Socio-economic and technological typology of avocado cv. Hass farms from Antioquia (Colombia)

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ABSTRACT: *A typology of avocado cv. Hass farms was constructed based on information collected from productive units in Antioquia, Colombia. The study aimed to provide key information about the farms for those involved in the design of programs and public policies directed to growers. The data were scrutinized through Multiple Correspondence Analysis (MCA) and Cluster Analysis. The sample was made up of 214 growers of the crop. Quantitative and qualitative variables were employed for the MCA, which rendered 40 dimensions, out of which 16 accounted for 70% of the total inertia (variance) found in the data. These 16 dimensions were used as input for the Cluster Analysis, which provided the following results: 52%, 32% and 15% of the farms were located in Clusters 1, 2 and 3, respectively. The identified farm types can be associated to peasant (Cluster 1) and commercial (Cluster 3) agricultural schemes, plus a transition between them (Cluster 2). The most discriminating variables regarding such categorization were: farm size, farm registry at ICA (Colombian Agricultural Institute), Avocado cv. Hass yield, labor source, presence of crops other than avocado, existence of formal commercial alliances and technical assistance type. The percentage of farmers belonging to grower organizations was   high in the three clusters. Growers in Clusters 3 and 2 had established formal commercial alliances which enabled them to access better sale prices for the crop. A trend towards establishing cv. Hass as a monocrop is observed, which may threaten both crop biodiversity and the food security of peasant growers.*
Key words: *farm typology, multiple correspondence analysis, cluster analysis, Colombia.*

Tipologia socioeconômica e tecnológica do abacate cv. Granjas Hass de Antioquia (Colômbia)

RESUMO: *Uma tipologia de fazendas produtoras de abacate cv. Hass foi realizada a partir de informações levantadas em unidades produtivas no departamento de Antioquia, Colômbia. O objetivo do estudo foi fornecer informações importantes sobre as fazendas produtoras da variedade de abacate Hass, com o intuito de apoiar a elaboração de programas e políticas públicas destinados aos produtores desta variedade. Métodos estatísticos multivariados como Análise de Correspondência Múltipla (ACM) e Análise de Clusters foram utilizados. A amostra foi composta por 214 produtores de abacate cv. Hass. Variáveis categóricas de tipo quantitativo e qualitativo foram utilizadas no ACM, o que permitiu a obtenção de 40 dimensões, das quais 16 continham 70% da inércia total (variância) presente nos dados. As 16 dimensões serviram como entrada para a Análise de Clusters, a qual produziu os seguintes resultados: 52%, 32% e 15% das fazendas estiveram localizadas nos Clusters 1, 2 e 3, respectivamente. Os tipos de fazendas identificados podem ser associados a esquemas de agricultura camponesa (Cluster 1), agricultura comercial (Cluster 3), e uma transição entre elas (Cluster 2). Variáveis como a fonte de trabalho, a presença de culturas diferentes ao abacate, a existência de alianças comerciais formais e o tipo de assistência técnica recebida são as mais diferenciadas em relação a esta categorização. A percentagem de produtores pertencentes a organizações de produtores foi alta nos três clusters. Os produtores dos Clusters 3 e 2 estabeleceram alianças formais de negócios, o que lhes permitiu ter acesso a melhores preços de venda da cultura. Há uma tendência a estabelecer o abacate cv. Hass como uma monocultura, o que pode ameaçar tanto a diversidade da agricultura quanto a segurança alimentar dos produtores camponeses.*
Palavras-chave: *tipologia de fazendas, análise de correspondência múltipla, análise de clusters, Colômbia.*

INTRODUCTION

The "Green Gold", as avocado cv. Hass is popularly known, has already become one of the most promising cash crops of the Colombian agro-exports basket. Colombia is one of the leading producers of avocado worldwide, where it holds the third place, lagging only behind Mexico and the Dominican Republic (FAO, 2018). However, its participation in international markets is still marginal, since it is behind big exporters such as Mexico, Peru, Chile, Kenya and South Africa (TRADEMAP, 2018). Despite its negligible share of the world market, Colombia increased its avocado exports by more

than 800% in the 2014-2016 period. Furthermore, the recent lift on the ban imposed on Colombian cv. Hass exports has motivated growers and traders to conquer the American market.

Colombia has two main advantages when it comes to producing avocado cv. Hass: its strategic location, which allows quickly reaching American and European markets; and its tropical climate, which determines two yearly harvests (FRESHPLAZA, 2017). As noted by RAMÍREZ-GIL et al. (2017), avocado production in the country has grown considerably due to the existence of an unsatisfied demand in the foreign market. The department of Antioquia, which is the top Hass exporter of the country, had contributed almost half of the Colombian avocado exports by 2016 (SIERRA-SUAREZ, 2017), devoting an area of 7,644 ha to the production of this crop (GOBERNACIÓN DE ANTIOQUIA, 2015). Data provided by the Agricultural Department of Antioquia's Governor's office report the existence of 1,024 avocado cv. Hass growers.

Multiple programs and policies are being deployed to boost this crop in Antioquia, including technical assistance to growers, cropping research, production programs and diverse economic incentives such as soft credit and subsidies directed to growers (SIOC, 2018; FINAGRO, 2018; CORPOICA, 2017). Despite the support provided to farmers, there is little information on the different farm types currently producing avocado cv. Hass, the specific needs of which are important when it comes to assessing the impact of such interventions. It is important to take into account that the variety in question is mostly exports-driven, which forces growers to comply with specific regulations and standards required by the target markets. This is particularly critical for small growers, because of their limited access to technical assistance and the elevated costs of export certifications, which make them prohibitive when it comes to accessing foreign markets (BARRENA et al. 2013). These small growers maintain many of the peasant agriculture features mentioned by BACKER (1997), such as assigning an important fraction of the farm's food production to household consumption, employing family labor, and having limited access to technical assistance and no formal alliances with traders/marketers.

In this context, the present study adds to the existent knowledge on avocado cv. Hass by developing a farm typology based on socioeconomic and technological aspects. This is accomplished through multivariate statistical methods applied to the characterization of the studied farms, based on a representative sample from three regions of the department of Antioquia (Colombia). These methods have often been used for the development of farm typologies in agricultural research (TITTONELL et al.2010; KÖBRICH et al. 2003; PARDOS et al. 2008; VÁSQUEZ et al. 2011; ABAS et al. 2013; BARRENA et al. 2013; CLEVES-LEGUÍZAMO et al. 2014; GOSWANI et al. 2014; TODDE et al. 2016). This type of study allows: (a) identifying change trends in a particular production system; (b) detecting the main productivity constraints and thus targeting better agricultural innovations (TITTONELL et al. 2010); (c) establishing public policy design priorities (PARDOS et al. 2008); (d) optimizing the impact of development projects through the identification of "target groups"; and (e) providing support to advisors through key information about individual farmers, thus basing the assessment of each particular situation on known functional types (GIBON et al., 1999).

VÁSQUEZ et al. (2011) performed an initial characterization of avocado cv. Hass farms in Antioquia, in which they surveyed 83 farms in the eastern, western and northern sub regions of the department. They resorted to socioeconomic and technical variables such as grower's age and educational level, tenure type, labor type and its monetary value, associativity between growers, access to technical assistance, and type of phytosanitary management, among others. SANGERMAN-JARQUÍN et al. (2014) also typified avocado farms in the state of Mexico (Mexico), using a similar approach to that of VÁSQUEZ et al. (2011). The former studies described some of the main features of cv. Hass farms in a general fashion, but falling short to identify a typology of productive systems with their corresponding features and needs.

Thus, the general aim of the present study was to identify a typology of the avocado cv. Hass farms of Antioquia, Colombia. Considering the dimensions with the highest inertia (variance) in the data, a set of three groups was obtained and then analyzed. The results of this study were used as input for a land zoning of the crop in question, also resorting to biophysical and environmental variables.

The present study contributed to the current knowledge on avocado cv. Hass activity in Antioquia by providing advisors, researchers and program developers with specific information about the different farm types existing in the region.

MATERIALS AND METHODS

Study area

The study area covers the eastern, southwestern and northern regions of the department
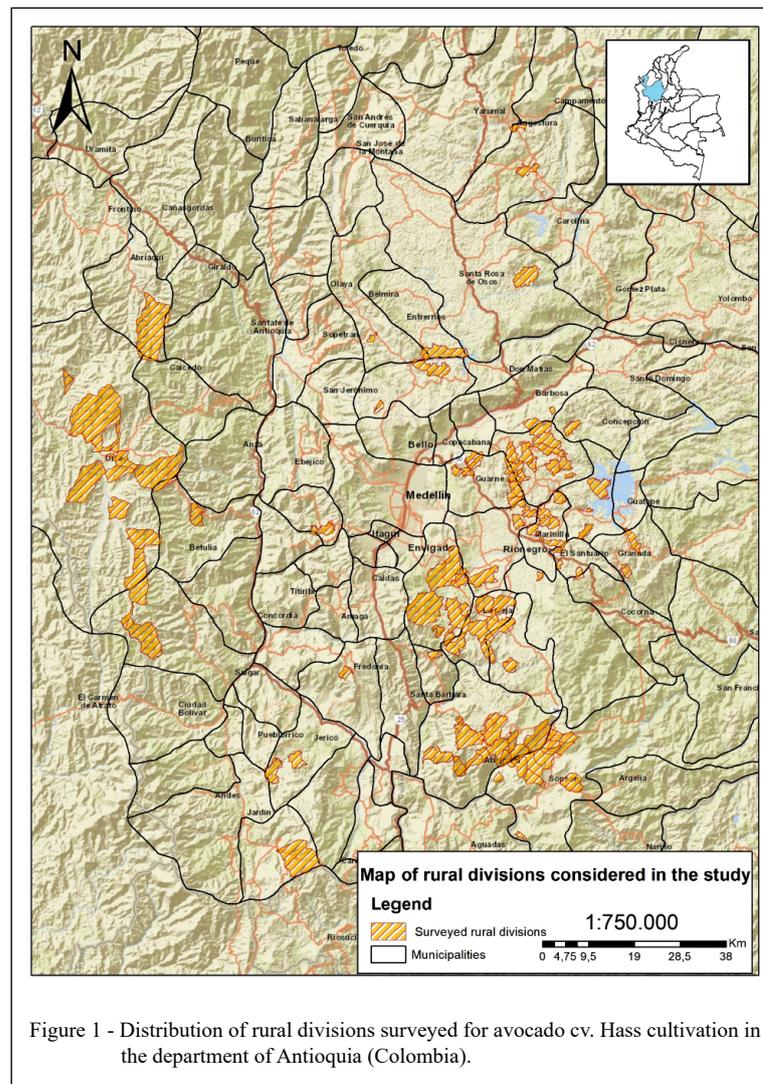
of Antioquia in Colombia. Figure 1 shows the studied area with the rural divisions where the surveyed farms are located.

In the area in question, the precipitation levels reach an annual average of 2,000 mm, whereas the altitude ranges between 200 and 3,340 m asl (CORNARE, 2015; ARAMBURO et al., 2007). The climatic and edaphological features of the three regions have allowed the development of a sound agricultural activity where crops such as plantain, coffee, panela sugarcane, potato and tree tomato play a major role (CÁMARA DE COMERCIO DE MEDELLÍN, 2014a, 2014b, 2014c). Avocado cv. Hass has been so far established in the eastern, southwestern, and northern sub regions of the department, in municipalities with moderate cold

climate (BERNAL et al. 2014), which offer ideal conditions for this activity.

Data collection and sampling

In order to define the farm sample to be surveyed, a data base was created with information provided by several instances: list of avocado cv. Hass farms monitored by the Colombian Agricultural Institute (ICA) in Antioquia, pre-existing lists of growers of the crop available in *Agrosavia* (former *Corpoica*), and lists provided by the different UMATAS (Municipal Technical Assistance Units) of those municipalities where growers had been previously identified. This information allowed determining the approximate population of avocado cv. Hass farms of Antioquia at 1,003 productive units

Figure 1 - Distribution of rural divisions surveyed for avocado cv. Hass cultivation in the department of Antioquia (Colombia).

distributed in 39 municipalities, out of which 73% were located in the eastern sub region of Antioquia, 13% in the southwest sub region, and 8% and 3% in western and northern Antioquia, respectively.

Stratified random sampling with proportional affixation allowed selecting the farms, considering the 39 municipalities as strata. This methodology, which allowed establishing the representativeness of the different groups (strata) of the population, was developed in two steps: after (i) calculating the total size of the sample, (ii) the elements were proportionally assigned to each stratum (SCHEAFFER et al. 1986). Sample size was defined through the equation below. For such calculation, based on both conversations with agronomists of some UMATAS and interviews with knowledgeable experts on the crop in the department, 23% of the growers were estimated to have registered at ICA. We assumed that this parameter was directly related to farm modernization levels. Since this value could not be assessed at every studied municipality, it was extrapolated to all of them by default. A 95% confidence interval was estimated, with an error margin of 5%. Although, the sample size was set at 212 growers, two additional surveys collected in the field were incorporated to the analysis, giving a total of 214 surveys.

$$ n = \frac{\sum_{i=1}^{L} N_i^2 \ p_i q_i / wi}{N^2 D + \sum_{i=1}^{L} N_i p_i q_i} $$

where $w_i = \frac{N_i}{N}$ and $D = \frac{\varepsilon}{z^2}$
and
N: Population Size
n: Sample Size
z: Percentile value corresponding to 95% confidence according to standard normal distribution
W_i: Stratum relative weight
p_i: Ratio of farmers registered at ICA in stratum i (this value was assumed to be the same for all strata); $q_i = 1 - p_i$
L: Number of strata
ε: Estimated error

The agricultural household survey designed to obtain information about the farms collected demographic, socioeconomic and production variables, together with avocado cv. Hass activity and farm household related variables. A total of 35 variables were assessed through the survey (Table 1 and 2), which was applied from October to December of 2016.

Statistical analysis

Due to the large number of variables considered in the survey, a Multiple Correspondence Analysis (MCA) was run in order to obtain a smaller group of variables (dimensions). Most of the data were qualitative in nature, which made it easier to work with categorical variables, as required by MCA (HUSSON et al. 2010). Once the qualitative and quantitative variables had been categorized, they were used for the MCA, which generated a series of synthetic variables that were later employed for the Cluster Analysis.

It is worthwhile noting that MCA is the counterpart of Principal Component Analysis (PCA). While the input of the latter are quantitative data, the former uses nominal categorical data. Nonetheless, MCA resembles its counterpart in that it searches for underlying structures in a data set and identifies those dimensions or components that contain the most variance/inertia. This is achieved by representing data points in a low-dimensional Euclidean space (GREENACRE, 2006). MCA was run on R FactoMineR software package.

Out of a number of initial variables, MCA derives a series of "synthetic" dimensions (HUSSON et al., 2010) containing those variables with higher correlation ratios (i.e., coefficients of non-linear association). The latter actually measure the relation between each one of the categorical variables and its specific dimension (HUSSON, 2016). Each dimension is analyzed in terms of the variables it contains (HUSSON et al. 2010). The MCA is often used for analyzing data obtained from surveys, wherein each question corresponds to a variable and each possible answer is a category of that variable (HUSSON et al. 2010).

In selecting the qualitative variables that were likely to facilitate greater differentiation in the MCA, an inspection of their relative frequencies was carried out through contingency tables. Those variables exhibiting homogeneous behavior in all farms were not taken into account, since they did not allow clear distinction between the productive units. In the case of the quantitative variables, Sturges law was applied in order to obtain an optimal number of groups, based on the observations of each variable. Thus, twenty-one variables were selected for the MCA: farm size and dominant land use, avocado cv. Hass planted area and yield (t ha^{-1}), type of phytosanitary control, avocado cv. Hass plantation registry at ICA, number of permanent workers at the farm, number of workers hired at harvest time, type of technical assistance, existence of commercial agreements, bookkeeping costs, application for formal credit, distance to municipality seat, main access to the farm (road type), source of economic

Table 1 - Surveyed variables describing the farms.

Category	Variable	Description	Unit
Demographics and socioeconomics	Grower's age	Age of grower	Years
	Grower's gender	Gender of grower	Female=0 Male=1
	Grower's educational level	Level of education of grower	None=0, Incomplete Primary school= 1, Primary school=2, Incomplete Secondary School= 3, Secondary school=3,Technical=4, Undergraduate=5, Graduate=6
Farm features	Farm size	Number of ha of the farm	Number
	Main access to the farm	Farm's main access to road	Path=0, Primary road= 1, Secondary road=2, tertiary road=3
	Tenure	Type of tenure	Owner=0, renter=1, sharecropper=2, colonist/settler=3, other=4
	Distance to municipality seat	Range of distance to municipality seat	1-5 km=0, 5-10 km=1, 10-15 km=2, more than 15 km=3
	Farm relief	Main type of farm's relieve	Flat=0, hilly=1, very hilly=2
	Permanent labor at the farm	Number of people working permanently at the farm	Number
	Labor at Harvest time	Number of people working at harvest time at the farm	Number
Productive activities	Dominant land use	Main farm's land use	Crops=0, Pastures=1, Fallow=2, Native forest=3, Commercial forest=4, Mining=5
	Presence of food crops	Existence of food crops	Yes=0, No=1
	Existence of cattle	Existence of cattle	Yes=0, No=1
	Labor source	Type of labor source	Family labor=0, External labor=1, Mixed labor=3

Source: Prepared by the authors.

resources employed for avocado cv. Hass activity, access to support or subsidies, income from avocado cv. Hass, grower's age, educational level, avocado production experience and membership of a growers association. Out of these twenty-one variables, seven were initially quantitative in nature.

Once the main dimensions had been obtained, a Cluster Analysis was run based on them. This type of analysis allows identifying homogeneous groups (clusters) of objects and/or individuals in a particular database, by recognizing patterns in the data (KAUFMAN et al., 2005). This analysis is not guided by *a priori* ideas on how the groups are formed and which variables determine the distribution of the objects and/or individuals in the groups (STHDA, 2018). The farms in this study were grouped following to contrasting features (GARCÍA et al. 2010). The clusters were obtained by applying the following algorithm: (i) the main dimensions retaining most of the inertia present in the data were produced by MCA; (ii) a Hierarchical cluster with suggested groups was generated by applying "Ward", a hierarchy criterion, and using Euclidean distance; (iii) the clusters were selected based on their internal variance/inertia, which is shown in the hierarchical tree (Figure 2). The cutoff line was traced slightly above a split in category 1, in order to avoid an important loss of inertia when passing from three to four clusters. The cutoff comes from the previously defined 0.05 significance level. This method, which starts with each observation in its particular cluster, progressively joins them until they are all included in a single cluster (CHÁVEZ et al. 2010).

RESULTS

Multiple correspondence analysis

The MCA resulted in forty dimensions containing 100% of the total inertia (variance) of the data. According to HUSSON et al. (2010), data variance content was the criterion applied to select the number of dimensions to be retained for the subsequent Cluster Analysis, which made use of 16 dimensions containing 70% of the total original variance. Figure 2 shows the sixteen dimensions in question and the corresponding variance they express.
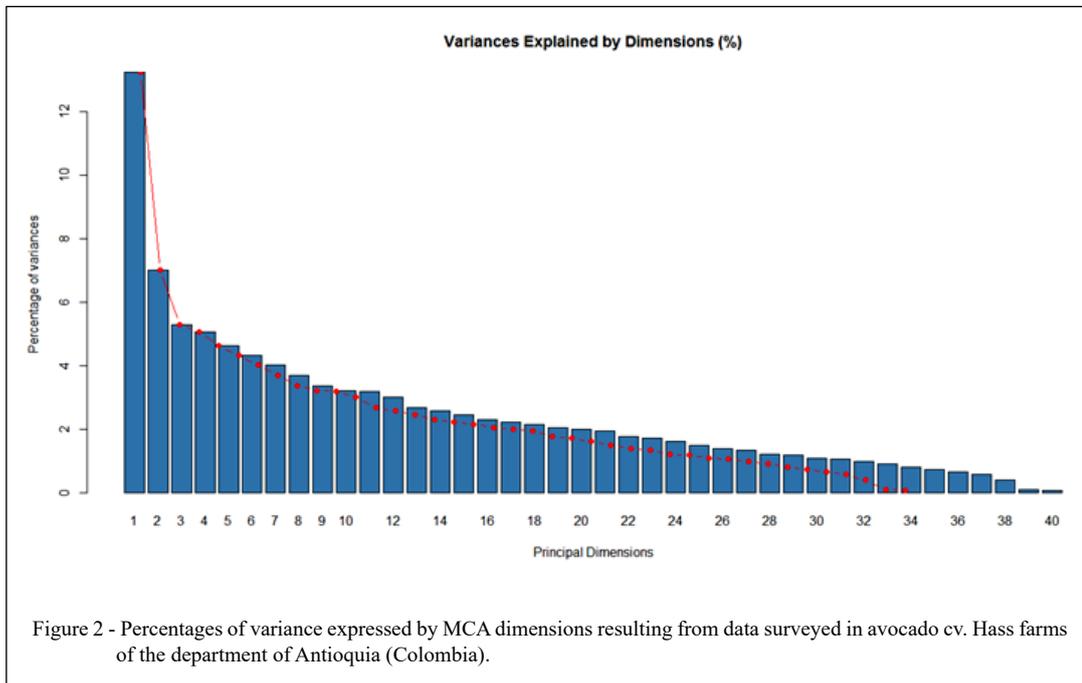
Table 2 - Surveyed variables describing avocado cv. Hass activity in farms.

Category	Variable	Description	Unit
	cv. Hass avocado planted/harvested area	Number of cv. Hass avocado planted/harvested ha.	Number of Ha
	Age of cv. Hass avocado plantation	Orchard age	Years
	cv. Hass avocado production	Total production of the farm	Kg
	Price paid by to growers (USD $/kg)	Price paid by 1 kg of avocado cv. Hass	$ United Stated Dollars
	Income from cv. Hass avocado (USD $/ha)	Income derived from cv. Hass avocado	$ United Stated Dollars
	Intercropping	Avocado cv. Hass intercropped with other crops	Yes=0, No=1
	Origin of seedings	Type of origin of seedlings	Registered nursery=0, Non registered nursery=1, Self-propagation=2
	Type of Fertilization	Type of Fertilization	Chemical=0, organic=1, both (chemical and organic)=2
	Type of Phitosanitary control	Type of pests and diseases management	Chemical=0, Manual=1, Biologic=2, Other=3
	Avocado cv. Hass production experience (>5 yrs)	Whether farmer has experience with avocado cv. Hass of more than 5 years	Yes=0, No=1
Features of Avocado cv. Hass activity	Access to technical assistance	Whether having acces to technical assistance	Yes=0, No=1
	Type of Technical Assistance	Type of Technical assistance	Independent agronomist=0, Public entity agronomist=1,Grower's association agronomist=2, Commercial house agronomist=3
	Exports registration (ICA)	Whether having ICA registration	Yes=0, No=1
	Exports Certificate (Global GAP)	Whether having Global Gap Certificate	Yes=0, No=1
	Grower's associativity	Whether the grower belongs to a grower's organization	Yes=0, No=1
	Formal commercial alliances with markets	Whether having access to formal alliances with marketers/traders	Yes=0, No=1
	Access to Institutional Support	Whether having access to subsidies, technical assistance or other programs provided by Government	Yes=0, No=1
	Book keeping costs	Whether book keeping costs	Yes=0, No=1
	Application to Credit in the last year	Whether having applied to credit in the last year	Yes=0, No=1
	Constraints to avocado cv. Hass activity	Type of main constraint	Commercial=0, technical=1, financial resources=2, infrastructure=3, social=4

Source: Prepared by authors.

In the lines that follow, we detailed only three of these sixteen dimensions, considering the highest correlation ratios between variables and dimensions. Containing 13.2% of the total variance, dimension 1 is mostly explained by labor at harvest time, Avocado cv. Hass planted area, and registration at ICA, with correlation ratios of 0.54, 0.53 and 0.52, respectively.

Conversely, dimension 2 is strongly connected to yield and labor at harvest time, with respective correlation ratios of 0.53 and 0.51. Finally, dimension 3 is mostly described by grower's educational level and farm size, respectively corresponding to correlation ratios of 0.27 and 0.22 . Correlation ratios between variables and dimensions are shown in table 3.

Figure 2 - Percentages of variance expressed by MCA dimensions resulting from data surveyed in avocado cv. Hass farms of the department of Antioquia (Colombia).

Cluster analysis

      Avocado cv. Hass households were clustered into three main groups, based on the sixteen dimensions derived from the MCA (Figure 3 and figure 4). The clusters are individually described below and summarized in table 4. Results of descriptive variables of each cluster are presented in table 5 and 6, the former including the mean, median and standard deviation values of the quantitative variables and the latter, the percentages of farms participating in each cluster's variable. Figures 5 and 6 present some of the most relevant variables for each cluster.

Cluster 1

      Containing 52% of the farms in the sample, Cluster 1 actually grouped the smallest ones (9 ha size on average), mainly located in the municipalities of Rionegro, El Retiro and Urrao. These were the most limited farms in terms of technical assistance and market access for avocado cv. Hass, and also the newest ones in this cropping activity, with orchards averaging 4 years of age and 1.9 ha in size. Most of them produced food for own consumption and had established avocado cv. Hass in association with other crops, primarily beans, maize and peas. Labor sources were almost evenly shared between family and external sources. Fertilization schemes based on chemical and organic fertilizers were applied by 70% of the farms, whereas 30% of them employed only chemical fertilizers. Phytosanitary controls resorting to chemical compounds were applied in more than half of the farms. Nearly all of them (90%) had been registered at ICA and only 1% had Global GAP certification. The average price paid per kg of avocado to growers in this group was the lowest in the sample: around $0.60 USD. These growers reported the lowest educational levels, corresponding to incomplete primary school. Sixty percent of them had access to technical assistance, mainly offered by private agronomists and commercial houses. The majority of them did not have any formal commercial alliances, yet more than half belonged to a growers' association and 75% received institutional support in the form of subsidies, seedlings or production supplies. Their mayor difficulties were the financial support of the crop, access to good output prices, and facing market middlemen.

Cluster 2

      This cluster grouped 69 of the studied farms, which were actually medium sized (17 ha on average) and, making up 32% of the total sample, were mainly located in the municipalities of Guarne, Rionegro, El Retiro, Urrao and Sonsón. More than half of the labor employed in these farms came from
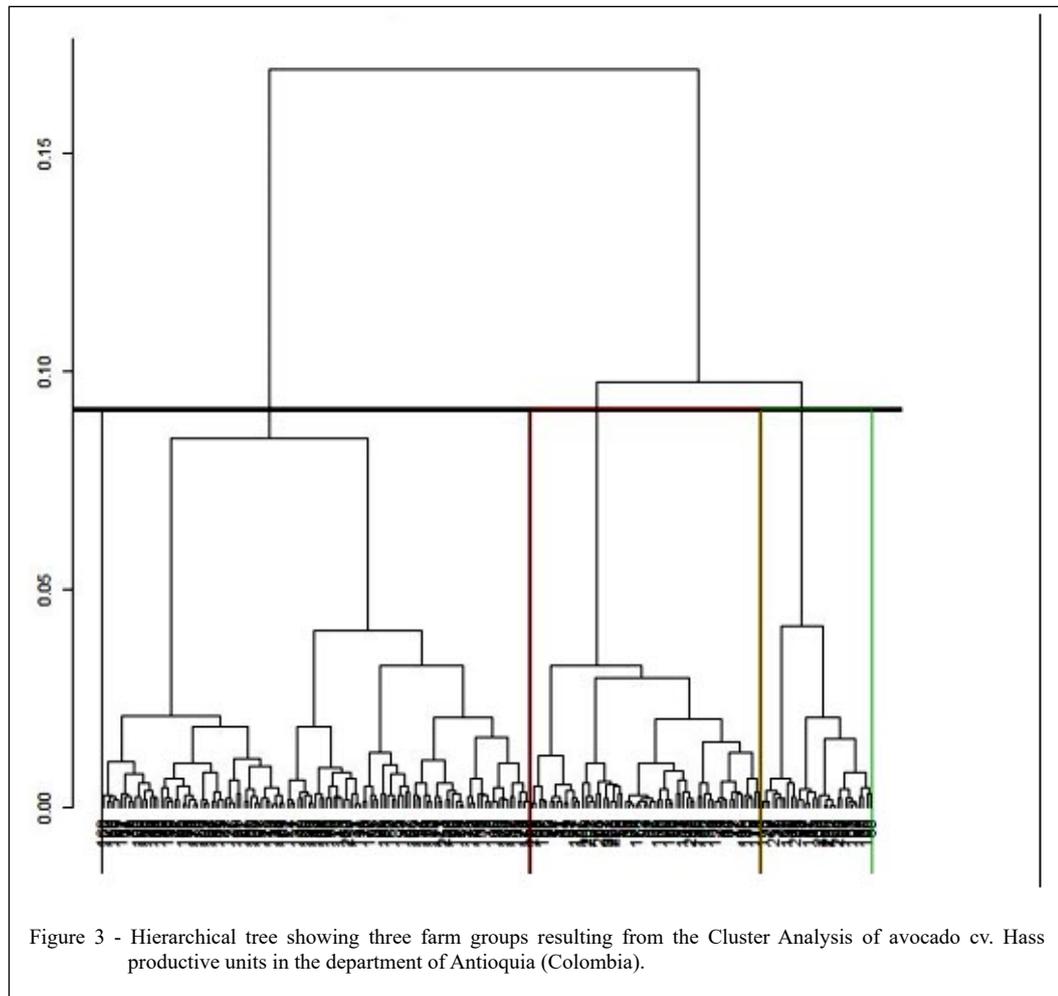
Ciência Rural, v.50, n.7, 2020.

Table 3 - Squared correlation ratios between variables and dimensions.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Grower's age	0.32	0.27	0.21	0.04	0.12	0.1	0.16	0.15	0.11	0.26	0.08	0.04	0.09	0.1	0.13	
Grower's educational Level	0.42	0.27	0.27	0.19	0.11	0.08	0.18	0.11	0.07	0.15	0.37	0.14	0.15	0.05	0.12	0.17
Farm size	0.29	0.05	0.22	0.06	0.24	0.14	0.1	0.03	0.18			0.06			0.06	
Main access to the farm	0.07					0.14	0.16		0.08	0.11	0.05	0.25	0.2	0.08	0.14	0.1
Distance to municipality seat	0.04			0.06	0.21	0.11	0.22	0.02	0.1	0.04	0.04			0.13	0.07	0.12
Permanent labor at the farm	0.3		0.09			0.11	0.03	0.12	0.13	0.19		0.03		0.09	0.06	
Labor at Harvest time	0.54	0.51	0.14		0.07	0.15		0.06		0.11	0.07	0.04			0.07	0.05
Dominant Land Use			0.07	0.05	0.12	0.07	0.1		0.1			0.04	0.16			
cv. Hass avocado planted area	0.53	0.22		0.07	0.18	0.09	0.05	0.07	0.05				0.02	0.05		
cv. Hass avocado Yield (t ha^{-1})	0.21	0.53		0.06	0.22	0.09	0.08	0.28			0.15	0.08	0.09	0.11	0.15	0.05
Income from cv. Hass avocado	0.53	0.56	0.21	0.04	0.15	0.33		0.04	0.03	0.06	0.05		0.05	0.19		
Type of Phitosanitary control		0.05	0.06	0.08			0.16	0.05			0.02	0.09		0.03		0.05
Avocado cv. Hass production experience (>5 yrs)	0.18	0.06			0.03	0.04	0.06	0.09	0.06	0.02	0.07		0.01			
Type of Technical Assistance	0.3	0.06	0.12	0.21	0.2	0.04	0.03	0.07	0.09	0.16	0.07	0.08	0.1	0.05	0.05	0.14
Exports registration (ICA)	0.52	0.04	0.02	0.03		0.03					0.02					
Grower's associativity		0.04		0.16	0.06	0.08		0.07			0.03	0.02		0.05		0.02
Formal commercial alliances with markets	0.42		0.03	0.05		0.02	0.05									0.02
Access to Institutional Support	0.19						0.04	0.09				0.06			0.01	
Book keeping costs	0.34			0.04	0.03						0.02	0.06				
Origin of Economic resources for avocado cv. Hass activity			0.07	0.44			0.02	0.06	0.05		0.02					0.02
Application for Credit in the last year			0.04	0.33		0.02		0.03	0.17	0.02	0.03					

Source: Prepared by authors.

external sources, but family labor had an important participation. Fewer people were working permanently and at harvest time in comparison to Cluster 3. Most of these farms produced food for the household's own consumption. The avocado cv. Hass orchards, many of which included an associated second crop, had an average size of 4 ha, yielding about 8 tons ha^{-1}. The most common fertilization schemes were based

Figure 3 - Hierarchical tree showing three farm groups resulting from the Cluster Analysis of avocado cv. Hass productive units in the department of Antioquia (Colombia).
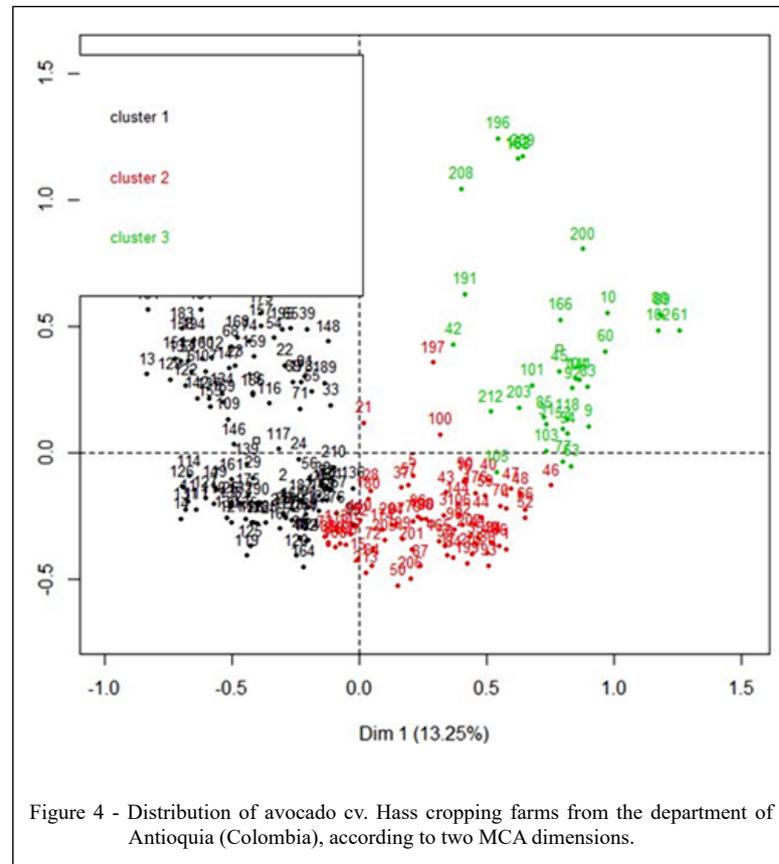
on chemical and organic fertilizers. Phytosanitary measures applied in more than half of these farms mixed different control modes, namely chemical, biological and organic, among others; whereas the sole application of chemical controls was observed in 42% of the orchards. More than seventy percent of the farms were registered at ICA, but fewer had received the Global GAP certificate. The price received by these growers per kg of avocado cv. Hass was around $0.80 USD, most of them having more than 5 years of experience with the crop. All of them claimed to have access to technical assistance, mainly provided by private agronomists, and many of them had already established formal links with avocado cv. Hass commercial companies. Sixty-six percent of these farmers belonged to growers' associations, while 45% had received institutional support. The main limitations they faced were the technical

management of the crop and the difficulty to steadily finance the activity.

Cluster 3

It contains the largest farms, but also the fewest farms in the sample, with an average size of 136 ha, a median size of 51 ha, and an average age of 6 years. They were mainly located in the municipalities of Sonsón, Abejorral and San Vicente de Ferrer, most of them already constituted as agricultural companies. A number of variables registered their highest values in this cluster: grower's educational level, orchard size, avocado cv. Hass yield, number of people working permanently and at harvest time in the productive units, and avocado cv. Hass price ($1.09 USD per kg). The majority of these farms applied chemical fertilization and had integral phytosanitary control schemes consisting in manual

Figure 4 - Distribution of avocado cv. Hass cropping farms from the department of Antioquia (Colombia), according to two MCA dimensions.

practices and both chemical and biological inputs. All the growers in this cluster had access to technical assistance from private agronomists, had their farms registered at ICA, and had received the Global GAP certificate. The main economic resource to sustain the plantation was growers' own income. Most of these farmers belonged to an avocado cv. Hass growers' association and had established formal commercial alliances to sell the crop. The main constraints they faced were the lack of labor to work in the plantations and the difficulty to find qualified avocado cv. Hass technical assistance.

DISCUSSION

The present study characterized different avocado cv. Hass farms in Antioquia, Colombia, aiming to identify technical management and market orientation patterns. Due to the cross-sectional nature of the data, the results presented here can be read as a snapshot of such farms. The three identified farm clusters differed mainly regarding farm size, farm

registry at ICA, avocado planted area, farm labor at harvest time, avocado cv. Hass yield per farm, labor source, technical assistance type, farmer's experience with the crop larger than five years, and existence of formal commercial alliances (Figure 5 and figure 6). As pointed out by TITTONELL et al. (2010) agricultural household categorization is a key element, not only to direct agricultural technologies, but also to improve agricultural policy design (PARDOS et al. 2008). The farms in Cluster 3 were the most organized ones of them all, having already ruled out many of the constraints faced by those in Clusters 1 and 2, as it was the case of access to formal markets. Yet, all the farms in the sample would certainly benefit from agricultural research and development.

Cluster 1 grouped more than half of the farms (52%) of the sample and also the smallest ones. It contained the largest fraction of productive units employing family labor in the crop and producing food for own consumption. These features bring Cluster 1 close to peasant agriculture (BACKER,

Table 4 - Typology of avocado cv. Hass farms.

Farm Type	Product orientation	Main Characteristics
1	Small farmer. New in avocado cv. Hass production. Subsistence and market oriented.	Containing 52% of the farms under study, this group was mostly composed of mid-aged farmers who were novice to avocado cv. Hass activity. They worked in small farms and small orchards also producing food for household consumption. Intercropped avocado cv. Hass with important participation of family labor. No formal connection to markets or Global Gap certification for the crop. Main limitations are financial support for the crop and access to good sell prices (associated to price control by middlemen).
2	Medium farmer. Experienced in avocado cv. Has production. Semi-commercially oriented.	This group contained 32% of the farms, which were large in size and also produced food for household consumption. Mainly mid-aged farmers with more than five-years of experience cultivating avocado cv. Hass, which, being rarely intercropped, was cultivated by mixed family and external labor force. Most of the farmers had formal connections with avocado cv. Hass commercial/exporting enterprises. The main constraints were financial support for the crop and managing the technical aspects of the crop.
3	Entrepreneurial farmer. Experience in avocado cv. Hass production. Market oriented.	Fifteen per cent of the farms corresponded to this group, which contained the largest farms and orchards growing avocado cv. Hass as a monocrop. The youngest growers in the sample, managed their avocado cv. Hass activity in an entrepreneurial fashion and did not produce food for their own consumption. Labor force employed at the farm was predominantly external. Most of the farms had established formal agreements with avocado cv. Hass commercial/exporting companies. Their main restrictions were the access to labor and qualified technical assistance.

Source: Prepared by the authors.

Table 5 - Quantitative farm descriptors. Frequency, mean, median and standard deviation where applicable.

Items	--------Cluster 1 (n= 112)-------			----------Cluster 2 (n= 69)--------			---------Cluster 3 (n= 33)---------		
Quantitative Variables	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Grower's age (yr)	50.78	50.00	12.90	56.53	56.00	10.73	49.54	50.00	11.84
Farm size (ha)	9.35	5.00	11.30	17.14	10.00	22.28	136.2	51	235.21
Permanent labor at the farm	1.80	2.00	1.06	2.869	2.00	1.999	12.48	8.00	10.66
Labor at Harvest time	3.22	3.00	2.69	7.49	7.00	3.85	21.17	15.00	11.16
Age of avocado cv. Hass plantation (yr)	4.06	4.00	2.78	6.60	6.00	3.24	6.42	6.00	3.84
Number of avocado cv. Hass trees	448	355	312	1201	800	1,095	6914	4500.0	6671.1
Avocado cv. Hass planted area (ha)	1.95	1.47	1.32	4.898	3.690	3.831	22.38	15.79	19.24
Avocado cv. Hass harvested area (ha)	1.37	0.98	1.02	3.247	2.390	24.275	11.64	8.710	10.50
Avocado cv. Hass yield (t ha^{-1})	6.20	3.62	6.58	8.32	6.71	7.09	9.899	7.812	7.864
Price paid to growers ($USD/kg)	0.60	0.61	0.21	0.81	0.71	0.38	1.09	1.07	0.40
Income from avocado cv. Hass ($USD/ha)	1,863	454	3,043	6,298	4316	7,004	8863	6454	9,686

Source: Prepared by authors.

Table 6 - Qualitative descriptors of the farms.

Qualitative variables	-----Cluster 1 (n= 112)-----					-------Cluster 2 (n= 69)------					------Cluster 3 (n= 33)------				
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
Dominant Land use (%): 0 = crops, 1 = pastures, 2 = fallow, 3 = native forest, 4 = commercial forest	65	28	0	6	1	63	21	10	4	1	75	9	0	9	6
Type of fertilization (%): 0 = chemical; 1 = organic; 2 = both (chemical and organic)	30	2	70			30	4	65			58	0	42		
Access to technical assistance (%): 0 = yes (1) otherwise	60	40				100	0				100	0			
Type of phytosanitary control (%): 0 = chemical; 1 = manual; 2 = biologic; 3 = organic; 4 = integral (using two or more of the previous types)	66	9	0.9	4	20	42	4	1	0	52	21	0	0	3	76
Exports registration (ICA *Instituto Colombiano Agropecuario*) (%): 0 = yes; 1 = otherwise	90	10				79	21				85	15			
Exports certificate (Global GAP) (%): 0 = yes; 1 = otherwise	1	99				23	77				57	43			
Food production for household consumption (%): 0 = yes; 1 = otherwise	81	19				71	29				42	58			
Origin of Economic Resources: 0 = own resources, 1 = formal credit, 2 = informal Credit	45	30	2	23		39	20	0	40		53	19	0	28	
Institutional support (subsidies, programs, other): 0 = yes; 1 = otherwise	75	25				45	55				21	79			
Growers' associativity: 0 = yes; 1 = otherwise	51	49				66	33				61	39			

Source: Prepared by authors.

1997). The farmers in this group had the lowest education level of them all, the most limited access to technical assistance, and were also the newest ones in the avocado cv. Hass activity (less than five years of experience). These factors probably account for the lower yields of these farms. The fertilization schemes applied by these farms, based on organic and chemical inputs, differed from those featuring Cluster 3. Technical assistance for the crop typically advises not to use organic matter unless it is very well composted. The phytosanitary control of this crop requires integral management of pests and diseases (ALARCÓN et al., 2012), which was not being applied in these farms, since they mostly relied on agrochemical inputs. The limited access of these farms to formal markets may be linked to their lower technological level and lack of both ICA registration and Global Gap certification. The latter is probably explained by the elevated cost of this certificate (which particularly affects small growers) and the fact that these were the youngest plantations and; therefore, their production had not stabilized. As

stated by BARRENA et al. (2013), when it comes to fruit production, exporters seek to ensure a minimal level of good agricultural practices, so as to have access to a wider range of markets. However, this usually implies more restrictions for peasant growers. This group of farms were facing major difficulties to get economic benefits from avocado cv. Hass cultivation, which are not only associated to limited access to information via technical assistance, but to the lack of the necessary formal alliances and export certifications to access international markets and, hence, better prices. Consequently, the production of these farms is circumscribed to the domestic market, since the European one (actually the main purchaser of Colombian avocado exports) requires the Global GAP certification (BAIN, 2010). This is disadvantageous since, at the national level, they do not negotiate with formal commercial partners. Most of these farms claimed to be at the mercy of middlemen who controlled the prices paid for the crop in municipal markets. One additional concern that stands out for this group is the trend towards
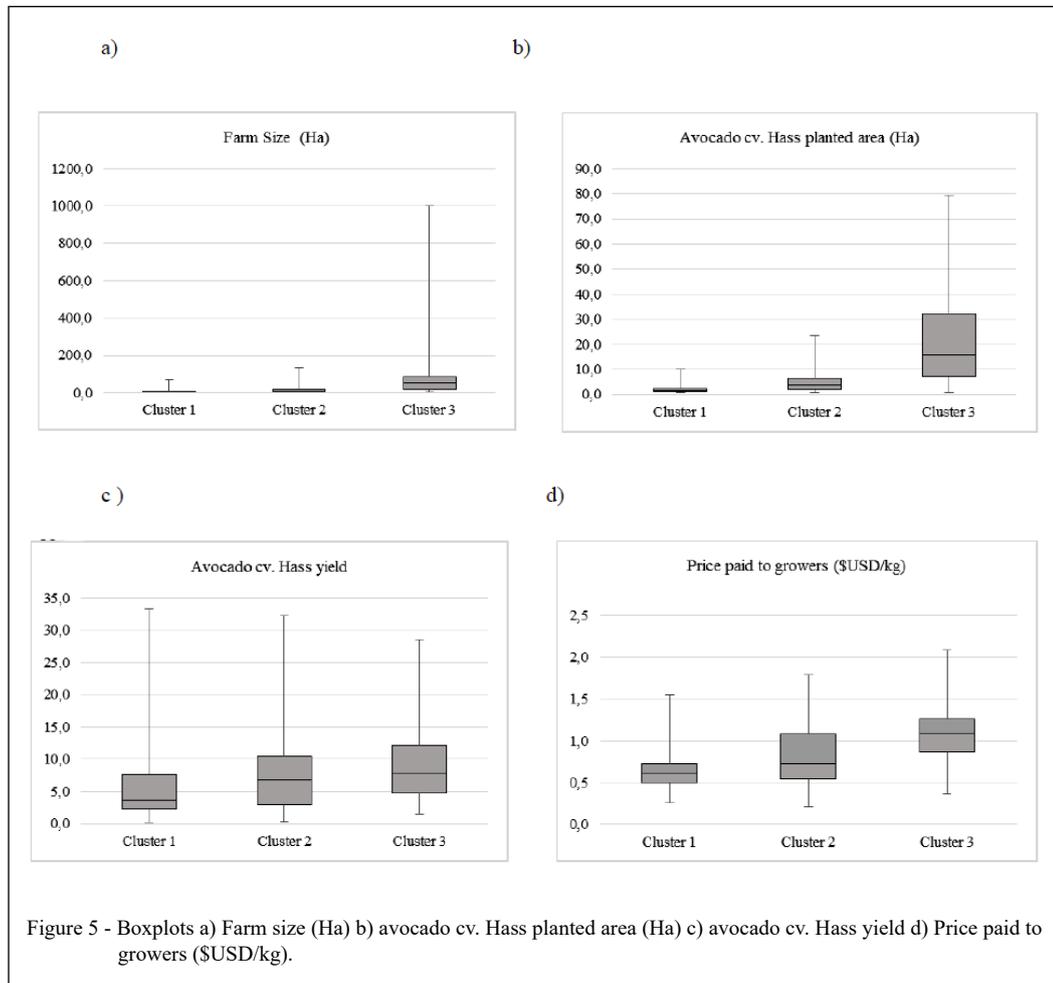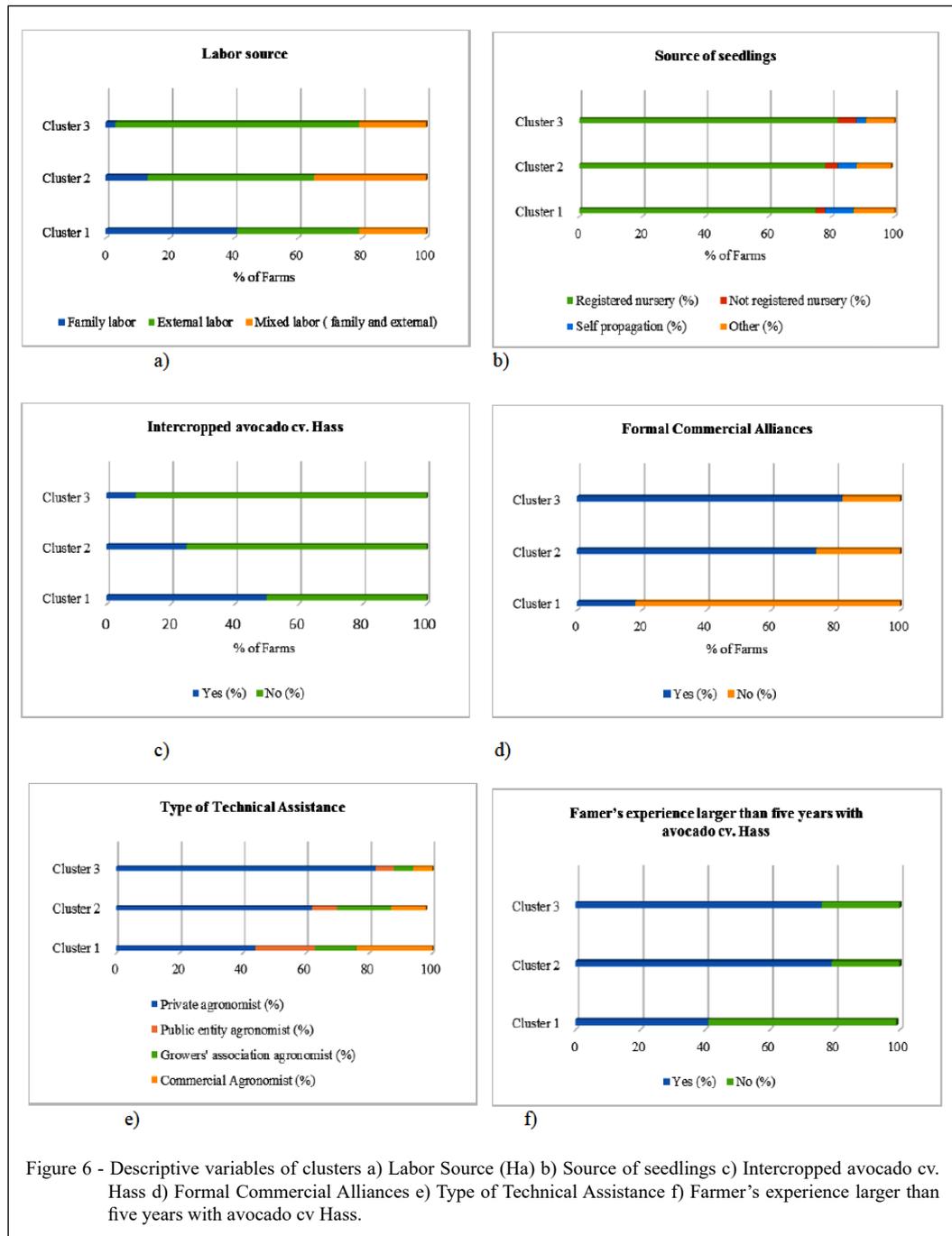
Figure 5 - Boxplots a) Farm size (Ha) b) avocado cv. Hass planted area (Ha) c) avocado cv. Hass yield d) Price paid to growers ($USD/kg).

establishing avocado as a monocrop, which may affect both crop biodiversity and food production for household consumption. This farm cluster needs to be assisted in the financial support of their cropping activity, naturally aiming at a higher productivity (TITTONELL et al. 2010) as a result not only of better access to supplies, credit and institutional support programs, but also of an adequate guidance on accessing formal national or international markets. Due to the fact that many of these growers still rely on other crops for household food consumption, it would be necessary to study the coexistence of the avocado cv. Hass production system with other crops, in order not to affect the food security of these farms. With a better access to qualified technical assistance, these farms would be able to implement a more integral management of pests and diseases which, in turn, would allow them to reduce costs (agrochemical supplies), thus taking advantage of available family

labor. Technical assistance could also provide information on how to deal with soil erosion, which is likely present in most of the farms, since they are located on hilly sites. Nonetheless, as suggested by TITTONELL et al. (2010), farms exhibiting these characteristics may have economic constraints that hinder their engagement in technological innovation and extension activities.

The farms in Cluster 3 did not face the same obstacles as those in Cluster 1, since they had access to technical assistance, Global GAP certification and formal alliances with exporting companies. As a consequence, the farmers in this group appear to have benefited the most from these conditions when compared to those of the other clusters. Contrary to the observations of BARRENA et al. (2013) in Chile, export certifications have enabled these Colombian growers to access new markets and obtain better prices in the domestic market.

Figure 6 - Descriptive variables of clusters a) Labor Source (Ha) b) Source of seedlings c) Intercropped avocado cv. Hass d) Formal Commercial Alliances e) Type of Technical Assistance f) Farmer's experience larger than five years with avocado cv Hass.

Most of the farms in Cluster 3 had established avocado as a monoculture. They employed external labor and had five or more years of experience with the crop, book keeping costs and access to technical assistance. These factors indicated that these farms have a rather commercial agricultural profile (BACKER, 1997). Research and development for these

farms should focus on capitalization and less labor-intensive agricultural technologies in order to cope with the lack of workforce in the surroundings. Just as well, it should provide training facilities for technical assistants to specialize in avocado cv. Hass technical management.

The farms in Cluster 2 share some features with those of Cluster 1, such as the use of family

and external labor, food production for household consumption, and fertilization and phytosanitary schemes. This group also shares some of the characteristics of Cluster 3 in terms of avocado cv. Hass yield, type of technical assistance, and access to formal commercial alliances. These farms need better technical assistance aimed to access better seedlings and improving phytosanitary management, therefore increasing their yields.

The current results revealed considerable homogeneity in parameters such as type of tenure, distance from the farm to municipality seats and growers' associativity, all of which are important for the development of avocado cv. Hass cultivation. As pointed out by VÁSQUEZ et al. (2011), tenure security is especially relevant to this crop, not only because it is semi-perennial and; therefore, requires long-term investments, but also because the plantations can be used as collateral to apply for formal credit. Just as well, proximity to markets benefits cv. Hass growers as a result of the quick dispatch of the product from the farms, which, in turn, reduces transport costs and preserves fruit quality by avoiding long travelling distances along non-paved roads. Finally, associativity was found to be a common feature of the three farm types, resulting in numerous benefits such as access to technical training and institutional support in the form of subsidies, increased bargaining power of small and medium growers to negotiate with middlemen, and new possibilities to establish commercial alliances with big marketers.

CONCLUSION

Three types of avocado cv. Hass farms were identified in Antioquia, Colombia. They differed mainly regarding farm size, farm registry at ICA, avocado planted area, farm labor at harvest time, avocado yield per farm, labor source, technical assistance type, and farmer's experience with avocado cv. Hass. One of the observed farm types was found to be related to peasant agriculture, while another one came close to commercial agriculture, and a third one shares features with both of them.

The results of this study may contribute to increasing the positive impact of future agricultural innovations and public policies and programs aimed at avocado cv. Hass farms. Most of the current programs intended to support the production of this variety do not rely on sound information such as the one provided by the current farm typology in terms of the different profiles and needs of avocado cv. Hass productive units. Such information is valuable when

it comes to deciding which programs may be more beneficial for a particular farm type, thus enhancing the impact of any intervention. Particularly, the farms in Cluster 1 should be targeted by special support policies and development programs in order to sustain their activity.

DECLARATION OF CONFLICT OF INTERESTS

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AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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