confirmation (Rogers, 2003). There have been several studies on the factors influencing technology adoption of new or improved technologies and practices in relation to grower characteristics, method of information transfer, attitudes and kind of technology (Kumar *et al*., 2018; Martínez-garcía *et al.*, 2016). Adoption is often approached from a technology push perspective and is judged in terms of a scale ranging from "innovators," "early adopters," "late adopters," to "laggards (Valente, 1996); however, these farmers scales can also be associated with the potential effect of a new technology depends on whether farmers adopt it and, if they do, whether the adoption is to the extent that it can deliver results in a certain period of time (Jara-Rojas *et al*., 2020).

Also an essential element in the adoption of technologies and practices that are not incremental and easy to fit within existing farming systems is that it requires working on a reconfiguration of institutional frameworks (such as rules, regulations, habits, values), generally developed at the meso-level, where many actors have direct relationship with farmers (Vinholis *et al*., 2021), which may also imply governance dynamics in rural extension systems (Nettle *et al*., 2017). While there is a lot of work in farmers behavior studies that focuses on the technology adoption of new or improved technologies and practices (Kumar *et al.*, 2018; Swathi Lekshmi *et al.*, 2005), even considering extension strategies (Jara-Rojas *et al*., 2020), in this paper we focus on the relationship between extension methods and farmers learning preferences and styles.

Case description

This case study was based on empirical evidence and included the rural municipalities of Sonsón and San Vicente, in the Department of Antioquia (Colombia). The Hass avocado production subsector for export was studied herein (Figure 1). Due to the favorable agroecological conditions for farming, a growing productive dynamic of Hass avocado has been generated in both these rural municipalities. These municipalities have different geographic distances, as well as contrasting social contexts within the same rural region. The municipality of San Vicente has a recognized associative organization of farmers, and a growing trend in the areas cultivated with avocado. The

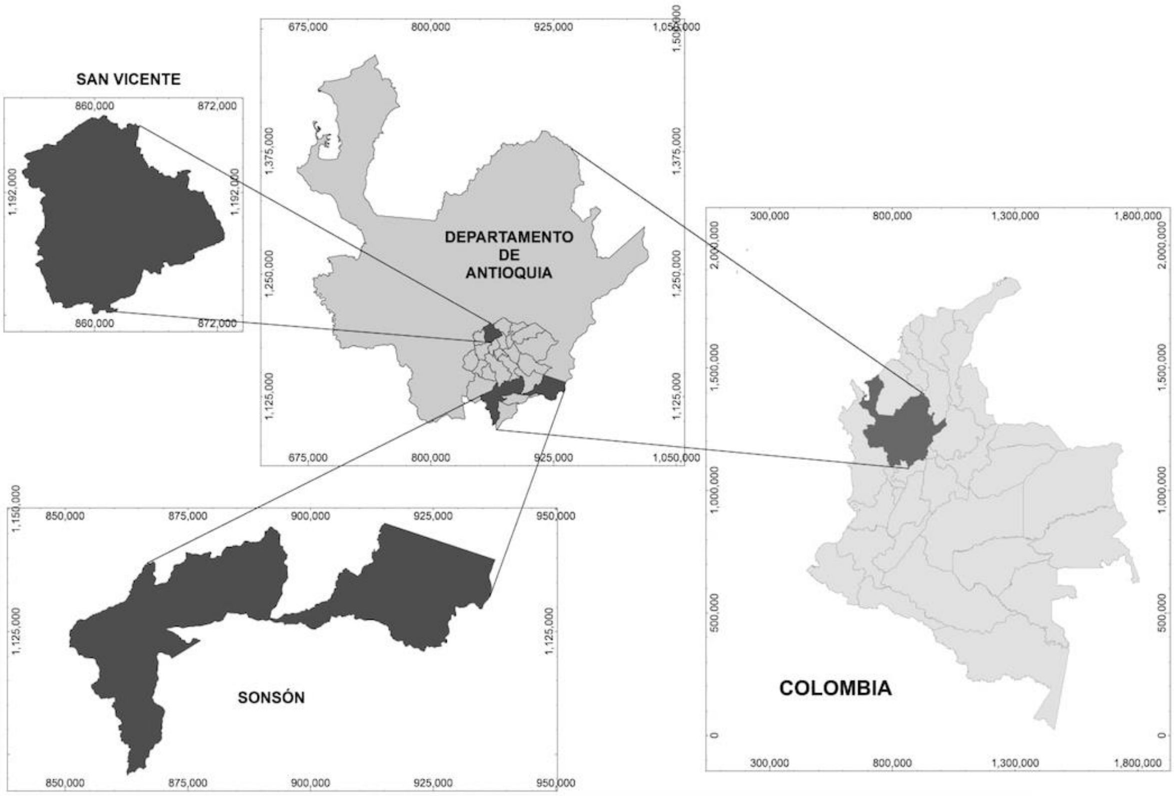

Figure 1. Map of the study area, with the eastern rural region and the municipal territories of San Vicente and Sonsón.

second municipality is that of Sonsón. Being a municipality with a history of armed conflict, it has had the support of various national and international cooperation entities. Both selected municipalities are located within a rural region, and small producers predominate, with technological levels in the process of improvement, to adjust to the quality requirements of the international market. Given the growing productive dynamics, and the privileged geographical location, different international marketing companies, as well as public and private entities, have been developing training actions with both farmer organizations of the two municipalities with the aim of improving the conditions of insertion in the international markets.

This study was conducted with 94 farmers that had been part of two training groups for over a year and that had committed themselves to the adoption of technologies and technological practices in the farming of Hass avocado for export, in plantations that have ages that vary between one to ten years. Forty-five farmers were from San Vicente, and 49 farmers were from Sonsón. Furthermore, the collection of information was complemented by the participation of farmers from each municipality in training events, such as meetings, field schools, and field days. Participation as an observer is a systematic way of observing a certain phenomenon as it takes place (Kumar, 2005). Semi-structured interviews were conducted with an average duration of 40 min and the farmers were asked about the following domains: (i) farmer profile (age, years of experience, level of education, years of residence in the territory, and membership to a farmer organization), (ii) learning styles (practical, reflective, and theoretical styles), (iii) teaching methods used by extension agents (guided tours of farms, practical activities and demonstrations, discussion groups, farm visits, and theoretical exhibitions), (iv) preferred learning method by farmers (tours and internships on farms within the territory, demonstrations of results on farms, discussion groups with other people, and visits to their own farms), and (v) technology adoption (37 technologies and technological practices in Hass avocado farming). The research variables selection were according to the hypothesis and question of a research. In the technology adoption section, farmers are asked about a list containing 37 technologies and technological practices, which were identified and validated with professionals who are experts in farming. These technologies were grouped into 7 categories (Table 1): crop fertilization, phytosanitary management, conservation practices, cultural practices of crop management, administration, organization, and harvest and postharvest (Muñoz *et al*., 2007). For this study, the farmers responded using the bivariate response option (yes or no) regarding each technology (adopted (1) and (0) not adopted). The technology adoption index (TAI) was calculated based on the farmers' innovative capacities, where TAIk corresponds to the technology adoption index in category "k," which comprises a certain number of technologies and practices. Moreover, "K" corresponds to the number of categories, which is seven in this case (Muñoz *et al*., 2007).

$$TAI = \frac{\sum_{J=1}^{K} TAINk}{K} * 100$$

To classify growers a cluster analysis was performed following the approach proposed by Aguilar-Gallegos *et al*. (2015). A dendrogram to define the number of groups, was determined using pseudostatistical tools t2 of Hotelling (1951) and the cubic grouping criterion (Johnson, 1998). The analyses were done with SAS, version 9.0, software (SAS, 2004). Multivariate cluster analysis was conducted to classify farmers based on the five domains. In turn, averages and standard deviation were calculated for both qualitative and quantitative variables within each cluster of adopters

RESULTS

Grouping of avocado producers based on the adoption of 37 technologies and technological practices

The cluster analysis allowed the identification of three conglomerates generated among farmers based on 37 technologies and technological practices using TAI. Furthermore, three groups that are evident in the dendrogram (Figure 2) were identified using cluster analysis. Cluster 2 corresponds to the producers with the highest level of adoption, which represents 39,4% of the farmers; Cluster 3 corresponds to medium level of adoption, which represents 45,7% of the farmers, and Cluster 1 corresponds to low level of adoption, which represents 14,9% of the farmers.

The four aspects of the focus of analysis in this investigation vary for these three adoption clusters: farmer profile, farmer learning styles, extension agent teaching methods, and farmer learning method preference (Table 2). The first cluster (low adoption) comprises 14 farmers; the second (high adoption) comprises 37 farmers, and the third cluster (intermediate adoption) comprises 43 farmers.

The high adoption cluster (C2)

The results of this group allow the description of the dynamics of their behavior in TAI. Regarding the farmer profiles, they are older with more experience in productive activity, a higher level of education, and higher percentage of membership to producer organizations. With regards to learning style, a mix of the three styles stands out among these producers, with a predominance of the practical style. This is the only cluster of adopters associated with a theoretical learning style, where it can be inferred from the field evidence that several farmers have an interest in seeking greater conceptual scope and access and analysis of information by professionals and experts.

Table 1. Technologies and practices analyzed.

Category	Technologies and Practices
Plant Nutrition	1. Soil fertilization; 2. Foliar fertilization; 3. Soil analysis; 4. Foliar analysis; 5. Results-based fertilization plan
Phytosanitary management	6. Pest monitoring; 7. Pest control; 8. Management of quarantine pests; 9. Disease monitoring; 10. Disease control; 11. Management protocol; 12. Weed control; 13. Calibration of spray equipment; 14. Record of application; 15. Personal protective clothing; 16. Use of allowed pesticides.
Sustainable practices	17. Collection of containers and packaging; 18. Adequate storage of products; 19. Mixing and washing sites; 20. Integrated pest and disease management; 21. Production of organic fertilizers
Agronomic Management	22. Use of certified seed; 23. Pruning training; 24. Maintenance and sanitation pruning; 25. Replanting plants; 26. Stimulation of flowering.
Administration	27. Record of farm activities; 28. Production and sale records; 29. Record of expenses and income; 30. Record of exports.
Organization	31. Collective purchases of farm inputs; 32. Associative collective sale; 33. Associative collection of the final product
Harvest and Postharvest	34. Harvest based on maturation; 35. Harvest based on size, weight, and quality; 36. Farm selection processes; 37. Postharvest treatments of the fruit.

Source: Own elaboration.

This cluster with the highest level of technological adoption indicates teaching mainly through theoretical lectures, for up to 52% of the farmers in this group. This does not correlate with the theoretical learning style that represents only 9,5% of the farmers in this group. Moreover, compared to the practical learning style that 79% of farmers in this group represent, the teaching method in percentage terms for the practical and demonstrative methods is significantly lower.

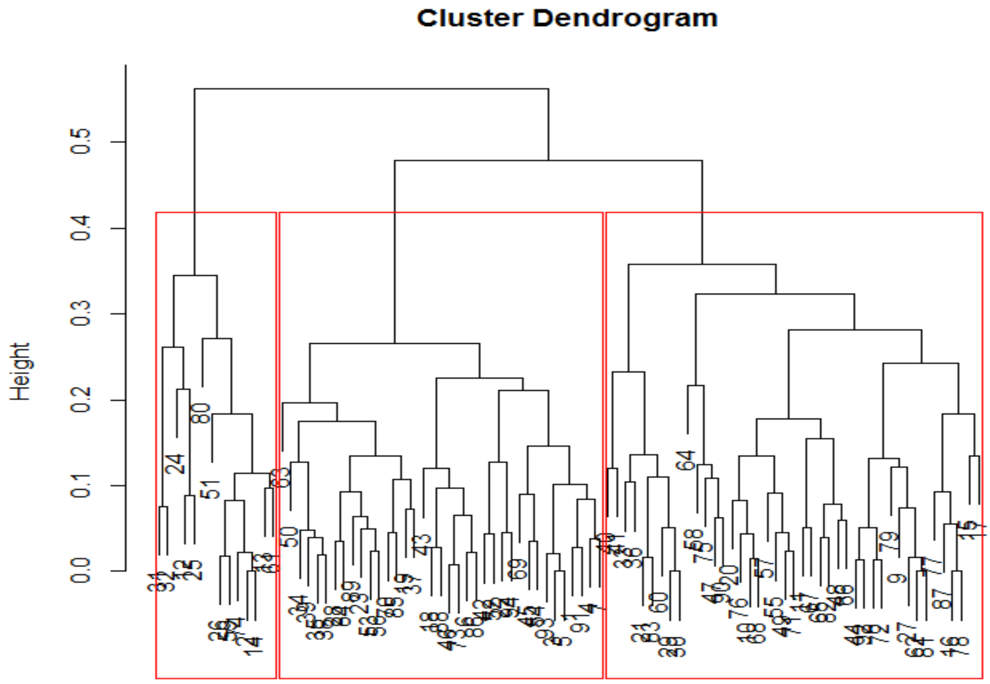

Figure 2. Dendrogram of 94 avocado producers based on the adoption of technology.Source: Own elaboration

Table 2. Characteristics of farmers by cluster of adopters.

Variable	**Cluster 1**	**Cluster 2**	**Cluster 3**
	(n = 14)	**(n = 37)**	**(n = 43)**
Farmer Profile	*Average SD*	*Average SD*	*Average SD*
Age (years)	53±15	55±16	47±15
Experience (years)	8±13	15±20	10±8
Schooling (years)	2.5±0.5	3.9±1.2	3.9±1.8
Territorial residence (years)	43±22	39±23	34±9
Membership to Organizations (yes/not)	33.3%	70%	41%
Learning styles	%	%	%
Practical	100	79	75
Reflexive	0	11.5	25
Theoretical	0	9.5	0
Teaching methods employed by extension agents	**%**	**%**	**%**
Guided tours of farms	11.1	17.3	0
Practical activities and demonstrations	33.3	15.3	37.5
Discussion groups	0	5,8	12.5
Farm visit	22.2	9.6	25
Theoretical exhibits	33.3	52	25
Learning method preferred by farmers	%	%	%
Tours on farms within the territory	66.6	54	37.5
Demonstrations of results on farms	11.1	17.3	37.5
Discussion groups with other people	0	1.9	0
Visit to their own farms	22.2	26.9	25

Likewise, some teaching methods that encourage observation and reflection by farmers, such as guided tours of farms and discussion groups, also exceed the reflective learning style in this cluster of adopters in percentage points. Although a high rate of adoption of technologies and technological practices is present among this group of farmers, the discussion regarding the existing discrepancies in the teaching–learning environment is well corroborated. Furthermore, even among a certain group of farmers, a combination of styles and a set of learning preferences may exist, but the teaching methods employed are not necessarily consistent with these aspects.

However, these discrepancies are also related to farmer profile since, for example, the high percentage of farmers with membership to organizations (70%) and the high style of practical learning (79%) are not being fully used by the extension agents who intervene in these communities, given that they mainly focus their teaching methods on more theoretical approaches (52%). In fact, more participatory teaching methods may improve interactions and exchanges of information and knowledge, even generating a better diffusion of technology within associative organizations.

Finally, the results of the study reveal that this cluster of farmers managed to incorporate up to 67% of technologies and technological practices, which are classified into seven analysis categories (Table 3). A higher percentage in the organization category also stands out in these results. However, even though several farmers are members of a producer organization, the rate of incorporation of practices reflecting a consistent collective action is still very low. Next, a high rate of adoption of technologies and technological practices in the farm administration category (70%) can be highlighted. This is important because it implies management of various farm records to attain traceability within the international Hass avocado market and because it involves more complex practices of incorporating and learning.

Table 3. Rate of adoption of technology and practices.

Variable	Cluster 1	Cluster 2	Cluster 3
	Average SD	Average SD	Average SD
TAI	0.34 ± 0.08	0.67 ± 0.07	0.42 ± 0.04
Nutrition	0.56 ± 0.21	0.82 ± 0.11	0.44 ± 0.16
Health Management	0.60 ± 0.22	0.81 ± 0.13	0.64 ± 0.20
BPA	0.53 ± 0.20	0.78 ± 0.19	0.53 ± 0.17
Agronomic Management	0.40 ± 0.22	0.84 ± 0.12	0.70 ± 0.22
Administration	0.04 ± 0.10	0.70 ± 0.32	0.05 ± 0.10
Organization	0 ± 0	0.06 ± 0.13	0.02 ± 0.09
Postharvest	0.29 ± 0.24	0.69 ± 0.21	0.52 ± 0.10

Intermediate adoption cluster (C3)

This cluster of adopters, with an intermediate rate of technology adoption, presents a dynamic that contrasts with that of the previous group. From the farmer profile, the analyzed characteristics show lower percentages than the previous group, i.e., they are younger individuals, with less experience in the activity, fewer years of permanence in the territory, and a lower percentage of membership to producer organizations. Although the reflective learning style becomes more relevant (25%) in this cluster of adopters, no farmer preferred to learn through peer discussion groups. However, it continues to be a teaching method used by extension agents. On the other hand, within the teaching–learning environment, certain coherence exists between the practical and reflective style in this group of farmers and learning preferences regarding practical and demonstrative teaching methods.

Although tours of other farms led by farmers is not a method used by extension agents and do not favor farmers with a reflective style, demonstrations of results at certain farms can allow farmers to follow and monitor implemented production systems, which can enhance this reflective style of learning. Therefore, unlike the high rate of adoption cluster, farmers in this group have a certain preference toward demonstrations of results, which implies that several farmers not only practice from experiments but also require some validation of technologies and practices through observation and reflection at other farms. Therefore, farmer participation in field trips, with evidence of results presented by another peer, may contribute to technological adoption in this group. Adoption of technologies and technological practices in Hass avocado farming in this cluster of adopters reached 42%. The agronomic management category has the highest rate of adoption with 70% and incorporates various important aspects, such as the use of certified seed and crop pruning (Table 3).

Low adoption cluster (C1)

In this low rate of technology adoption cluster, a farmer profile with characteristics of lower percentages compared to the other two groups stands out. For example, fewer years of experience in farming activity, despite having the highest average number of years of residence in the territory, as well as a lower level of schooling and the lowest percentage of membership to producer organizations. Their learning styles show a unique behavior among the analyzed groups, where 100% of farmers report a practical style. This result has a certain relationship with learning preference, in which tours and hands-on sessions at other farms stand out (66,6%). When analyzing the relationship between style and learning preference, farmers in this low rate of technology adoption group are evidently just in the process of seeking to develop practical skills, without having any major interest in learning from their peers, in the demonstration of results, or in the theoretical conceptual understanding of technologies and technological practices.

Low rate of technology adoption may well be associated with an eminently practical learning style, considering that the reflective style tends to stand out for its interest in guided tours to other farms and result demonstrations, where farmers conduct observations and analyses. The theorists, however, after having developed certain practical skills, seek conceptual understanding and exchange with their peers and with the extension agents themselves. The discrepancies surrounding the teaching–learning relationship lie in the theoretical methods used by extension agents (33,3%), given the absence of a theoretical learning style among farmers of this group and given that they are still in a phase of interest in the development of practical skills. As Table 3 shows, this low rate of technology adoption cluster only managed to incorporate up to 34% of the technologies and technological practices associated with the Hass avocado production system. In general, for this cluster, adoption rate is very low in all categories, specifically in the organizational category. Although 33% of the farmers in this cluster are members of an organization (Table 1), the development of collective action capacities is non-existent.

DISCUSSION

This study demonstrated the influence of new variables on the adoption of technology by farmers, generating high, medium, and low adoption clusters. Therefore, this study revealed differences between clusters of technology adopters, from the perspective of the farmers' profiles, their learning environment, and the teaching methods of extension agents. Some variables of the farmer's profile, such as age, years of experience, and level of schooling, have also been addressed by several studies in the context of groups of adopters, with some results contrasting those of our study (Aguilar-Gallegos *et al*., 2015; Joffre *et al*., 2019). However, our results are consistent with those of Adesina and Chianu (2002), for whom the experience of the farmer is a variable that influenced the adoption of technology. Our study also coincides with the assumptions of Akudugu *et al*. (2012) for whom age is a variable that influences adoption rate, because farmers may not have the experience, capacity, or resources to incorporate certain technologies at a younger age.

Furthermore, an important aspect of this study implies the inclusion of farmers' memberships to producer organizations in the technology adopter clusters. The study showed that the cluster with a high rate of technological adoption coincided with the highest percentage of farmers with memberships to organizations. Authors such as Abebaw and Haile (2013) revealed that membership to producer organizations showed a high positive impact on the adoption of various practices. Empirical field evidence made it possible to understand that these types of organizations have greater incentives that may be influencing their adoption, such as market benchmarking as well as access to different kinds of resources and public goods.

Likewise, our framework for adopter cluster analysis explained that the levels of adoption in the three groups differ due to their combination of learning styles; only the high adoption cluster comprised farmers with practical, reflective, and theoretical learning styles. The farmers with a high rate of adoption also have a higher average age, years of experience in crop production, and membership to organizations. The dynamics of this high rate of adoption group are important for two main reasons. First, because older farmers with many years of experience have generally developed extensive experimentation, observation, and a probable perception of technological benefits (Akudugu *et al*., 2012). Second, because according to the farmers' profiles, it is possible to understand how a combination of experiential learning styles based on practice as well as the reflective styles from observation cause farmers to often reaffirm their adoption decisions once they see errors and successes in terms of the benefits of a technology (Ingram, 2010). In fact, other authors have also discussed the important role of experiential learning in the understanding of the farmer and its positive impact on the adoption of agricultural technologies (Okumah *et al*., 2021).

However, a group of farmers in this cluster, despite the practical and reflective learning style, require more information and conceptual deepening, which leads to theoretical learning, generally as a mechanism to reduce their risks and uncertainties (Sligo and Massey, 2007). Conversely, in the low rate of technology adoption cluster, farmers presented a 100% practical learning style, indicating that this group is still in what could be considered a first phase of the adoption process, which involves self-experimentation at the farm level in search of the development of practical skills. Similarly, it was established that only the high rate of technology adoption group presented a combination of farmer learning preferences. This is consistent with proposals that farmers prefer to learn in various ways, improving the development of both basic and abstract capacities (Kilpatrick and Rosenblatt, 1998). This investigation attempted to identify learning styles as it has rarely been addressed in literature.

However, this should be differentiated from farmers' learning preferences, as discussed by Franz *et al*. (2010), who argue that farmers expect assistance with the interpretation of the information, construction of relationships, possibilities of socialization, and validation of their knowledge and expectations, among others, apart from the learning style. On the other hand, although the low rate of adoption cluster has a learning style that favors hands-on sessions, it has the highest preference for learning by touring other farms in the region. Even though a farmer may not know his own learning style, if they manage to establish their learning preference, extension agents should be able to identify both the teaching and learning aspects. Then, in this context, the extension agent's teaching style and the existing discrepancies with the farmers' learning environment, already discussed by other authors (Porr *et al.*, 2014), come into discussion. Therefore, this issue is related to the impact of extension programs on farmers' learning and agricultural technologies adoption (Norton and Alwang, 2020).

The cluster with the highest rate of technology adoption presented a combination of teaching methods, which allows us to infer that farmers' access to different approaches to interaction and information processing may be positively related to rate of technology adoption. However, the discrepancies appear in all groups of farmers, since a style and a preference for practical learning are widely highlighted in the low rate of adoption group. However, extension agents use high percentages of farm visits and theoretical exposures, which do not develop the skills that farmer's request in their preferences. The concept of a disconnection in the teaching–learning relationship has also been discussed by in other studies (Franz *et al*., 2010), where in addition to the suitability of extension methods, the farmers' profile characteristics should also be considered (Nikitha *et al*., 2018). Finally, these issues require further investigation to generate more effective tools for adequate provision of the rural extension service. A possible limitation of our study involves the sample size. However, our study represents an opportunity to continue validating new hypotheses related to the relationship between rural extension, farmer learning styles and preferences, and the adoption of technology.

CONCLUSIONS

Based on the complexity and existing gaps in the approach to the adoption of agricultural technology, this study proposes an analysis that integrates the influence of farmers' profiles and their teaching–learning context on technology adoption. The analysis of adopter clusters allowed us to classify the farmers in high, medium, and low rates of adoption of technology and technological practices. This grouping made it possible to determine certain differences in farmer profiles at each adoption level, the combination of farmers' learning styles and preferences, and the disconnection in the teaching–learning relationship.

Furthermore, the results of this investigation can be used to understand how farmers present an eminently practical learning style in the low rate of adoption cluster, which implies a weak experimentation and development phase of the farmers' technical skills. An intermediate adoption cluster transcends the reflective learning style, where some farmers require further peer discussion as well as the observation of other processes to validate results. Finally, the high adoption cluster combines the three learning styles and goes beyond the theoretical style, in which some farmers seek further conceptualization. In addition, farmers' learning preference may make the development of both technical skills and local social interaction possible. Hence, both farmer style and learning preference are elements that can be identified by extension agents to more adequately plan teaching methods and help lessen the discrepancies that still exist in the teaching–learning context within the framework of a basic farmer characteristics profile.

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Data availability. Data is available upon reasonable request with the corresponding author carlosj.ramirez@ucaldas.edu.co

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