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Efficiency of small enterprises of protected agriculture in the adoption of innovations in Mexico

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Abstract

The aim of this research was to identify the factors that influence the efficiency in the adoption of innovations in protected agricultural systems. For the study of these factors, a hierarchical cluster analysis was performed in which three clusters were obtained that showed clearly differentiated behavior. To identify the differences between groups, a variance analysis and a chi-square test was performed. The results show that efficiency in the adoption of innovations is related to the producer's schooling, his experience, and access to extension services. Derived from the above, it is important to promote greater articulation among producers, promote an integral extensionism capable of promoting collective development and interactions that are developed and evolved in the territories.

Keywords: adoption of innovations, index, extension services, technology transfer.

Eficiencia de pequeñas empresas de agricultura protegida en la adopción de innovaciones en México

Resumen

El objetivo de esta investigación fue identificar los factores que influyen en la eficiencia en la adopción de innovaciones en agricultura protegida. Para su estudio se realizó un análisis de conglomerados jerárquico del cual se obtuvieron tres clústeres que presentaron comportamientos distintos. Para identificar las diferencias entre clústeres se realizó un análisis de varianza y una prueba de chi-cuadrado. Los resultados muestran que la eficiencia en la adopción de innovaciones está relacionada con la escolaridad del productor, su experiencia y el acceso al servicio de extensión. Derivado de lo anterior, es importante promover una mayor articulación entre los productores, fomentar un extensionismo integral capaz de promover el desarrollo colectivo y las interacciones que se desarrollan y evolucionan en los territorios.

Palabras clave: adopción de innovaciones, índice, servicio de extensión, transferencia de tecnología.

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Eficiência de pequenas empresas agrícolas protegidas na adoção de inovações no México

Resumo

O objetivo desta pesquisa foi identificar os fatores que influem na eficiência na adoção de inovações em agricultura protegida. Para o estudo, foi realizada uma análise de conglomerado hierárquico, a partir da qual foram obtidos três *clusters* que apresentaram comportamentos diferentes. Para identificar as diferenças entre *clusters*, foram realizadas análises de variância e teste do qui-quadrado. Os resultados mostram que a eficiência na adoção de inovações está relacionada à educação do produtor, sua experiência e acesso ao serviço de extensão. Derivado do acima, é importante promover uma maior articulação entre os produtores, promover um extensionismo integral capaz de propiciar o desenvolvimento coletivo e as interações que se desenvolvem e evoluem nos territórios.

Palavras-chave: adoção de inovações, índice, serviço de extensão, transferência tecnológica.

1. Introduction

The rapid increase in population and food demand exerts pressure on the environment and on production systems. Such a situation increases competition for land, water, energy and its overexploitation, thus affecting the ability of agricultural systems to produce sufficient food. For this, there is an urgency to reduce this negative impact on agriculture and agro-food systems on the environment (Godfray et al., 2010). In this sense, the only form to achieve this is by innovating efficient and sustainable food production systems using technologies in the appropriate manner and with sufficient political will (Godfray et al., 2010).

One of the technologies that is viable for improving the efficiency in food production is protected agriculture. This can be defined as a production system that helps to reduce uncertainty in the management of environmental conditions and minimize other threats (pests and diseases) in obtaining adequate crop development. By this means, it is possible to increase productivity in terms of quantity, quality, and commercial values (Bastida, 2008; Castañeda-Miranda, Ventura-Ramos, Peniche-Vera, & Herrera-Ruiz, 2007; Moreno, Aguilar, & Luévano, 2011), and even increase yields up to 200% depending on the crop (Servicio de Información Agroalimentaria y Pesquera - SIAP, 2013). Furthermore, this allows the efficient use of resources such as water, fertilizers and agrochemicals (García, Van der Valk, & Elings, 2011). Therefore, it is believed that the current goal of achieving and maintaining a sustainable agriculture implies a deep knowledge of these production systems (Vargas-Canales, Castillo-González, Pineda-Pineda, Ramírez-Arias, & Avitia-García, 2014).

This type of production system has positioned itself to be a sustainable technology with a high capacity for intensive food production. Moreover, this is not only occurring in Mexico, but also on a global level, considering that this phenomenon will be consolidated in the agricultural sector in the coming years. In Mexico, protected agriculture has expanded rapidly over the past two decades and is one of the systems that is most promoted in government programs, being considered as a substantial part of a viable strategy for boosting growth and productivity in the agricultural sector.

Although its insertion in the rural sector has little over forty years, its implementation has increased dynamically in the last few years, which has resulted in a noticeable change in the national rural landscape. Moreover, in 1980 the production area intended for this type of technology was only 300 hectares; while in 2010 the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA, 2012) in Mexico reported up to 11,760 hectares, and by 2013 there were more than 19,985 production units registered for these protected agricultural systems (SIAP, 2013). However, there was no precise information on national production under these systems (García et al., 2011). Likewise, little information has been documented on the processes in which they transfer or implement innovate technology, and the use of management, administration or commercial strategies. This situation worsens for the States of Puebla, Hidalgo, Tlaxcala, and Oaxaca (Mexico) where production is oriented to local markets. This prevents the development of strategies to help reduce the negative impacts that affect the industry, such as technology gaps and training that arise among producers by eliminating certain imbalances faced by the value network in which they are inserted.

Despite this great dynamism, it is important to mention that the construction and management of these systems do have some disadvantages, among which are: a high cost of infrastructure, highly specialized products and services that depends extremely on the fresh market because of the number of perishable products (Pacheco & Bastida, 2011).

This suggests that there is a need to promote an agricultural extension program based on the dialogue between actors that articulates the network of institutions with the purpose of interacting, modifying and disseminating new technologies; that is, it is necessary to improve the functioning of the regional innovation system (Cooke, Uranga, & Etxebarria, 1997) or as Hekkert, Suurs, Negro, Kuhlmann and Smits (2007) mentioned, as innovation systems are dynamic (in constant reconfiguration), if necessary, it would have to generate a new adaption plan for the current conditions presented by this activity.

However, little projection and identification of this dynamic for development by all the actors currently involved in this activity has led to 39% inactive or abandoned greenhouses, while 19% shows a low level of productivity (Aguilar Gallegos, Muñoz Rodríguez, Santoyo Cortes, & Aguilar Ávila, 2013a). This implies a considerable loss of public funds invested, because most of the greenhouses that have been constructed in the country have been subsidized with public funds provided by the federal and state government.

Given the problems described, it is necessary to explain the factors that influence significantly adoption, adaptation, and the efficient use of protected agriculture. In this sense, the aim of this paper was to identify factors that influence efficiency in the adoption of innovation related to the income of small enterprises engaged in protected agriculture in the state of Hidalgo (Mexico), in order to promote new management strategies. In this paper, the efficiency in the use and adoption of innovations is understood as the ability to obtain higher yields and income from the process of incorporating innovations while minimizing the inherent risk.

This paper is structured in the following sections: section 2 presents a conceptual framework related to the analysis of technological change and innovation in the agricultural sector, and the factors that they influence; section 3 explains the methodology used; section 4 is based on the results obtained during this study; section 5 is a discussion on the main findings, and section 6 has the main conclusions obtained from this study.

2. Conceptual framework

Since the beginning of the 21st century, innovation and technological changes were consolidated as the main instrument in order to boost productivity growth, international competitiveness and improve living standards (Wynarczyk, Piperopoulos, & McAdam, 2013). However, most of these analyses were focused on investigating high-tech businesses. There were little to none that focused on smaller and medium-size rural enterprises, and almost nonexistent, those engaged in protected agriculture. Based on the above mentioned, there were some tactics on how to approach the analysis of innovation and technological change in agriculture and the factors that influence them.

2.1. Technological changes and innovation in the agricultural sector

Studies on agricultural innovation are focused on the analysis of generating new or improved technologies and practices (Klerkx, Aarts, & Leeuwis, 2010). Similarly, there are other authors who carried out an analysis on the adoption and adaptation of new or improved technologies and practices (Hermans, Stuiver, Beers, & Kok, 2013). In this sense, technological changes and innovation can be defined as the incorporation of old techniques into new production systems where there is a mixture of both technologies, including technological implements such as tractors, blowers, sprayers, etc. They also include new or different techniques (such as fertilization, pollination, pruning, etc.) and different areas related to production (Cáceres, Silvetti, Soto, & Rebolledo, 1997; Custer, 1995; Dorfman, 1993); additionally including forms of organization in either production or marketing, and even the regulations that govern agrifood systems (Organisation for Economic Co-operation and Development - OECD, 2005; Thomas, 2010).

Usually, the analysis of adoption of technology is approached from the perspective of a technology push, and for this reason it is studied in terms of elapsed time adopters (e.g. early adopters and laggards) (Rogers, 2003). This takes an approach that looks at diffusion of technology thoroughly, i.e., assumes that innovation and technology is always the correct form of accomplishment (Gilles, Thomas, Valdivia, & Yucra, 2013). However, this approach loses sight that the availability of resources and the environment, e.g., inherent conditions in any process of technological change, creates different production systems, and the adoption of new technologies is conditioned by negotiation between different actors, the environment in which the proposal will be inserted and the type of innovation proposed until adaptation is achieved.

In some cases it occurs that the producers can adapt to certain technology or practices and then decide to stop their use, then in the near future take them up again because their version or perception has been enlightened under other circumstances (Kiptot, Hebinck, Franzel, & Richards, 2007), which depends mainly on the behavior of the markets in which they operate.

From another point of view, technology that is generally generated out of research is considered as a finished innovation product that can be used immediately. However, this can only be put into action when it is adopted by producers and integrated (in total or modified form) into their production system. In addition, there must be some assurance that its use will provide them value (Leeuwis & Van den Ban, 2004). Thus, the process of adoption is not presented purely but requires interpretation (Latour, 2007) ,i.e., that technological innovation may still require further adaptation adjustments to be able to meet the terms needed within the rationality of the producer and the production system. This means that technological change must be complemented with innovation generated by the farmers themselves or developed jointly (Douthwaite, Keatinge, & Park, 2001; Garb & Friedlander, 2014; Millar & Connell, 2010; Novo, Jansen, & Slingerland, 2015). Therefore, dialogue between actors and technological translation does play a key role in this process.

An essential element in the adoption of technologies and practices that are not incremental nor easy to integrate into existing production systems, is the reconfiguration of institutional frameworks, for example, rules, regulations, customs or values (Hounkonnou et al., 2012; Muñoz, Altamirano, Aguilar, Rendón, & Espejel, 2007). Innovation is not only creative destruction in a schumpeterian sense, but also a social reconfiguration of knowledge, artifacts and actors in order to reach its full adaptation (Köhler & Begega, 2014).

This research considers innovation (incorporating new technologies or better management practices) as a set of strategies adopted by enterprises to become more efficient and competitive with the central idea of always improving profits, since it enables a better use of the opportunities that guarantee increased productivity and growth, thereby increasing profitability in the markets in which they operate.

2.2. Factors influencing technological changes and innovation

An aspect that is very important in the field of technological change is obtaining greater economic benefits, which is a determining factor in the adoption of innovations. In this regard, various authors agree that the producers hope to maximize their utility by incorporating innovations, and that interest in adopting them depends on the expected benefits of integration (Feder & Umali, 1993; Guardiola, Díaz-Guilera, Pérez, Arenas, & Llas, 2002; Marra, Pannell, & Abadi, 2003); hence, the willingness to invest in the development of innovation, and for larger enterprises to generate their I+D permanently. While the economic benefits that support technological change and innovation are important, some authors emphasize that the socio-psychological and behavioral factors beyond utility maximization processes also play a key role in the decision to adopt innovations (Jansen, Steuten, Renes, Aarts, & Lam, 2010; Leeuwis & Van den Ban, 2004; Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2014; Pannell et al., 2006).

There have been several studies on the factors influencing the adoption of technologies and practices in relation to the characteristics of producers, production processes and availability of resources (Aguilar-Gallegos, Muñoz-Rodríguez, Santoyo-Cortés, Aguilar-Ávila, & Klerkx, 2015; Lowitt et al., 2015; Pannell et al., 2006; Spielman, Davis, Negash, & Ayele, 2011). For example, talking about the efficiency of production vegetable units, it was found that the age of the producer and the size of the farm is a positive variable that determines its efficiency of these units in generating more revenue (Bozoğlu & Ceyhan, 2007). In addition, Martínez-González, Muñoz-Rodríguez, García-Muñiz, Santoyo-Cortés y Romero-Márquez (2011) suggest that the experience of producers is a positive factor in successful sheep production units.

In turn, Aguilar-Gallegos et al. (2013b) found no relationship in terms of the age of the producer, level of education, experience, size of production units, with levels of adoption of innovation in cocoa, rubber and palm oil. In other research (Avilez et al., 2010; Jara-Rojas, Bravo-Ureta, & Díaz, 2012; Mariano, Villano, & Fleming, 2012) has observed that the larger production units in different activities are associated with higher performance production, greater adoption of best practices, higher levels of technology and higher incomes. Vargas Canales, Palacios Rangel, Camacho Vera, Aguilar Ávila, & Ocampo Ledesma (2015) found a positive influence on the size of production units, with regard to the adoption of innovations in protected agriculture due, perhaps, to show greater willingness to invest in new technologies.

As for the diffusion of innovations, Monge and Hartwich (2008) point out the importance of extension in this process. For example, Friederichsen, Minh, Neef and Hoffmann (2013) point out as the central element of the extensionism, because of the links that are developed between public and private enterprises who shaped the agricultural innovation systems. However, it is important to note that agricultural extension services are the result of historical and political factors which are subject to change processes that give new forms, functions and dimensions. However, in either case it comes down to technology transfer, information, technical advice, facilitation, and mediation (Christoplos, Sandison, & Chipeta, 2012).

Also Oreszczyn, Lane and Carr (2010) found that when producers make decisions on new adoption technologies, there is an influence that exists in their immediate environment. This creates a relatively stable network of actors, where the extensionist is especially important, because they are able to cross the border between networks and communities of practice, for example, the articulation that can exist between agricultural extensions services to small producers either public or private with input suppliers (Klerkx & Jansen, 2010). At the same time, there is no doubt about ignoring the influence that other producers and input suppliers have in the dissemination of information (Sligo, Massey, & Lewis, 2005; Solano, León, Pérez, & Herrero, 2003; Thuo et al., 2014; Wood et al., 2014).

Other studies have shown the effects of the interaction of farmers with extension on adoption of innovations. Mariano et al. (2012) found that producers have access to extension services increased adoption of innovative practices. In this regard, Isaac (2012) found that these agents introduce new information to the producer that stimulates increased innovation adoption. Meanwhile, Spielman et al. (2011) found that integrating extensionism joins new actors and thus amplifies the innovation that arises from the interaction between a wider diversity of actors.

Another important aspect is the confidence factor in the successful development of relationships and adoption of innovations. This becomes more important when the main sources of information are other producers and extension workers. In this regard, Vargas Canales et al. (2015) found a positive influence on the adoption of innovations in protected agriculture, similar to those shown by Valenzuela and Contreras (2013). These authors argued that confidence does influence learning and the more that is being learnt, the more innovation results.

3. Methodology

The methodology is structured in the following subsections: subsection 3.1 presents the location of the study area; subsection 3.2 the data collection and variables; subsection 3.3 explains the design, construction and calculation of the adoption of innovation index; subsection 3.4 explains the design, construction and calculation of the confidence index, and subsection 3.5 specifies the way in which the information was analyzed.

3.1. Location

The information supporting this investigation was gathered from 58 small enterprises engaged in protected agricultural systems in the communities of Acaxochitlan, Acatlán, Huasca de Ocampo, Metepec and Tulancingo. These are known for having the largest production areas of these systems in the state of Hidalgo (figure 1).

3.2. Data collection and variables

Data collection consisted of the application of semi-structured surveys, conducted during 2013. For the survey design, characteristics of the region and production systems were considered. Prior to their application, a pilot test was carried out to meet the specifications of the enterprises. In this case, three sections were included; the first focused on the attributes of the producers and production units (age, education, field experience, yields, production area, access to extension service and income). The second referred to the production process, from planting to marketing, which allowed to build an adoption of the innovation index. The third section evaluated aspects related to confidence which was the basis for the construction of the index to measure this attribute.

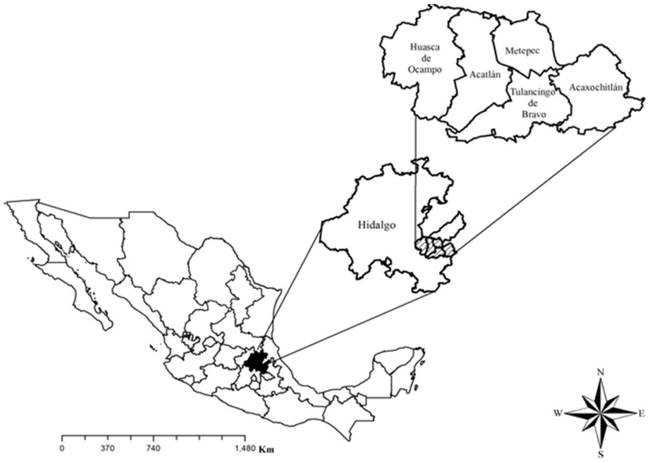

Figure 1. Geographic location of the study area.
Source: own elaboration.

In relation to access to extension services, the Christoplos et al. (2012) method was implemented. In this respect, this research study aims to find out whether the enterprises received technical advice in their production processes, if they received information on new technologies or practices and if it facilitated access to information related to services in the sector such as market prices, demonstrative events, lab analyses, grants, and loans, etc.

The selection of information units was done using non-parametrical sampling, a technique widely used by researchers in order to select units or representative portions, when no information on the sample universe is known; depending on certain characteristics, according to the criterion of the expert (Muñoz, Rendón, Aguilar, García, & Altamirano, 2004; Pimienta, 2000). In this case defined as a criterion permanence in the activity, i.e., the largest number of enterprises were surveyed in the region that were active or operating using the snowball method.

3.3. Design, construction and calculation of the adoption of innovation index

With the information gathered about the innovations implemented by the enterprises, adoption of innovation index was constructed. This was calculated adapting the methodology described by Muñoz et al. (2007) using an innovations catalog and good agricultural practices and management carried out by the producer. This catalog was adapted to four innovation categories considered in the Oslo Manual (OECD, 2005), including processing, production, marketing and organization (figure 2).

In each category, a Likert scale was used with a range of values between one and five for each category to identify the degree of innovation adoption, whereby a coefficient was obtained using the total sum of the values in each component and divided between maximum values according to the scale to be analyzed as a continuous variable. In order to corroborate the reliability of the categories with which the index was constructed, the Cronbach's alpha analysis was performed and an acceptable internal consistency level (0.72) was obtained (Oviedo & Campo-Arias, 2005; Santos, 1999).

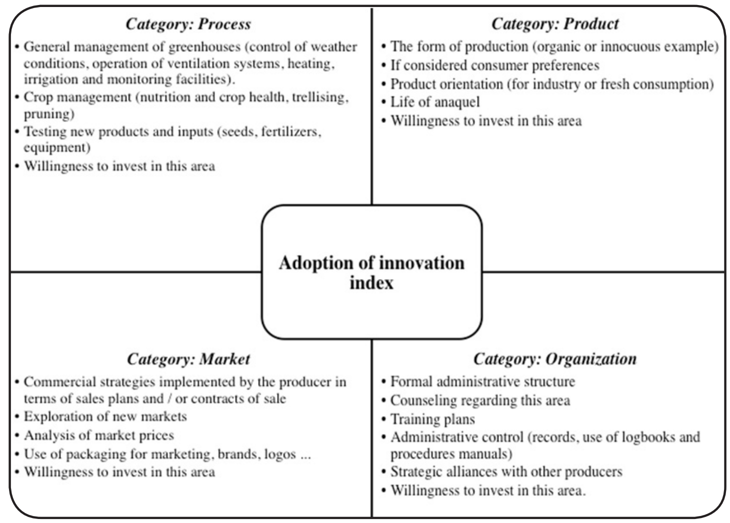

Figure 2. Categories and main variables used to construct the adoption of innovation index.
Source: own elaboration.

3.4. Design, construction and calculation of the confidence index

To analyze the confidence index the dimensions proposed by Luna and Velasco (2005) were adopted. They were classified in three levels ranging from technical, including business relationships with suppliers and extensionist; interpersonal, based on horizontal relationships between producers and enterprises, and strategic focusing on relations with institutions. A Likert scale with a range of values between one and five for the confidence index was used. The index was calculated by the sum of the total of the values obtained in each component divided between the maximum values obtained according to the scale to be analyzed as a continuous variable. Finally, to corroborate the reliability of the categories with which the index was constructed, the Cronbach's alpha analysis was performed and an acceptable internal consistency level (0.75) was obtained (Oviedo & Campo-Arias, 2005; Santos, 1999).

3.5. Analysis of the information

To systematize the information obtained in the investigation, a database was developed with Excel® using the SPSS program for the statistical analysis. Furthermore, a cluster analysis was realized in order to generate a typology with the help of cumulative hierarchical algorithms as the classification method. The squared Euclidean distance was taken into consideration, linking with the furthest neighbor; the analysis was performed with standardized data, which avoids inconsistencies due to scales differences (Hair, Aanderson, Tatham, & Black, 1999). The use of this multivariate technique, using mathematical algorithms defined clusters of more or less homogeneous operators without fixing a priori the number (Pérez, 2004). Subsequently, an analysis of variance (ANOVA) and mean comparison Scheffe tests between clusters. This procedure applies to non-equilibrium models, as was the case.

For the analysis of the extension service, a chi-square statistical test determined the dependence on each cluster formed. This test determined whether there was a relationship between two categorical variables and assumed that the extensionism variable was independent of the groups formed. However, this test indicates whether there was a relationship between variables but does not indicate the extent or type of relationship. That is, it does not indicate the percentage of influence of one variable on the other or the variable that causes the most influence (Hair et al., 1999; Tinoco, 2008); nonetheless, it identifies whether a relationship exists between the presence of extensionism and a defined group.

4. Results

The protected agriculture system began in the region in the late 1990's. Since then, it has experienced rapid growth in both, area and number of enterprises found within the system. The technology in the region is classified as an intermediate technology according to Costa and Giacomelli (2005). It is characterized because most of the greenhouses are built of metal structure, covered with polyethylene and have a passive ventilation and heating system. They have simple control panels for fertigation, soil-based production, and long production cycles established for eight months from transplant to harvest.

The variables from the 58 protected agriculture enterprises were analyzed and showed very high variation. The age of the producers ranged from 24 to 63 years. The level of schooling was recorded for producers ranging from 1 to 17 years (the producers with the highest level of education are agronomists) and an average of 9.1. With regard to the years of experience, understood as the knowledge that the producer has accumulated in the activity, this ranged from 1 year or 1 production cycle to 15 years which is approximately the time that protected agricultural systems were established in the region. In terms of yield, the lowest value was 10 kilograms per square meter (kg m^{-2}) and the maximum 44 kg m^{-2} with an average of 21.43 kg m^{-2}. As for the production area, the size of the units was very variable. Its dimensions range from 6000 square meters (m^{-2}) to 15000 m^{-2}, with an average of 3463.10 m^{-2}.

The confidence value measured as an index varied between surveyed producers from 0.3 to 0.9 and an average of 0.68. The adoption of innovation index showed a minimum of 0.38, a maximum of 0.94, and has an average of 0.58. Moreover, the market innovations and organization (figure 3) are those with lower levels and coincide with the taxonomy of Pavitt (1984) for the primary sector. With regard to the extension service, only 26% obtained it, and is provided by input suppliers and extension workers with extensive experience, located in the region and dedicated to the same activity.

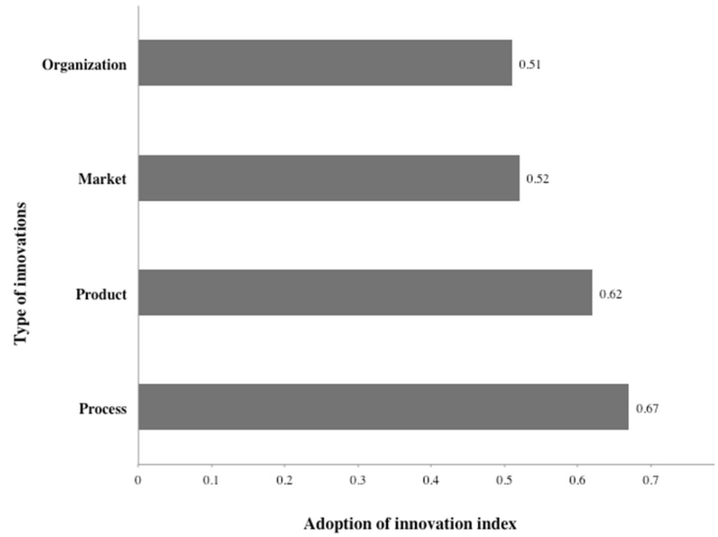

Figure 3. Adoption of innovation index in protected agriculture.
Source: own elaboration.

4.1. Typology of the enterprises: efficient use and adoption of innovation

The application of the cluster analysis allowed the creation of a taxonomy of producers based on the efficiency and use of adoption of innovations. For the analyses two factors were considered as discriminants: the yields obtained and innovation adoption index in which three groups was formed (figure 4).

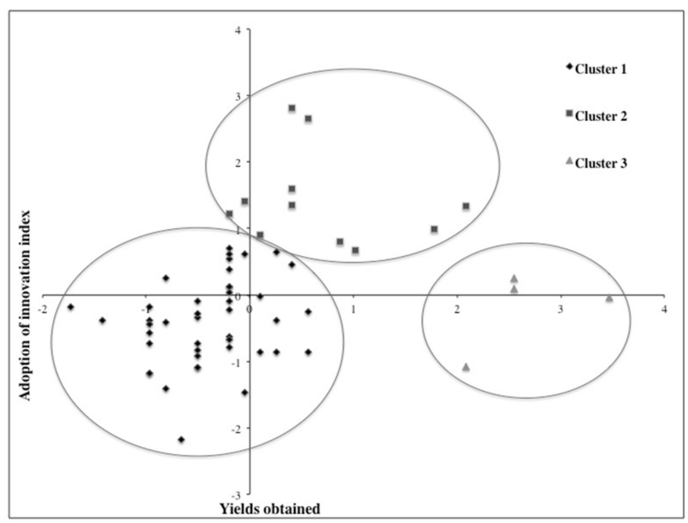

Figure 4. Typology of enterprises according to performance of adoption of innovation index.
Source: own elaboration.

4.1.1. Cluster 1: enterprises with low efficiency in the use of adoption of innovation

This is the largest group, composed of 43 enterprises (74.1% of the total) who have an indolent behavior to innovation. Although the level of Education wasn't the lowest, there was a significant difference with Cluster 2 (table 1).

The group was characterized for its role in integrating producers with little experience, in addition to those who have entered the activity more recently. Low yields compared to the other groups (18.72 kg m^{-2}), for which there are significant differences. Also, the rate of adoption of innovations turned out to be less compared to the other groups studied; i.e., they implement to a lesser extent new technologies and/or new or improved practices in their production systems. As for production areas and level of confidence, these variables were not significantly different.

4.1.2. Cluster 2: enterprises with average efficiency in the use of adoption of innovation

This group is made up of 11 enterprises (19% of the total amount) that show a very active behavior towards innovation. The level of schooling in years is the highest, although the results indicate that there is a significant difference with Cluster 1. This coincides with the fact that they register the highest adoption of innovation index (table 1), which may suggest that the level of education directly influences the propensity to integrate innovations in their processes.

This group is characterized by bringing together producers with less experience. The yields obtained are average compared to other groups (25.73 kg m^{-2}), with which there are significant differences.

Table 1. Comparison of averages of attributes based enterprises formed clusters.

Variables	Cluster 1	Cluster 2	Cluster 3
N° of enterprises	43	11	4
Age of the producer	41.53 a	44.82 a	41.50 a
Producer education (years)	8.60 ab	11.73 a	7.25 b
Producer experience (years)	4.98 b	4.55 b	10.25 a
Yields obtained (kg m^{-2})	18.72 c	25.73 b	38.75 a
Production area (m^{-2})	2,846.74 a	5,131.82 a	5,500.00 a
Confidence index	0.68 a	0.72 a	0.62 a
Adoption of innovation index	0.55 b	0.71 a	0.57 b

Note: means with different letters in rows indicate significant differences ($p < 0.05$), according to the Scheffe test.
Source: own elaboration.

4.1.3. Cluster 3: enterprises with high efficiency and adoption of innovations

This group is composed of four enterprises (6.9% of the total amount) that have greater efficiency in the use and adoption of innovations. Paradoxically, it is the one with the lowest levels of education; however, it includes enterprises that have more experience in years carrying out the activity (table 1), suggesting that they were the first to introduce it in the region.

At the same time, it highlights a liability for the use and adoption of innovations behavior, as their rate of innovation is low with respect to cluster 2. In contrast to the above, they obtain higher yields than the other groups (38.75 kg m^{-2}) (table 1), situation indicates that the experience and skills acquired in the activity allow them to identify more efficiently new and improved technologies and practices to incorporate into their processes.

4.2. Analysis of the extension service

To evaluate the relationship of extension services (table 2) efficiency in the use and adoption of innovations, the chi-square independence test was used. The results obtained by performing the contrast between the influence of extensionism and formed clusters indicated that 5% was significant; that is, there is a dependency relationship between the variable and the groups in question.

Table 2. Chi-square test based on clusters formed between agricultural extension services.

	Value	Degrees of freedom	Sig. Asymptotic (bilateral)
Chi-square Pearson	9.20a	2	0.010
Likelihood Ratio	10.71	2	0.005
N° of valid cases	58		

Note: the expected frequency for a 3 (50%) was less than 5. The minimum expected frequency is 97%.
Source: own elaboration.

As noted above, this type of analysis does not identify the degree of influence or the relationship between the two variables; however, it indicates the dependence of variables regarding the efficiency and adoption of innovations, which allows us to infer that the agricultural extension service is related largely to clusters 2 and 3. That is, these enterprises have greater access to extension services. In addition, based on the above, they are more linked to educational and state institutions, a situation that generates a greater flow of information and diffusion of innovations. Another important aspect is the link that the extensionist creates, serving as the intermediate actor, a situation that generates a greater flow of information between the educational institutions, the state, and the producer, and confirms that this actor becomes a means for the distributing of innovations.

4.3. Adoption of innovations and income

Significant differences were obtained among the three clusters (figure 5). The results indicated that income earned in the production of tomatoes in the greenhouse varied among groups. Enterprises belonging to Cluster 3 were earning higher incomes (US$18.16 m^{-2}), followed by those found in cluster 2 (US $12.05 m^{-2}), and earning the lowest incomes were those belonging to Cluster 1 (US $8.77 m^{-2}), which in this case the great majority of the producers belong to.

The results obtained on income were directly related to the performance of each enterprise, and these with the efficiency and the adoption of innovations. In the cluster 1 there are enterprises that incorporated fewer innovations and earn less income, their behavior is probably explained by the need to remain in the market while minimizing the costs of incorporating innovation. In cluster 2, which is located at an intermediate level, the incorporation of more innovations is influenced by the higher level of schooling; this results suggests a logic in which profit maximization is sought through the adoption of innovations. In the cluster 3, the adoption of innovations was determined by greater experience and the upgrading of technology, so it has higher incomes, and their behavior can be explained because the experience allows you to make better decisions about the innovations to be incorporated, which derives in maximizing utilities in the incorporation of innovations.

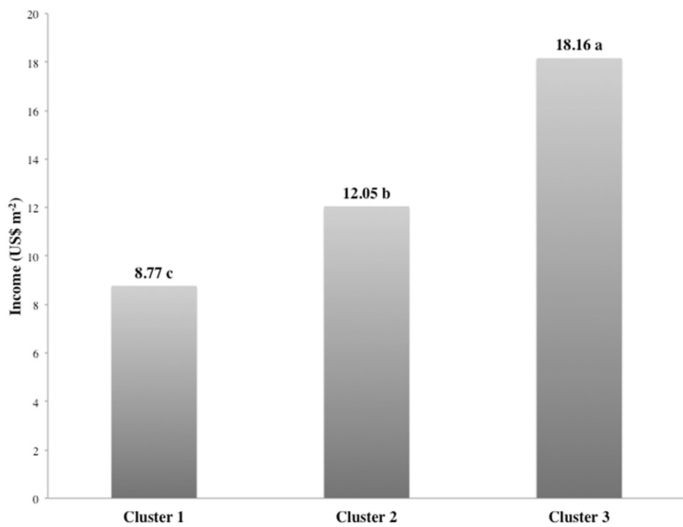

Figure 5. Comparison of average income, based on clusters formed.
Note: the different letters indicated significant differences ($p < 0.05$), according to the Scheffe test.
Source: own elaboration.

5. Discussion

The low value of the adoption of innovation index generally indicates that there are few incorporations of new or improved agricultural technologies or practices. Also, the lowest levels are in the category of the market and organization, which limits access to other markets and developing innovations that allow them to reap greater benefits. The highest levels in the category of the process are explained by the effect of extension services that focuses primarily on improving this area. From the results of this research, it was confirmed that the dynamics in the adoption of innovations found among the clusters of enterprises showed a dependence on factors that matches those found by other authors. For example, Pannell et al. (2006) and Rogers (2003) found that producers with experience in managing their production systems, and with an accumulation of knowledge about their operation, allowed them to identify the most relevant type of innovations and discriminate some factors in order to enforce adoption. In this sense, we can say that the above factors have enabled the development of more skills and accuracy in managing the technology they have; i.e., they have appropriated, adapted, and controlled the technology. This coincides with that described by Bozoğlu and Ceyhan (2007) on the positive effect of experience on the efficiency of vegetable production units. In addition, Aguilar et al. (2013b) found positive relationships of this variable in the adoption of innovation in cocoa producers.

Perhaps the importance of experience factor is due, to a greater extent, to the characteristics and needs of the activity. Protected agriculture requires producers of different skills and characteristics from those who acquired them traditionally. In protected agriculture, producers generally have a low learning curve (García et al., 2011; Moreno et al., 2011), because the conditions in which production cycles develop are very changeable and the problems that are presented are very diverse (competition, price fluctuations, rising inputs, etc.). According to Salom (2003), the best way to accumulate and communicate knowledge is by demonstration and practice, therefore tacit forms of knowledge can only be acquired through practice and experience. In this regard, it is necessary to promote the exchange of knowledge that fosters collective learning and reduces uncertainty in the adoption of innovations (García Sánchez, Aguilar Ávila, & Bernal Muñoz, 2011). This coincides with Kilelu, Klerkx and Leeuwis (2013) who mentioned that innovation occurs through collective interaction between producers, researchers and service providers. In addition, extension workers are the ones that facilitate effective interaction between all actors of the innovation system (Davis, 2015).

Education is another variable related positively to the dynamics of the incorporation of innovations. This means that producers who have the highest level of education are generally those with the highest adoption of innovation index. This being a factor which has multiple interpretations, the reason for this is probably related to the fact that producers with more education are more likely to experience and incorporate innovations in the production process.

Furthermore, a possible explanation is related to the fact that producers with a higher educational level are more likely to experiment and incorporate innovations into their production process. These results coincide with those of Namara, Nagar and Upadhyay (2007), who found that more educated producers seek more information, are more experimenters and are more likely to lean towards adopting innovations, although this does not guarantee an effective adoption. This also corresponds with the point made by Águila and Padilla (2010) in their research on social economy enterprises, in which it was found that a higher level of education could increase the willingness to innovate.

Another factor connected to adoption of innovations is access to extension services. Arguably, it is possible to have access to more information and new technologies by involving producers within a wide network of actors of various kinds (technological, financial, government, etc.). The combined action of all these forces multiplies the effect of each individual factor, and this synergy conditions the economic return, firm productivity and competitiveness, capital accumulation and economic and social progress (Vázquez-Barquero & Rodríguez-Cohard, 2016). The results indicated that the extension service does positively influence the incorporation of more and better innovations; these results are consistent with those found by Isaac (2012), Mariano et al. (2012) and Spielman et al. (2011). This suggests that extension services disseminate information on innovation previously tested and the effects of extensionism (Birner et al., 2009) is reflected in the increase in yields, product quality and innovative behavior of producers.

Similarly, Aguilar-Gallegos et al. (2015) and Abdulai and Huffman (2005) show that in the existence of more linkages with extension, levels of adoption of innovations and the productive and economic parameters tend to improve. Similar effects were reported by Genius, Koundouri, Nauges and Tzouvelekas (2014) on the adoption and diffusion of irrigation technologies. In this regard, the extension service has multiple functions (Christoplos et al., 2012; Klerkx & Leeuwis, 2009; Lubell, Niles, & Hoffman, 2014; Rivera & Sulaiman, 2009); however, the most important is the direct link of enterprises with public and educational institutions. According to Isaac (2012), Thuo et al. (2014) and Friederichsen et al. (2013), in order to adopt certain technologies and practices, certain links are required to develop beyond the inner circle of producers and those who fulfill these functions are extensionist.

Significant differences in yields coincided with the findings of Avilez et al. (2010), Jara-Rojas et al. (2012) and Mariano et al. (2012); also, it corresponds to obtaining higher earnings, which shows that some producers could be more efficient and competitive when they develop better technological adaptation. The results also suggest that those who earn lower yields and incomes are less efficient and competitive. This is related to limited access to new technologies resulting in low levels of adoption of innovations (Bozoğlu & Ceyhan, 2007; Hartwich, Monge, Ampuero, & Soto, 2007; Muñoz-Rodríguez & Altamirano-Cárdenas, 2008).

Finally, based on the above mentioned and according to Galdeano-Gómez, Aznar-Sánchez, & Pérez-Mesa (2011), there are multiple development trajectories resulting from various combinations of local, regional, national and global forces in the territories, which have been the result of the action of various endogenous and exogenous factors. In this sense and according to Vázquez-Barquero and Rodríguez-Cohard (2016), it is necessary to strengthen institutions, foment the interaction of development forces and the combination of the objectives of the different actors linked to production systems, in order to change the comparative advantages into competitive advantages. Derived from the above, it is necessary to think about collective development schemes that consider the characteristics and interactions that are developed and evolve in the territories, in order to propose a comprehensive policy that triggers technological change, innovation and sustained economic development.

6. Conclusions

The adoption of innovation index in general is low, and organizational innovations and market have the lowest levels. The main factors behind the efficient use and adoption of innovations for protected agriculture groups studied in Hidalgo, Mexico are the education level, experience in the activity, and access to extension services. Although the level of education plays an important role in the propensity to adopt innovations, it is not the most relevant variable in terms of efficiency.

In relation to the experience variable in this activity, it was shown to be the most significant in the efficiency and adoption of innovations, since it was related to the higher yields and income. Moreover, with regard to access to extension services, the results suggest that the information network that was created around the extensionism is one factor that allowed and encouraged the incorporation of more and better innovations. Also, the extensionists are those who facilitated the coordination and interaction between the actors of the innovation system. However, it must not only focus on technical aspects, it is essential to consider socioeconomic aspects and to promote market innovations and organization.

Finally, it is necessary to think about collective development schemes that consider the characteristics and interactions that are developed and evolved in the territories, in order to design an integral policy that stimulates the coordination of the different actors (economic, political and social) through the combination of its objectives and interests, to promote technological change, innovation and sustained economic development.

Conflict of interest

The authors declare no conflict of interest.

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