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Typology of small producers in transition to agroecological production

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Abstract. Agroecology is now emerging as the fundamental science to guide the conversion of conventional production systems to more diversified and self-sufficient systems. The agroecological transition is defined as the gradual change that farmers undergo to adapt and move from more conventional towards agroecological farming principles, encompassing technological, societal, institutional and organisational changes in the food system. To analyze a transition process, it is initially necessary to understand how agroecosystems work (their structure and processes), and the different ways human beings intervene an ecosystem in order to transform it for productive purposes.Farm systems typology and classification techniques are used to guide strategic lines of research, sectorial policies, and promote sustainable development in response to farmer's needs. Determining multidimensional classification methods in agricultural systems is necessary, considering both the variables inherent to the production system and those of an external nature that indirectly impact the development and long-term sustainability of production systems. One of the purposes of this research was to characterize agricultural production based on sustainability systems and environmental, social, and economic indicators. The study was carried out based on data collected from 71 farm surveys, considering the social, economic, environmental, and technological dimensions. Multiple correspondence and cluster analysis were done. Three types of production systems were obtained: Group I, organic producers in transition; Group II, conventional producers in transition to organic production; and Group III, conventional producers interested in organic production. Producers need to focus on processes that allow them to improve their skills to develop human talent and social capital in terms of integration, collaborative work, trust, political and cultural capital, so that they can make progress easily and start implementing agroecological, infrastructure, and natural resources management practices, while improving their living standards. The information yielded by a typology process allows for us to know the current state of agricultural production systems based on the implementation of agroecological practices; thus facilitating the preparation and implementation of participatory plans and/or integrative proposals that promote agrofood sustainability.

Key words: sustainability, organic agriculture, rural development.

INTRODUCTION

To cope with the production systems complexity and the agroecological transition (AE), it is necessary to understand how the agroecosystem works. For this, a systemic approach is crucial, where the limits of the system, the components that integrate it, and the interrelations that occur between them are considered. This approach allows to organize the knowledge about the agroecosystem functioning, interpreting the particular properties that emerge from these relationships and those responsible for providing useful ecological services from an agroecological approach Duru & Therond, 2015).

Transforming conventional systems to other ecologically based systems is not a simple and quick task, it requires gradual changes in the ways of managing agroecosystems (Caporal et al., 2009). It is necessary to consider productive, cultural, social, economic and political aspects that demand an integral and systemic view. Therefore, a transition process involves a multitude of foreseen and unforeseen causes and effects, and it is constructed over time. As stated by Gliessman et al. (2007), it implies a change in farmers and consumers' values and way of acting, in their social, productive and natural resource relations, i.e. transition occurs not only on the farm, but also at community level.

Typology has been defined by Daloğlu et al. (2014) as a method to identify production systems diversity by ordering or classifying reality. The term 'typology' is used to define types, analyze a complex reality and order objects that, despite being different, fall under the same type, e.g. a farm. Every system or productive unit is different in both structure and function; these two characteristics will determine the relations of homogeneity or heterogeneity between agroecological production systems (Varela, 2010).

Producers typology can be based on previous studies and information available to territorial entities, seeking a first approach to targeted places. Therefore, field work to be in direct contact with producers is necessary for obtaining information for analysis and draw conclusions to improve region's productive systems (Garcia & Calle, 1998). Typology seeks to group producers under similar management, production, and techniques as some producers are in delimited geographical areas.

For decades, methodologies for agricultural production systems typology have been under development. Valuable experiences on their applications have contributed to the knowledge of the agricultural development dynamics of a region, by analyzing the relationship between the types of farms, and their socioeconomic, physical, and biological environment (Varela, 2010). Typologies are a convenient tool to simplify the diversity of farming systems while effectively describing their heterogeneity (Daloğlu et al., 2014). This instrument is used to provide guidelines for the development of agricultural innovations and to better understand their implications in family behavior of the farmers (Douxchamps et al., 2015; Kuivanen et al., 2016; Contzen & Forney, 2017).

In Latin America, there is a need to know where agroecology is being adopted as a production system. The information yielded by a typology process allows to know the current state of the production systems. Agroecology territories are places where a transition process toward sustainable agriculture and food systems is engaged. Classification studies have also been used to manage specific research and development projects to select target groups and representative farms, among others (Escobar & Berdegue, 1990). These classification methods can be univariate or multivariate. The latter are more common due to the involvement of the systemic approach, by relating variables of the farm system with their surrounding environment (Varela, 2010) which allow the multiple measurements of the individuals studied to be analyzed (Carrillo et al., 2011). Shaner et al. (1982) developed criteria based on a limited number of indicators grounded in climate information and soils, to classify farms according to their area and number of farmers. The aim of this study was to typify agricultural production based on sustainability systems and environmental, social and economic indicators, as well as to identify opportunities and barriers for promoting agroecological transitions.

MATERIALS AND METHODS

This research was conducted in 7 stages: 1. Description of target population. 2. Sample selection and construction of data collection instrument. 3. Information processing (database building, classification and description of variables). 4. Review and selection of variables. 5. Application of multivariate statistical techniques. 6. Determination of types or subsystems. 7. Description of types or groups (Sraïri & Lyoubi, 2003).

Study zone

This study was conducted on producers in the Province of Sumapaz, in the department of Cundinamarca (Colombia) (Fig. 1). Land use in the Sumapaz region is focused on 28.6% pastures, 21.5% secondary forest, 14.8% paramo vegetation, 8.3% stubble, 5.3% grass with stubble, 4.4% natural forest, and 9.3% soils is used for agriculture. It has an average temperature between 18 °C and 24 °C and biannual rainy seasons (March-April and July-August) (Giraldo, 2008).

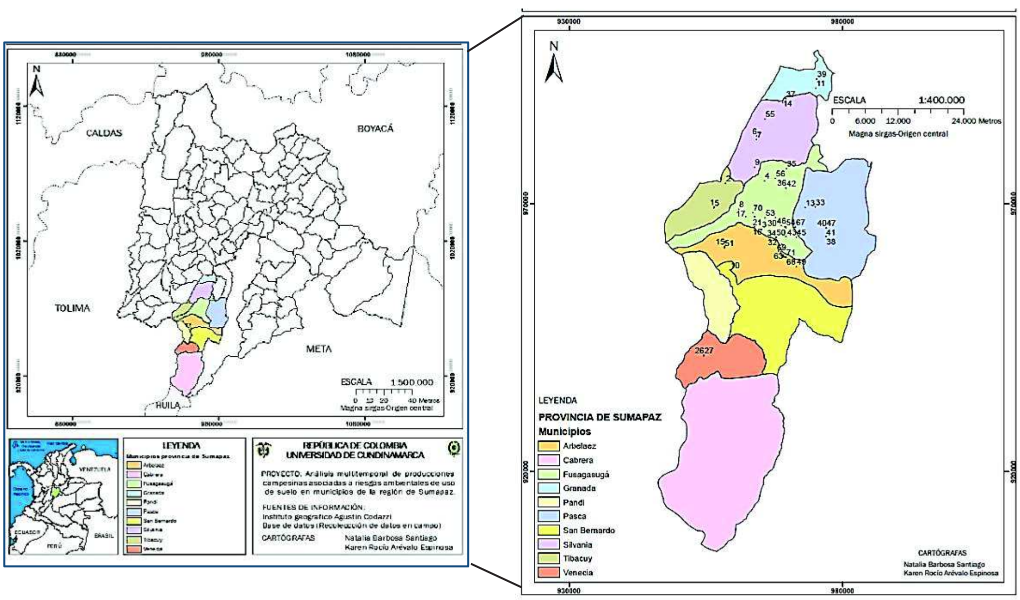

Figure 1. Location of the region of Sumapaz (the 10 municipalities represented in colors) Department of Cundinamarca (left). Location of the 71 respondents (right).

Description of target population, sample selection and collection instrument

Implementing organic agriculture practices within their productive systems was the common activity established. Since no reference framework was available, a snowball sampling was used until some SENA-based organic market producers were reached. They led to other farmers, and a total sample of 71 respondents was achieved (Fig. 1). The surveys, 200 questions each, were conducted from March to July 2015, and focused on for dimensions: Economic, Social, Environmental, and Technological variables. The surveys were carried out directly to producers through visits to the 71 farms.

Statistical analysis

A descriptive analysis to quantify repetition and redundancy observations (Romero, 2009) was carried out, and then the variables grouping the respondents' answers were unified and categorized. Based on this, 36 variables were obtained and narrowed to those being discriminatory so that differences were established. To that end, distribution of variable frequencies was used; e.g., if 98% of producers were farm owners, and only 2% were sharecroppers, such variable would not have contributed much to identify organic producers.

Multiple correspondence analysis (MCA) is an extension of correspondence analysis which allows one to analyze the pattern of relationships of several categorical dependent variables (Abdi et al., 2007). Multivariate techniques of MCA were applied through Burt's method and cluster analysis (CA), using the Euclidean distance and Ward's method (Blazy et al., 2009). The former one, is a factorial technique developed for studying a population of individuals described by a set of categorical variables, each of them with a certain number of categories (Aguirre, 2013), the latter one allows to classify individuals based on homogeneous characteristics to group them.

The *dimdesc* function was used to identify the most correlated variables to the dimensions generated in the MCA, through the coefficient of determination (R^2). Each dimension was analyzed through a factor variance analysis, and an F test was derived to find out if the variable had an impact on the analyzed dimension, and also a T test was performed category by category. In order to compare the variables within the groups resulting from the cluster analysis, contingency charts were made, and the chi-squared test (Chis-q) was used to determine statistical differences between groups with a 99% trust level; then, each cluster was described to characterize the relevant aspects. R 3.2.3v statistical software, using FactomineR, to calculate the results, and Factoextra for graphs visualization, were used.

RESULTS

In order to obtain a typification of the small producers, it is necessary to determine which variables (social, environmental, economic, technological) have the greatest influence on the characterization. Based on the results generated by the multiple correspondence analysis, eight optimal dimensions (axes) were obtained, which combined 74.3% of the cumulative variability. The first and second components explained 35.1% and 12.3% of the variance percentage respectively. The factor map for the distinct categories was obtained by selecting the 40 greatest contributing categories to the first and second components (Fig. 2 – supplementary material).

Component one was characterized by the following set of variables, as follows: produced inputs ($R^2 = 0.5813$, $p = < 0.01$), organic fertilizers ($R^2 = 0.5143$, $p = < 0.01$), infrastructure ($R^2 = 0.4253$, $p = < 0.01$), farm change ($R^2 = 0.4134$, $p = < 0.01$), participation in events ($R^2 = 0.3791$, p = < 0.01), agricultural waste management ($R^2 = 0.3337$, $p = < 0.01$), irrigation ($R^2 = 0.3148$, $p = < 0.01$), agricultural production ($R^2 = 0.2959$, $p = < 0.01$), mother duties ($R^2 = 0.2553$, $p = < 0.01$), product transformation ($R^2 = 0.2787$, $p = < 0.01$), agricultural communication ($R^2 = 0.2698$, $p = < 0.01$), agroecological practices ($R^2 = 0.2431$, $p = < 0.01$), technical assistance service ($R^2 = 0.2730$. p = < 0.01) and being part of an organization ($R^2 = 0.2667$, $p = < 0.01$).

The coordinates of the following categories are positive: '5 or more infrastructures', '3 or more inputs', 'Between 3 and 5 agricultural waste management processes', 'Irrigation', '4 or more events', 'Between 6 and 8 fertilizers', 'Mother with 3 or more duties', 'Between 3 and 5 means of communication', '3 or more livestock systems', '3 or more changes on the farm', 'Decisions made by father and mother',' 3 or more processed products', 'If there are accounting records' and 'If there are associations'; while the following categories are negative: 'There are between 1 and 4 pieces of infrastructures', 'There are no institutions', 'Less than two agricultural waste management processes', 'No irrigation systems', 'No changes on the farm', 'Less than 7 productive systems', 'Mother with less than two duties', 'No participation in events', 'Between 1 and 5 agricultural products', 'Assistant in associations', 'Between 1 and 2 chemicals', 'No technical assistance', 'No processed products', 'No fertilizers', 'Decisions 1', 'No associations', 'No accounting records' and 'Less than two livestock systems'.

This means that farms with positive coordinate tend to have efficient waste management practices, mainly used in composting; they produce and transform a large part of their raw material and have technical assistance and consultancy services for organic production. On the other hand, they have adequate spaces for their agricultural activities, possibly directed towards agroindustry and/or livestock production. Farmers are characterized for participating, training, and attending events offered by the associations they belong to, or other governmental entities, aspects observed in the adoption of practices aimed at organic production.

Component two was characterized by the following variables: children age ($R^2 = 0.4433$, $p = < 0.01$), type of work ($R^2 = 0.3606$, $p = < 0.01$), adolescent work ($R^2 = 0.2791$, $p = < 0.01$), children's education level ($R^2 = 0.3307$, $p = < 0.01$), environmental problems ($R^2 = 0.2475$, $p = < 0.01$), farm work ($R^2 = 0.2269$, $p = < 0.01$), farm money ($R^2 = 0.2635$, $p = < 0.01$), chemical inputs ($R^2 = 0.2433$, $p = < 0.01$), agricultural production ($R^2 = 0.2090$, $p = < 0.01$), farm decisions ($R^2 = 0.1685$, $p = < 0.01$), agricultural communication ($R^2 = 0.2635$, $p = < 0.01$) and father age ($R^2 = 0.2183$, $p = < 0.01$).

The coordinates of the following categories are positive: 'Children between 10.1 and 20', 'Adolescent with 3 or more duties', 'High school children', 'Parent's money', 'If there are environmental problems', 'All members', '3 or more chemicals', 'Parents' Decisions', 'Parents between 35.1 and 50 years old', 'Less than 7 productive systems', 'Between 3 and 5 agricultural waste management processes', and 'Family labor'; while the following categories are negative: 'Contracted labor', 'Adolescent with less than 2 tasks', 'No environmental problems', 'Between 1 and 2 intermediaries', 'Children without education level', 'Between 1 and 2 education systems', '11 or more productive systems', 'Non-chemical', 'Decisions 1', 'Mother with no education level', 'Parents' money', 'Less than 2 agricultural waste management processes' and 'Over 30.1 year-old children'. The positive findings in this dimension show that the decisions and money management are made jointly by father and mother, the average age of the parents ranges between 35.1 and 50 and children between 10.1 and 20, with secondary education; regarding the farm, it is evident that most of the work is carried out by the family members, they have environmental problems associated. With respect to waste management, it is evident that they manage agricultural waste, whether in composting, fertilizers, or food for livestock.

A dendogram is a diagram that shows the hierarchical relationship between objects. It is most commonly created as an output from hierarchical clustering. Cluster analysis (CA) (Figs 3 and 4) classified three farm groups. The first group was called '*Organic Producers in Transition*' (*OPT-1*), which consists of 27 farms (38.03%), the second, '*Conventional Producers in Transition Process to Organic Production*' (*CPTPOP-2*), which comprises 15 farms (21%), and finally, the third one, '*Conventional Producers Interested in Organic Production*' (*CPIOP-3*), conformed by 29 farms (40.84%); In this regard, studies conducted by Fargue -Lelièvre et al. (2011), Tuesta et al. (2014), Petit & Aubry (2015) and Cleves-Leguízamo & Jarma-Orozco (2014), have found the organic management component is discriminatory.

The most significant variables and categories in the characterization of producers ($p < 0.01$) are shown in Table 1 of supplementary material.

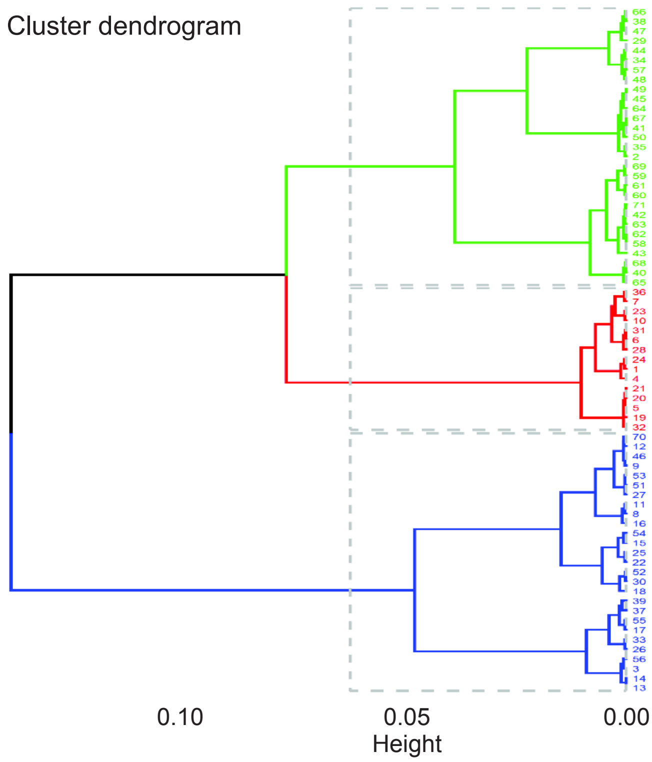

Figure 3. Grouping of production farms (*OPT-1blue*), (*CPTPOP-2red*) ((*CPIOP-3green*).

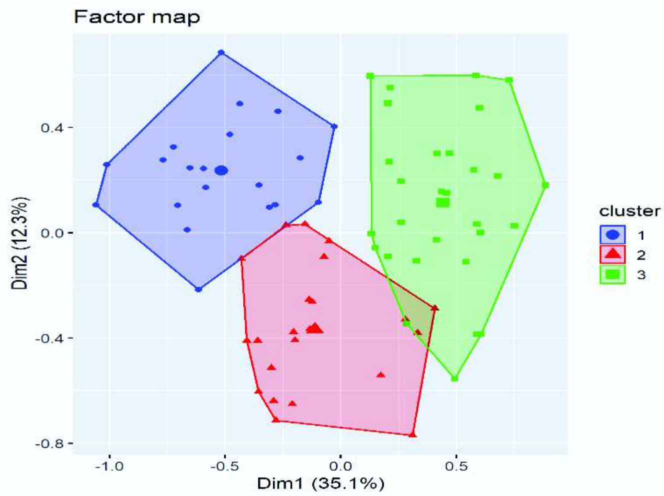

Figure 4. Grouping of producers TIF.

OPT-1, were characterized for being the most advanced organic producers due to their farms infrastructure, diversification of agricultural and livestock systems, with high production and processing of inputs. Socially, they are established nuclear families where team work prevails, and belong to associations at management level, mainly. Regarding the environment component, these producers evince the best water management and agricultural waste practices; their agroecological practices and use of organic fertilizers are extensive and many do not resort to chemical alternatives. Finally, in the technological dimension, they count on technical assistance services from one or more entities, and participate in events with access to different means of agricultural communication.

CPTPOP-2, were characterized because their infrastructure, number of agricultural production systems, elaboration and processing of inputs are lower compared to *OPT*, but higher than *CPIOP*. At a social level, the work is carried out by one or two members. Unlike the first group, a large part of these producers is associated, acting as administrative staff or associates. Their family group is not defined since most of the families do not have one or more members and decision-making and money management are carried out only by one person. Regarding the environmental aspect, this group of producers performs between 1 and 2 water management processes, some of them lack an irrigation system, agricultural waste management is scarce, resulting in a large number of environmental problems; concerning agroecological practices and use of organic fertilizers, many of them are in the implementation phase, often resorting to chemical management. Finally, at technological level, there are shortcomings in technical assistance services; however, they actively participate in events and have affordable communication systems.

CPIOP-3, were characterized by having insufficient infrastructure systems, low input processing and transformation rates, and little diversity of agricultural and livestock production systems; socially, work on the farm is carried out by one or two members, they are incipient producers in organic production, many of them do not belong to any associations and/or participate on an occasional basis. At environmental level, water and waste management is scarce, environmental problems are frequent, chemical management remains the main management alternative on the farm, and both agroecological practices and the use of organic fertilizers are just starting to be implemented. At a technological level, most of these producers do not count on any kind of technical assistance service, and most of the times they do not participate in events.

DISCUSSION

The agroecological transition is defined as the gradual change that farmers undergo to adapt and move from more conventional towards agroecological farming principles, encompassing technological, societal, institutional and organisational changes in the food system (Tittonell, 2014). Although the transition to agroecology follows general principles, each particular farm has a unique way to adopt and adapt practices and management strategies. According to Weltin et al. (2017), the challenges towards agroecological transitions are not the same for all farmers as farmers differ in objectives and values and are embedded in different social and ecological contexts. To assess the implications of farm diversity for promoting agroecological transitions, one main challenge need to be addressed, it refers to a conceptual and empirical understanding of how to assess the diversity of farmers within transition processes. Earlier studies have sought to understand the diversity of farmers through the notion of 'farming styles' or 'farm typologies', which distinguish different groups of farmers on the basis of the strategies that they pursue, as well as farm structural variables (Kansiime, 2018).

Four levels of the agroecological transition process were set by Gliessman et al. (2007) and Altieri et al. (2017), to transform conventional systems characterized by monocultures highly dependent on external inputs, into diversified systems that favor ecological services and replace, as far as possible, synthetic inputs external to the system:

Level 1: Increase in conventional practices efficiency to reduce the consumption and use of costly, scarce, or environmentally harmful inputs.

Level 2: Substitution of synthetic inputs by alternative or organic ones. The goal is to replace toxic products with more environmentally friendly ones. However, the basic structure of the agroecosystem is not strongly altered.

Level 3: Redesign of the agroecosystem so that it works on the basis of a new set of ecological processes. Thus, rather than finding healthier ways of solving problems such as pests and/or diseases, their appearance is prevented through the design of agroecosystems with diversified management and structure.

Level 4: Change of ethics and values, thinking of the two most important components of food systems, those that produce the food and those that consume the products.

To start a transition process, a series of sequential steps do not need to be completed, but because it is such a complex process, several criteria need to be considered simultaneously. This determines the need to define the productive system starting situation, and according to this scenario, proposes the strategies for the transitional process. This is why it is important to typify producers as a diagnostic tool to know their current status. In this sense, there are three key criteria of the complex reality to consider (Berkes et al., 2000): 1. The structural attributes of the particular agroecosystem; 2. The local environmental knowledge of the farmer or farming family that makes the decisions and manages the system functioning; 3. The contextual factors that condition the possibilities of developing a transition process.

In this research four dimensions (economic, social, environmental, and technological variables) studied, grouped important variables in the typology of organic producers in the Sumapaz region. In this regard, Madry et al. (2013) stated that, to classify producer systems, social, environmental, as well as economic and technical variables should be integrated in the study of typologies. At economic level, '*Infrastructure*', '*Agricultural and livestock production*', variables and '*Produced and transformed inputs*' were those that showed highly significant differences (p-value < 0.01) among the three groups. Others, such as '*Labor*', and '*Loans*' were significant (p-value < 0.05).

74.7% of cumulative variability in the eight optimal components was similar to that of Cleves-Leguízamo & Jarma-Orozco (2014), who found 77.2% in the characterization and typology of citrus systems in the department of Meta. By combining the first two components (47.4%), a similarity was demonstrated with Chatterjee et al. (2015) who obtained 47.1%, Goswami et al. (2014) 43.7%, Cortez-Arriola et al. (2015) 45.2%, and Perea et al. (2014) 49.4%; higher than that found by Martin-Collado et al. (2015) with 26.6% and Choisis et al. (2012) 27.2%, and a lower variance percentage with respect to Righi et al. (2011) 65.1%.

Infrastructure has been found as a conditioning factor for organic production (Merma & Julca, 2012). In this regard, Cortez-Arriola et al. (2015), noted, as a constraint, the low availability of specific facilities for milking; likewise, Mena et al. (2016) detected deficiencies in the lack of specific housing for newborn lambs in 68% of the farms surveyed. The diversification of production systems is another relevant aspect in the typology of organic producers (Magcale-Macandog et al., 2010; Goswami et al., 2014; Chatterjee et al., 2015; Petit & Aubry, 2015; Haileslassie et al., 2016). Regarding this, Petit et al. (2010), suggested that there should be a link between diversification, technical management, and work organization for systems of organic vegetable crops. On the other hand, Nowak et al. (2015), in a study of nutrient recycling in organic farms, confirmed the benefit of diversity in agricultural production to improve the recycling of nutrients and recommended the design of agricultural policies to promote diversity in rural territories.

Another economic factor that allowed the classification of producers in a significant way was '*workforce*' (Gafsi et al., 2010; Cleves-Leguízamo & Jarma-Orozco, 2014). 84% of the producers surveyed in this study claim to have family workforce (FWF) and the remaining 16%, hired labor. Studies conducted by Choisis et al. (2012) noted the availability of family workforce as an influencer in the differentiation of farms, contrary to Cortez-Arriola et al. (2015), who reported that the use of hired labor was a differentiating factor between surveyed producers. On the other hand, Dinis et al. (2014), noted that farms with family workforce are probably more innovative in terms of sustainability; which allows us to deduce a possible approach of producers in the Sumapaz region with FWF (84%) towards innovation, and in the medium and/or long term towards sustainability.

The social dimension was characterized through '*Farm work*', '*Farm change*', '*Mother duties*', '*Association*', '*members of an organization*', '*Children age*', '*Mother education level*', and '*Children education level*', being statistically significant (p-value < 0.01) in the typology of producers in the Sumapaz region.

Being members to one or more associations was a relevant aspect in the classification of producers in transition to organic agriculture. According to this, Cleves-Leguízamo & Jarma-Orozco (2014) found that not being part of an association, the lack of technical assistance, and the low level of education result in not having a main agroecological structure, this was corroborated in group III (CPIOP) with 51.7% respondents not being members of any association, in comparison with group I (OPT, in which 85.2% were associated; similar results were reported by Tuesta et al. (2014), which in the typology of Cacao farms in Peru, found that in two of their groups, 90% belonged to an organization. Moreover, the educational level is a differentiating factor in typologies of agricultural producers (Magcale-Macandog et al., 2010; Pienaar, 2013; Chatterjee et al., 2015).

Romero (2009) found that in hog farms of the Sumapaz region the predominant level of education of decision-makers in production systems is primary education (59.3%), similar to what this study found for parents (54.0%), and contrary to reports by Claves & Jarma (2014), who found that 83.12% of citrus producers did not complete their primary education. Regarding age, Dinis et al. (2014) noted that organic producers are in average 46 years old, with 8 years of experience in organic agriculture; on his part, Pienaar (2013) reported in his study on typology of small farmers that most of the respondents were heads of household older than 60 years old, with very little education. The foregoing is similar to what was found in this study, as 53% of men are older than 50 years old.

Regarding farm work, 96% of the respondents answered that at least one family member performs the works; comparable results were reported by Mena et al. (2016), who affirmed that 88% of the total workers, mostly men, were members of the family. On the other hand, Lima-Vidal (2013) found that rural women in the semi-arid region perform most of the technical, administrative, and managerial farm activities, which agrees with the variable '*Mother duties*', which in group I (POTr) resulted in 92.53% of farms with the mother performing three or more duties. Finally, religion was not a discriminatory variable in this study; however, Keshavarz & Karami (2010), in a drought management study with farmers in Iran, reported that 'praying' is an important variable when setting groups.

The environmental dimension was typified according to the following variables: '*Water management*', '*Agricultural waste management* (AWM)', '*Irrigation*', '*Chemical inputs*', '*Agroecological practices*', and '*Organic fertilizers*', which were statistically significant (p-value < 0.01). It was found that water is a crucial factor in the typology of agricultural producers. In this context, *irrigation* is a key variable that influences the classification of the groups (Righi et al., 2011; Merma & Julca, 2012). Haileslassie et al. (2016) showed that, on average, 25% of the farms surveyed had access to irrigation wells and that the main water supply source to these farming systems was rain. Contrary to this, this study found that 62% of the producers in the Sumapaz region have access to at least one irrigation system; however, as a water resource, 92.9% also use rain.

Regarding the *use of water*, Mena et al. (2016) noted that the availability of drinking water was a problem, especially in the summer, since 70% of the farms were not connected to the aqueduct network; in this study, 66.2% of the families count on aqueduct services; however, the effect of the current dry season was not considered. With regard to waste management, Escobar et al. (2012), showed that some producers do not perform recycling or waste management practices, and some reuse domestic water; likewise, Nyaga et al. (2015), noted that 75% of farmers use cow manure as a source of organic fertilization in corn crops; in this study, waste management practices are scarce, with groups II and III showing that 100% and 89.6%, respectively, carry out less than two waste management practices.

In regard to '*Chemical inputs*' and '*Agroecological practices*', it is observed that producers in groups II and III use chemical inputs and scarce adoption of agroecological practices. Regarding this, Tittonell et al. (2010), Fargue-Lelièvre et al. (2011), Meylan et al. (2013) and Nyaga et al. (2015) point out that the use of pesticides and fertilizers are discriminatory variables. Finally, Dinis et al. (2014) concluded that organic farming has a significant effect on sustainability practices.

Regarding '*Technological variables*', 'Participation *in events*', '*Agricultural communication*', and '*Technical Assistance*' showed statistically significant differences (p-value < 0.01). Cleves-Leguízamo & Jarma-Orozco (2014), stated that technical assistance was the biggest limitation in the classification of citrus systems, and that only 41.75% of farmers said having received some type of assistance, and Romero (2009) pointed out that 50.6% of pig farmers in the Sumapaz region reported counting on technical assistance. According to this, it was found that 56% of respondents have received some type of assistance. Regarding the adoption of organic agriculture practices, Dinis et al. (2014) highlighted the role of universities and public advisory services (technical assistance) as representatives of a potential impact of innovation policies aimed at sustainability.

Regarding agricultural communication and participation in events, in a research on the behavior of farmers towards ecological conservation, Deng et al. (2016) determined that the influence of neighbors was the most powerful behavior controller, which means that people who reside near farmers could be ambassadors of ecological achievements to positively modify farmers' behavior, and Romero (2009) showed that 70.4% of producers did not participate in technology transfer events. Accordingly, group I (POTr) showed the highest participation in events and in the media, in comparison to groups II and III.

According to the variables evaluated in our typology study, which showed three groups in different transition process to agroecological production, actions that promote sustainable productions can be generated. In this regard, in Latin America, positive studies related to agroecological transition have been reported. Flores & Sarandón (2015), studied this transition in Argentine horticultural gardens, finding that after three years of evaluation, new technologies were improved and adopted. In Costa Rica, Babin (2015) noted the agroecological practices that benefited coffee producers in the area. On a negative level, Ferreira et al. (2013) studied the changes in the production of coffee mixed with timber trees was not profitable due to the decrease in yield.

In another study, Mancini et al. (2018), report that farming systems in the Zona da Mata (Brazil) are inherently complex and diverse. Despite the aim of typology approaches to identify discrete groups, in reality farm diversity can best be understood as a continuum where different farm types can co-evolve, interact and overlap. In fact, agroecological transitions may also be understood as a process in which farmers move along an infinite continuum, and it is therefore difficult to draw a sharp line that separates agroecological from non-agroecological farmers, as well as a specific end point of transition.

To our knowledge, this is the first study that developed farm typologies in Sumapaz Region, specifically to understand and analyse a long-term process of agroecological transition, focusing on changes at farm level. We used participatory methods to interest farmers to participate in a collective process of co-creation of knowledge. This was also important to generate a collective understanding of agroecology transition process. According to Mccune & Sánchez (2018), this collective understanding is relevant to increase awareness about agroecological ideas, farms and practices, as well as to identify opportunities and barriers for promoting agroecological transitions.

Agroecology gathers several ways of thinking, with a holistic approach, in which agronomic, natural and social knowledge areas converge, reaching a synergic dimension, which from the perspective of Guzman et al. (2000), promotes the ecological management of agricultural systems through collective forms of social action that redirect co-evolution between nature and society, based on strategies from the local dimension, promoting cultural and ecosystemic diversity, as a starting point for alternative agriculture and for the establishment of dynamic and sustainable rural societies.

CONCLUSIONS

This typology study showed 3 clearly differentiated groups based on their characteristics associated with the implementation of management strategies and practices in crops, social features, environmental management, and technology transfer. Producers show variable degrees of conversion to sustainable agricultural production, which defined the discrimination in groups of organic producers in transition, conventional producers in transition to organic production, and conventional producers interested in organic production. These groups were classified according to the level of progress in practices such as production and processing of inputs, diversity in agricultural production systems, number of facilities for the improvement of production, memberships and participation in associations, the level of schooling of mothers and children, the number of duties performed by mothers, the variety of agroecological practices, management of agricultural waste, use of organic fertilizers, water management, access to technical assistance, communications, and participation in events.

The resulting typology makes it possible to foresee the need for a differentiated process in at least three categories of organization, with a view to generating an effective impact on these systems so that they become in higher level of sustainability systems. Producers need to focus their attention on processes that allow them to improve their skills to help develop the required human talent and acquire the necessary social capital in terms of integration, collaborative work, trust, political and cultural capital, so that they can easily make progress in the implementation of agroecological practices, infrastructure, natural resources management and improve their living standards.

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Supplementary Material

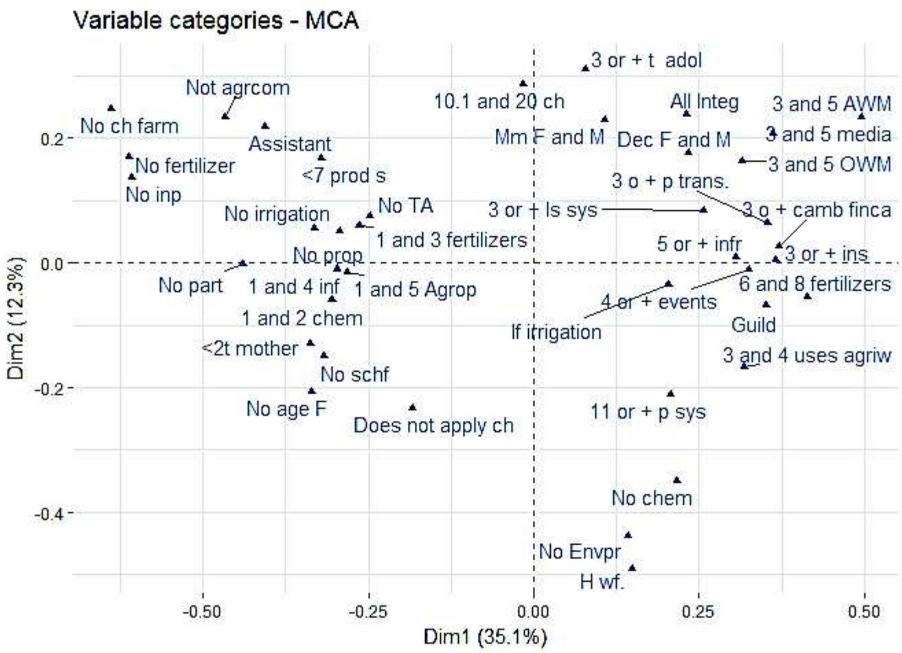

Figure 2. TIF Factor map showing the 40 main most-contributing categories to the multiple correspondence analysis (MCA). *

* Abbreviation meanings: H wf = Hired workforce; No Envpr = No environmental problems; No chem = No application of chemicals; 11 or + p sys = Eleven or more productive systems, 3 and 4 uses agriw = Three and four uses of agricultural water; Guild = Technical assistance by guild; 6 and 8 fertilizers = Between 6 and 8 organic fertilizers; If irrigation = if Irrigation system, 4 or + events = participation in 4 or more events, 5 or + infr = Five or more infrastructures, 3 or + ins = Three or more inputs produced, 3 or + farm chg = Three or more reasons for farm change, 3 or + ls sys = Three or more livestock systems, 3 and 5 OWM = Between 3 and 5 organic waste management processes, Dec F and M = Decisions made by father and mother, 3 and 5 media = Between 3 and 5 mass media, 3 and 5 AWM = Between 3 and 5 agricultural waste management processes; All Integ = Work done by all members, Mm F and M = Money management by father and mother, 3 or + t adol = Three or more tasks by adolescent, 10.1 and 20 ch = Age children between 10.1 and 20 years old, Does not apply ch = Does not apply in children, No age F = No father's age, No schf = No Level of education in father, < 2t mother = Mother with less than two tasks, No Ta = No technical assistance, 1 and 2 chem = Between 1 and 2 chemical applications, No irrigation = No irrigation system, 1 and 4 inf = Between 1 and 4 infrastructures, 1 and 5 Agrop = Between 1 and 5 agroecological practices, No part = No participation in events, 1 and 3 fertilizers = Between 1 and 3 organic fertilizers, No prop = No processed products, < 7 prod s = Less than seven productive systems, Assistant = Form of participation in association as assistant, Not agrcom = No agricultural communication, No ch farm = No changes in the farm, No fertilizer = No production of organic fertilizers, No inp = No production of inputs.

Table 1. The most significant variables and categories in the characterization of producers ($p < 0.01$)

VARIABLES	CATEGORIES	GROUPS I (n = 27)	GROUPS II (n = 15)	GROUPS III (n = 29)	*p*-value Chi square
ECONOMIC ASPECT					
Infrastructure	1 and 4 infrastructure	18.52%	**73.33%**	**72.41%**	**< 0.01**
	5 or more types of infrastructure	**81.48%**	26.67%	27.59%	
Agricultural production	< 7 production systems	11.11%	13.33%	**79.31%**	**< 0.01**
	Between 7 and 10 production systems	37.04%	**66.67%**	17.24%	
	11 or more agricultural production systems	**51.85%**	20.00%	3.45%	
Animal production	< 2 livestock systems	37.04%	**93.33%**	**68.97%**	**< 0.01**
	3 or more livestock systems	**62.96%**	6.67%	31.03%	
Produced inputs	No inputs	0.00%	13.33%	**41.38%**	**< 0.01**
	Between 1 and 2 inputs	25.93%	**66.67%**	**48.28%**	
	3 o more inputs	**74.07%**	20.00%	10.34%	
Processed products	No processed products	7.41%	33.33%	**58.62%**	**< 0.01**
	Between 1 and 2 processed products	**44.44%**	**60.00%**	34.48%	
	3 o more processed products	**48.15%**	6.67%	6.90%	
SOCIAL ASPECT					
Farm work	1 and 2 members	**48.15%**	**100.00%**	**68.97%**	**< 0.01**
	All members	**51.85%**	0.00%	31.03%	
Farm change	No changes farm	0.00%	0.00%	**34.48%**	**< 0.01**
	1 and 2 changes farm	**59.26%**	**86.67%**	**55.17%**	
	Three or more farm changes	**40.74%**	13.33%	10.34%	
Mother duties	< 2 mother duties	7.41%	**66.67%**	41.38%	**< 0.01**
	3 or more mother duties	**92.59%**	33.33%	**58.62%**	
Association	Associated	**85.19%**	**73.33%**	**48.28%**	**< 0.01**
	Not associated	14.81%	26.67%	**51.72%**	
Part of the organization	Administrator or associate	**66.67%**	**80.00%**	34.48%	**< 0.01**
	Assistant	11.11%	0.00%	**44.83%**	
	No part	11.11%	20.00%	13.79%	
	Operational	11.11%	0.00%	6.90%	
Children age	No age children	11.11%	**73.33%**	27.59%	**< 0.01**
	0 and 10 years	3.70%	0.00%	10.34%	
	10.1 and 20 years	**29.63%**	0.00%	**44.83%**	
	20.1 and 30 years	**37.04%**	**6.67%**	13.79%	
	Older than 30 years	18.52%	**20.00%**	3.45%	
Mother education level	No education	11.11%	**60.00%**	17.24%	**< 0.01**
	Primary school	**29.63%**	13.33%	**48.28%**	
	High school	**33.33%**	13.33%	**31.03%**	
	Higher education	25.93%	13.33%	3.45%	
Children education level	No education children	22.22%	**73.33%**	**24.14%**	**< 0.01**
	Primary school	0.00%	6.67%	17.24%	
	High school	**33.33%**	0.00%	**51.72%**	
	Higher education	**44.44%**	**20.00%**	6.90%	

Table 1 (continued)

ENVIRONMENTAL					
Water management	No water management	3.70%	0.00%	20.69%	**< 0.01**
	1 and 2 water management	**55.56%**	**93.33%**	**72.41%**	
	All water management	**40.74%**	6.67%	6.90%	
Agricultural waste management	< 2 waste management processes	**51.85%**	**100.00%**	**89.66%**	**< 0.01**
	3 and 5 waste management processes	**48.15%**	0.00%	10.34%	
Irrigation	Irrigation	**92.59%**	**60.00%**	34.48%	**< 0.01**
	No Irrigation	7.41%	**40.00%**	**65.52%**	
Chemical inputs	1 and 2 chemical inputs	22.22%	**53.33%**	48.28%	**< 0.01**
	3 o + chemical inputs	11.11%	13.33%	**51.72%**	
	Not chemicals	**66.67%**	33.33%	0.00%	
Agroecological practices	1 and 5 practices	14.81%	**53.33%**	**58.62%**	**< 0.01**
	6 and 10 practices	**66.67%**	33.33%	31.03%	
	11 and practices	18.52%	13.33%	10.34%	
Organic fertilizers	No organic fertilizers	0.00%	0.00%	**24.14%**	**< 0.01**
	1 and 3 organic fertilizers	11.11%	**33.33%**	**58.62%**	
	4 and 5 organic fertilizers	**48.15%**	**40.00%**	17.24%	
	6 and 8 organic fertilizers	**40.74%**	26.67%	0.00%	
TECHNOLOGICAL					
Participation in events	No participation	7.41%	26.67%	**34.48%**	**< 0.01**
	1 and 3 events	29.63%	33.33%	**55.17%**	
	4 o more events	**62.96%**	**40.00%**	10.34%	
Agricultural communication	No communication	7.41%	0.00%	17.24%	**< 0.01**
	1 and 2 media	**40.74%**	**100.00%**	**68.97%**	
	3 and 5 media	**51.85%**	0.00%	13.79%	
Technical assistance	No technical assistance	22.22%	**33.33%**	**68.97%**	**< 0.01**
	State	18.52%	13.33%	6.90%	
	Particular	**22.22%**	**33.33%**	24.14%	
	Guild	**37.04%**	20.00%	0.00%	