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Characterisation of avocado and asparagus farms in the Chavimochic irrigation project in La Libertad, Peru

Caracterización de fundos productores de palto y espárrago en la Irrigación Chavimochic, en la Libertad, Perú

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Abstract

The Chavimochic irrigation project is one of the leading projects in Peru. In this project, irrigation water is derived from the Santa river to irrigate the valleys of Chao, Viru, and Moche, including desert zones between valleys. In this study, we aimed to characterise the Hass avocado and asparagus farms in desert areas of the Chavimochic irrigation project. Social, economic and environmental information was collected through structured surveys of 12 asparagus and 17 avocado farms. Four groups of asparagus farms and three groups of avocado farms were identified based on principal component and cluster analyses. Profitability of the avocado crop was higher than that of the asparagus crop, and irrigation caused more significant variability in the crop yield of avocado than that of asparagus. From the social perspective, the income of farm personnel was related to the level of education, and female personnel showed more participation in the Chavimochic irrigation project than in other agroecosystems of Peru.

Keywords: *Avocado, asparagus, characterisation, farms, Chavimochic irrigation*

Resumen

La Irrigación de Chavimochic es uno de los proyectos más importantes realizados en el Perú. Esta irrigación usa el agua derivada del rio Santa para irrigar los valles de Chao, Virú y Moche. Incorporando las zonas de desierto entre valles. El presente trabajo tuvo como objetivos caracterizar los fundos productores de palto Hass y espárrago en las zonas de desierto de la Irrigación de Chavimochic. Información social, económica y ambiental fue recolectada mediante encuestas estructuradas realizadas a los 12 fundos de espárrago y 17 fundos de palto. Mediante la técnica de análisis de componentes principales y de agrupamientos de conglomerados se identificó 4 grupos de fundos de espárrago y tres grupos de fundos de palto. La rentabilidad del cultivo de palto es mayor que la de cultivo de espárrago, el uso del recurso hídrico por los fundos tiene mayor variabilidad en el cultivo de palto que el espárrago. En la parte social el nivel de ingresos del personal de los fundos tiene relación con el grado de instrucción, la participación del género femenino es mayor que en otros agroecosistemas del Perú.

Palabras Claves: *Palto, Espárrago, Caracterización, fundos, Irrigación Chavimochic*

Introduction

The Chavimochic irrigation project consists of the derivation of water from the Santa river for irrigating the valleys of Chao, Virú, Moche, and Chicama, including the desert zones between each valley. This irrigation has made possible to incorporate desert areas into agriculture. In this area, intensive agriculture has been developed under pressurised irrigation with agro-export crops. Crops grown in this area include avocado (8,402 ha), asparagus (5,528 ha), sugarcane (3,183 ha), blueberries (3,270 ha), and others, adding up to a total area of 21,297 ha (Junta de riego presurizado de Chao, Virú y Moche, 2016).

Chavimochic is one of the leading centres of agro-exports of Peru and generates substantial incomes for the development of La Libertad and the country in general. Recently, there has been a major change in the crop cultivation scheme in Chavimochic. Ten years ago, the main crop was asparagus (two types: white and green) reaching an area of 11,000 ha. Most of this area has subsequently been replaced by avocado, which is now the

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most important crop, with an area of 8,400 ha. Thus, with the increase in avocado cultivation area, the asparagus cultivation area is decreasing, leading to the decline of yield and profitability. Currently, avocado and asparagus are the most important crops in Chavimochic; therefore, the impact of Chavimochic on the agroecosystem is significant.

Multivariate statistical analysis is used in the typification of producer farms. This exploratory analysis makes it possible to classify, summarise and order all of the variables measured. These variables allow the farms with common characteristics to be grouped into sets (Escobar & Berdegué, 1990; Ortuño & Coronel de Renolfi, 2005).

The objective of this study was to characterise avocado and asparagus farms of the Chavimochic irrigation project in La Libertad, Peru.

Materials and methods

This research was carried out in the Chavimochic irrigation project located in La Libertad along the northwestern coast of Peru. Avocado and asparagus farms are located in the desert areas in this region. Crops are produced using a pressurised irrigation system, with the intention of agro-export. All farms have a social name and are grouped in the Pressurised Irrigation Board of Chao, Virú and Moche. This Irrigation Board administers and charges the consumption of irrigation water in the Chavimochic irrigation project. The farms have a high technological production level.

This research was carried out in all avocado (17) and asparagus farms (12) of the Chavimochic irrigation project. To characterise the avocado and asparagus farms, data were collected on several by handing out structured surveys to managers or heads of avocado and asparagus farms and to the workers on these farms. Soil samples were also collected to analyse soil microbiota. Additionally, data were collected on water consumption and area of the Pressurised Irrigation Board of Chao, Virú and Moche via in-situ visits.

Structured surveys

Visits were made to all producer farms, and structured surveys were carried out at different levels: managers or heads of farms and workers on each farm. Managers or heads of farms are the people who make the technical and administrative management decisions for the avocado and asparagus crops. Managers of all 17 avocado farms and 12 asparagus farms were included in the survey. Additionally, 10 workers were randomly selected from each farm, totalling 170 surveys on avocado farms and 120 surveys on asparagus farms. All surveys focused on social, economic and environmental variables.

Soil samples

Soil samples were taken from all avocado and asparagus production fields. A representative plot was selected at each farm, and 20 sub-samples were collected from each plot. Each sample was composed of 2 kg of soil. A total of 29 samples (17 avocado and 12 asparagus) were processed. All samples were collected from the root zone and used to analyse soil characteristics.

Soil characterisation

Samples were sent to the soil laboratory of the Universidad Nacional Agraria La Molina, and soil organic matter content, acidity, electrical conductivity, N, P_2O_5, and K_2O contents and cation exchange capacity were quantified.

Analysis of fungal flora

Fungal flora in soil samples were analysed in the laboratory of the Clínica de Diagnosis de Fitopatología. Six serial dilutions of soil samples were prepared using sterile water in test tubes and streaked in Petri dishes containing potato dextrose agar medium with oxytetracycline, as described previously (French & Torres, 1980). The Petri dishes were incubated at 25°C for 7 days, and the growing fungi were quantified and identified. The identification of fungi was performed according to the keys of Barnett and Hunter (1998), which differentiates among fungal genera based on morphological features. To perform diversity analysis, the number of identified species per gram of soil was determined.

In-situ visits

In-situ visits were made to all avocado and asparagus farms to validate the data generated in the surveys and to collect additional information on crop management practices from the farm managers or production chiefs. The data collected during the in-situ visits included vegetable crop coverage and diversity per farm, conservation zone percentage in the farms, and incidence of pests per crop and farm.

Data analysis

Data collected from the surveys (total of 65 variables per avocado and asparagus field), soil sample analysis, in-situ visits, and primary sources of the Pressurised Irrigation Board were analysed by multivariate analysis based on principal component and cluster analyses. Variables with less than 30% variation coefficient were discarded, as these were not discriminatory, according to Escobar and Berdegué (1990). The results of cluster analysis were displayed in a dendrogram (Valerio et al., 2004; Escobar & Berdegué, 1990). Distance between the farms was expressed as Euclidean distance squared and using the Ward method, the most recommended combination for perennial fruit trees (Miranda & Carranza, 2013).

Results and discussion

Characterisation of asparagus and avocado production farms

Farms in the Chavimochic irrigation project investigated in this study are listed in **Table 1.** Asparagus was cultivated over an area of 3,688.7 ha in 12 farms, while avocado was cultivated on an area of 8,515.2 ha in 17 farms. All farms were irrigated via drip irrigation. All avocados and asparagus produced on these farms are exported. Thus, intensive farming systems are employed with high technological level.

Table 1. Production areas of asparagus and avocado fields of the Chavimochic irrigation project in December 2017.

Asparagus farm areas			**Avocado farm areas**	
Farm code	White asparagus (ha)	Green asparagus (ha)	Farm code	Avocado (ha)
SCARLOS	57.00	0.00	ALPAM	410.93
ALIMA	553.41	0.00	BEGGIE	1120.34
YUGOSL	0.00	172.00	SIMON	567.94
DANPE	399.20	598.80	ARENA	68.71
MAUEL	50.00	50.15	AGRON	14.00
MILAG	35.00	0.00	LIMA	150.00
GREEN	884.71	0.00	ARATO	604.93
INSAC	55.08	0.00	YUGOS	360
MORAV	0.00	66.00	AVOP	512.76
TALSA	480.00	0.00	CAMPO	2523.61
SAVSA	1003.47	0.00	DESHI	149.20
UPAO	170.91	0.00	GREEN	216.91
			HASS	331.76
			INVER	18
			NORTE	56.20
			TALSA	60
			SAVSA	1350
12 farms	3688.78	886.95	17 farms	8515.29

Source: Junta de Riego presurizado de Chao, Virú y Moche.

Characterisation of asparagus farms

Principal component analysis separated the 29 farms into four groups (**Figure 1**). The results of cluster analysis (Ward-Euclidian distance) also revealed the same grouping of farms (**Figure 2**). The first group comprised farms not linked to the market (MILAG, SCARLOR, IANSAC, UPAO, and MAUEL), i.e. companies that do not directly export their products but sell it to other companies that export asparagus. The companies that constitute this group showed lower yield and usually smaller area of cultivation than companies in other groups. The second group comprised farms that produce asparagus both for canning and fresh export (ALIMA, GREEN, TALSA and DANPER). These companies process their produce and export it directly to different markets. These companies also grow other crops in addition to asparagus, such as avocado and blueberry, and have different quality certifications and good agronomic practices. The third group comprised companies of medium size (YUGOS and MORAV). These companies produce fresh green asparagus, which is used for processing and export. These companies also produce white asparagus. The fourth group comprised a large canning company (SAVSA), with diverse crops, various certifications and quality assurance. SAVSA is the largest cannery in the Chavimochic irrigation project and is currently diversifying its production with the avocado crop.

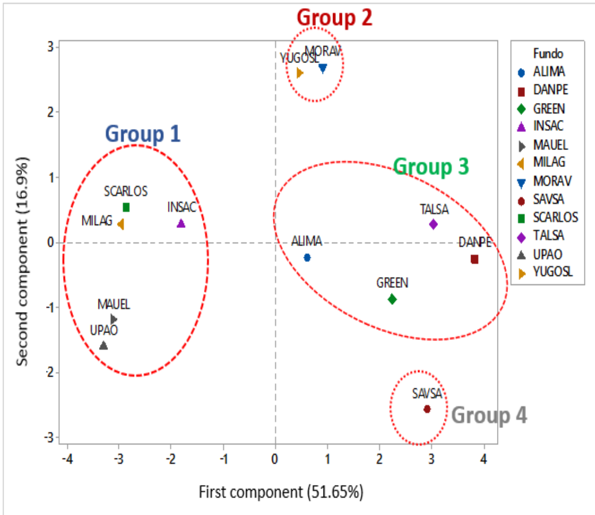

Figure 1. Biplot graph of the main components of the asparagus fields of the Chavimochic irrigation project in 2017.

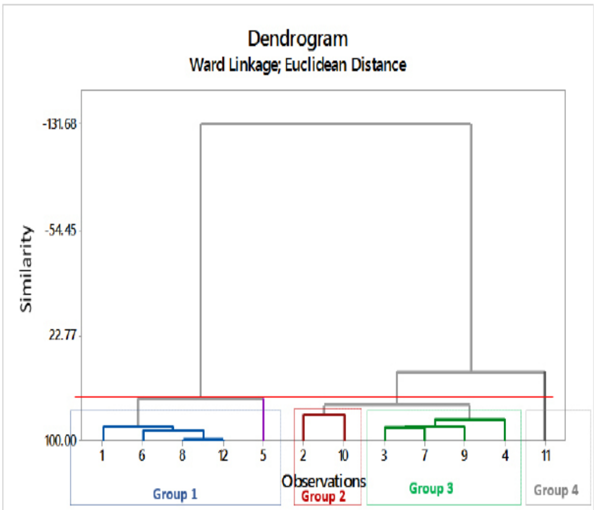

Figure 2. Dendrogram showing the similarity among asparagus producing farms of the Chavimochic irrigation project in 2017.

Figure 3 shows the relationship between variables used for principal component analysis. The variables were as follows: red label pesticides (pestroj), number of applications (nroapplica), exportable, organic matter (MO), microorganisms (microorg), another crops (otroscul), processing (procesa), biodiversity (biodiver), incomes (ingresos), yield (rto), certifications (certificaciones), area (area) and Blanco (blanco). The analysis suggests that companies with the highest asparagus production area, most considerable number of certifications, yields, incomes, and highest biodiversity are those that apply the least number of applications and do not make use of highly toxic pesticides. It is important to note that a number of the smaller companies that do not process their production use highly toxic pesticides (red label) because they do not have certifications that limit the use of these products. Farms with extensive areas are highly likely to leave areas for increased biodiversity.

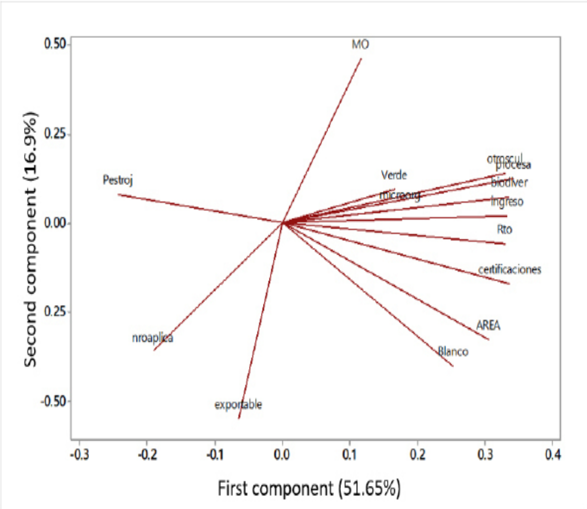

Figure 3. Variables analysed by principal component analysis of the asparagus farms.

Characterisation of avocado farms

Principal component analysis of 17 avocado farms is shown in **Figure 4**. In general, the analysis of the relation between the variables was not as defined as in the case of asparagus; therefore, component 1 explained 32.1% of the variability, and component 2 explained only 16.9% of the variability, i.e. between the two reaches 43.7%.

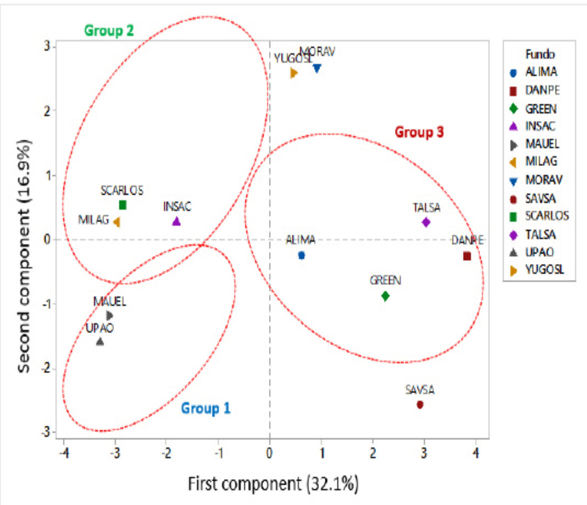

Figure 4. Biplot graph of the main components of the avocado plantation of the Chavimochic irrigation project in 2017.

The results of cluster analysis of these 17 avocado farms are shown in **Figure 5**. The grouping of avocado farms showed higher dispersion than asparagus farms, indicating greater variability in each of the components evaluated in the estates than in asparagus. Three large groups were differentiated using the two methods.

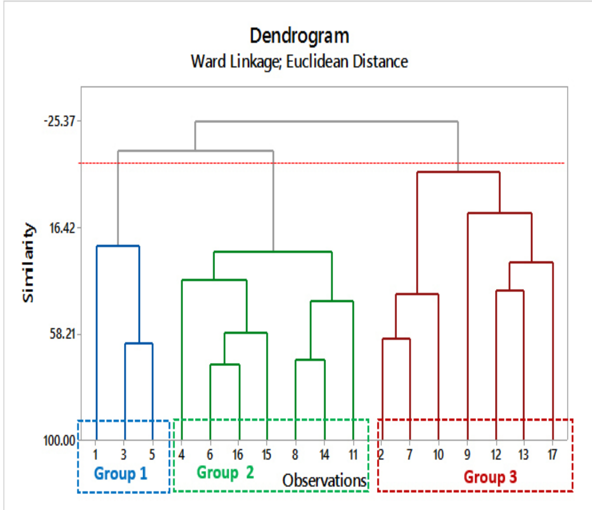

Figure 5. Dendrogram showing the similarity among avocado plantations of the Chavimochic irrigation project in 2017.

Group 1 comprised SIMON, AGRON and ALP farms, which sell their fruit to third parties, do not have many quality certifications, and apply high levels of pesticides, especially those with red labels. The second group comprised NORTE, TALSA, INVER, YOGOS. DESH, and AREN farms with medium-sized areas that sell their produce to third parties, do not have a processing plant, and require third party service. The third group comprised large companies, such as HASS, ARATO, BEGGIE, AVOP, CAMPO and SAVSA, with high fruit processing capacity that export their produce directly to different markets and have the highest number of quality certifications.

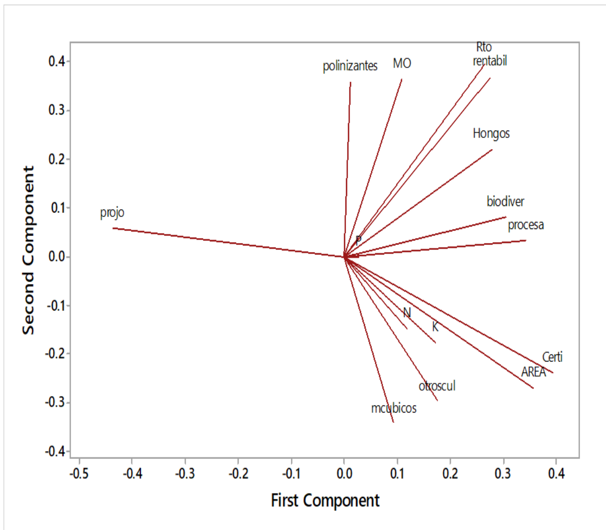

Figure 6. Variables analysed by main principal component analysis of the avocado plantations.

Figure 6 shows the quantity of red label pesticide applications plotted against the number of certifications, biodiversity and farm area. The higher the area of the avocado plantations, the smaller the use of red label pesticides. Thus, large farms have less environmental impact, as their certifications are very restrictive in the use of red label pesticides (Li, 2018; Ambrus & Yang, 2015).

Analysis of the dimensions of characterisation

Environmental dimension

Tables 2 and 3 show the environmental indicators for the asparagus and avocado farms. One of the critical indicators for arid agroecosystems, as in the case of the Chavimochic irrigation project, is the use of water resources. Asparagus requires an average of 9,433.3 m^3 of water per hectare per year, while avocado crop requires 16,941.2 m^3 water. The average water requirement of asparagus in Chavimochic is generally lower than that reported previously by other authors (Salazar, 2012; Muñoz, 2016) in other agroecosystems such as Ica, where the expenditure reaches 15,000 m^3/year. In the region of Ica, evapotranspiration is low, and the area of asparagus is exclusively used for fresh green production, which has higher water requirement than white asparagus, which is mostly produced in Chavimochic.

Figure 7 shows the water requirement of avocado and asparagus farms. The volume of water required for avocado cultivation per hectare per year showed greater variability between farms [standard deviation (SD) of 2,236.3] compared with asparagus whose variability was lower (SD of 290 for green asparagus and 568.9 for white asparagus). This is because the farmers who manage asparagus cultivation have a significant experience of more than 25 years in asparagus cultivation in that area, unlike avocado, whose intensive cultivation dates back to only 12 years. Over time, the water consumption of the avocado crop has decreased. In both crops, all farms use at least one method for calculating the irrigation requirement, with the largest farms using a greater number of methods for calculating the irrigation requirements.

In the Chavimochic irrigation project, the Pressurised Irrigation Board of Chao, Virú and Moche manages the

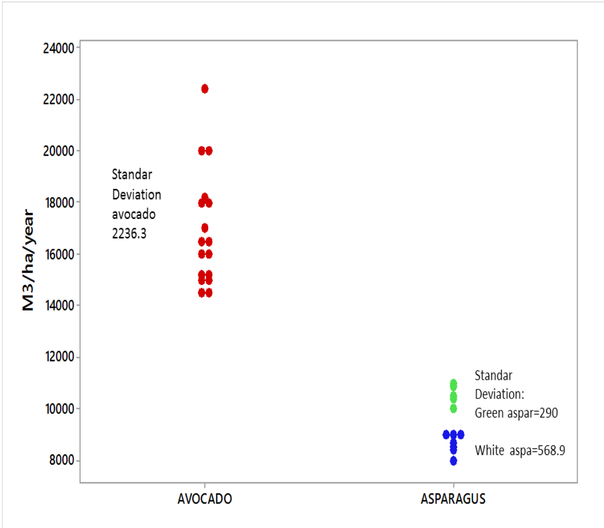

Figure 7. Water consumption (m3 ha−1 year−1) in avocado and asparagus farms of the Chavimochic irrigation project in December 2017.

Table 2. Environmental indicators at asparagus farms of the Chavimochic irrigation project in December 2017.

Farm code	Soil life conservation		Water resource use		Diversity management			Contamination			
	Plant cover (%)	Organic matter use (tm/ha)	Water use (m^3/ha/año)	Irrigation calculation methods (number)	Number soil fungi species [1]	Plant diversity [2]	Conservation areas [3]	Number of pesticide applications	Number of red label pesticides	Biological control method uses (N° of applications)	Number of certifications
SCARLOS	0	0	8000	2	1	0	2	26	5	0	1
ALIMA	25	0	9000	3	3	0	2	19	4	1	2
YUGOSL	0	25	10400	2	4	0	1	18	4	0	3
DANPE	25	0	11000	4	3	0	2	17	3	2	6
MAUEL	0	0	10400	3	2	0	0	25	5	0	1
MILAG	0	10	8400	2	2	0	0	19	6	0	1
GREEN	25	0	8700	3	1	0	1	17	3	1	4
INSAC	0	0	9000	2	3	0	0	18	6	0	2
MORAV	0	15	10900	2	3	0	1	15	4	1	2
TALSA	25	30	9000	3	4	0	2	22	3	2	6
SAVSA	0	10	10000	4	3	0	2	23	3	1	6
UPAO	25	0	8400	3	1	0	1	29	6	1	1
Average	10.4	7.5	9433.3	2.8	2.5	0.0	1.2	20.7	4.3	0.8	2.9

Notes
[1]Soil fungi diversity scale: 0, less than 2 species; 1, 2–4 species; 2, 5–7 species; 3, 8–10species; 4, more than 10 species.
[2]Plant cover scale: 0, monoculture; 1, low; 2, medium; 3, high; 4, total.
[3]Farm areas for conservation scale: 0, none; 1, 0.1–0.5% of the total farm area; 2, 0.51–1%, 3, 1.1–2.5%; 4, more than 2.5%.

Table 3. Environmental indicators of avocado farms of the Chavimochic irrigation project in December 2017.

Farm code	Soil life conservation		Water resource use		Diversity management			Contamination			
	Plant cover (%)	Organic matter use (tm/ha)	Water use (m^3/ha/año)	Irrigation calculation methods (number)	Number of soil fungi species[1]	Plant diversity [2]	Conservation areas[3]	Number of pesticide applications	Number of red label pesticides	Biological control method uses (N° of applications)	Number of certifications
ALPAM	25	0	18000	1	1	1	1	15	5	2	2
BEGGIE	25	0	14500	4	1	2	2	14	2	4	7
SIMON	5	0	18000	1	0	0	0	13	5	0	2
ARENA	25	0	15000	3	1	1	0	9	4	2	2
AGRON	7	0	18200	3	1	1	1	15	6	2	1
LIMA	35	0	16000	2	1	0	2	13	4	2	3
ARATO	35	5	16500	4	1	1	2	15	2	4	7
YUGOS	7	15	15200	2	2	2	1	12	3	2	2
AVOP	35	15	17000	3	2	3	4	14	2	4	5
CAMPO	25	0	16500	3	1	3	3	13	1	4	8
DESHI	0	10	14500	2	1	1	2	13	4	2	2
GREEN	10	0	20000	3	2	1	1	13	3	2	2
HASS	35	0	20000	2	1	2	3	10	3	3	4
INVER	5	15	15200	3	1	1	0	13	5	2	2
NORTE	5	0	15000	2	2	1	1	14	6	3	1
TALSA	40	0	16000	3	1	2	2	10	4	4	2
SAVSA	5	0	22400	3	1	2	2	12	2	3	7
Average	19.1	3.5	16941.2	2.6	1.2	1.4	1.6	12.8	3.6	2.6	3.5

Notes
[1]Soil fungi diversity scale: 0, less than 2 species; 1, 2–4 species; 2, 5–7 species; 3, 8–10 species; 4, more than 10 species.
[2]Plant cover scale: 0, monoculture; 1, low; 2, medium; 3, high; 4, total.
[3]Farm areas for conservation scale: 0, none; 1, 0.1–0.5% of the total farm area; 2, 0.51–1%, 3, 1.1–2.5%; 4, more than 2.5%.

distribution and cost of water used, based on the volume (m^3) of water used. The tariff is 0.114 Peruvian nuevos soles per m^3, if the water expense is between 10,000 and 13,000 m^3; and 0.218 Peruvian nuevos soles per m^3, if the water expense is higher than 13,000 m^3. Therefore, if an avocado plantation spends 16,000 m^3 ha^{-1} $year^{-1}$, the cost is S/.3488 Peruvian nuevos soles. Thus, companies try to use the water resource as efficiently as possible. The use of water resources is one of the main factors affecting the sustainability of arid agroecosystems.

Regarding the production diversity, asparagus is grown in a monoculture system, which does not allow other plant species to prosper. Cultivation of white asparagus involves tasks such as hilling and deshelling, which prevent the development of other plant species. In the case of avocado, several companies have managed to place crops such as legumes (beans) or Gramineae (barley) in the root development zone because the avocado crop requires no soil removal below the top of the plant. The use of associated crops is very low compared with other agroecosystems such as in the mountains (Pinedo, Gómez & Julca, 2018) and jungle (Tuesta, Julca, Borja, Rodríguez, & Santistevan, 2014), where the association with other crops is widespread because the production system is more familiar and extensive, whereas the avocado and asparagus farms are intensive systems that do not allow this type of management.

The relationship between yield and water consumption (m^3 ha^{-1} $year^{-1}$) in the avocado crop was tested via regression analysis, and the results were non-significant, implying that higher water consumption does not equate to a higher yield. There are other factors, besides water, that influence the yield of avocado (Teliz, 2006).

The number of fungal species was higher in asparagus farms than in avocado farms. However, this indicator is quite relative, as the high biomass that has the asparagus in the soil allows the proliferation of fungi that develop on the crown (Delgado de la Flor, Montauban, & Hurtado, 1987), whereas in avocado, the highest biomass of the crop is in the aerial part. The application of pesticides was more frequent in the asparagus crop (average 20.7 times) than in the avocado crop (12.8 applications). One of the major insect pests in the farms is *Prodiplodis longifilia*, which affects not only the yield of asparagus because of its effect on shoots but also the quality of green asparagus (Castillo, 2006). The use of red label pesticides is higher in the cultivation of asparagus than in avocado, and Methomyl is the most highly used red label pesticide.

Figure 8 shows the results of the assessment of different diseases encountered during the cultivation of asparagus and avocado. In asparagus cultivation, *Prodiplosis* was the biggest problem, followed by foliar spot caused by *Stemphylium vesicarium* and Lepidoptera because these disease problems can directly affect the commercial product as well as have a high impact on the harvest. Therefore, these are the two main phytosanitary problems accounting for most of the pesticide applications, consistent with Castillo (2019) and Delgado (2016). In the avocado crop, scales is the most important disease that needs to be controlled. Although this pest does not affect avocado yield, it limits access to markets in United States and China, where tolerance levels are very low (SENASA, 2014). Mites are the second most crucial pest for avocado producers that account for most of the pesticide application. These two pests are widespread in arid agroecosystems lacking rainfall, which facilitates their development.

All avocado and asparagus production farms have at least one certification. Larger farms have more certifications because of their connection with the market and the demand of their buyers. Many of the certifications require less use of pesticides, especially red label pesticides (Rain forest, Tesco and Fair for Life). In all cases, the high requirement of food safety implies that no residues are permitted in the destination markets to comply with the indications on labels, and a maximum limit of residues is compulsory for the farms of both crops.

Regression analysis of the percentage of red label pesticides and number of certifications of each farm revealed a significant relationship in avocado farms (r = 0.754). However, in both crops, an inverse relationship was detected between the number of certifications and use of red label pesticides (**Figure 9**).

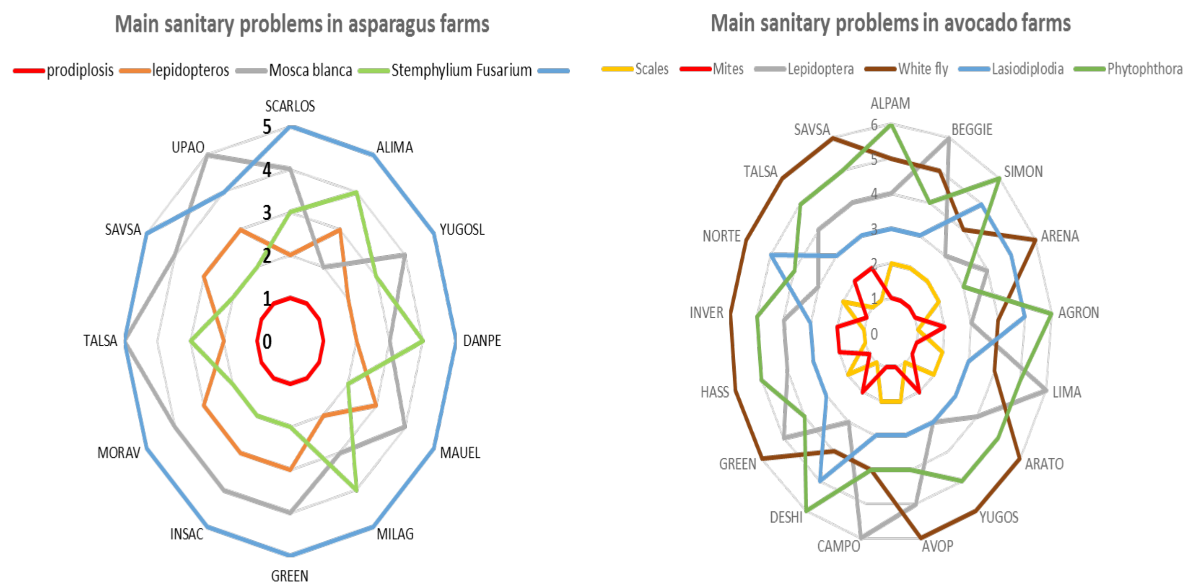

Figure 8. Main sanitary problems of the asparagus and avocado fields in 2017.

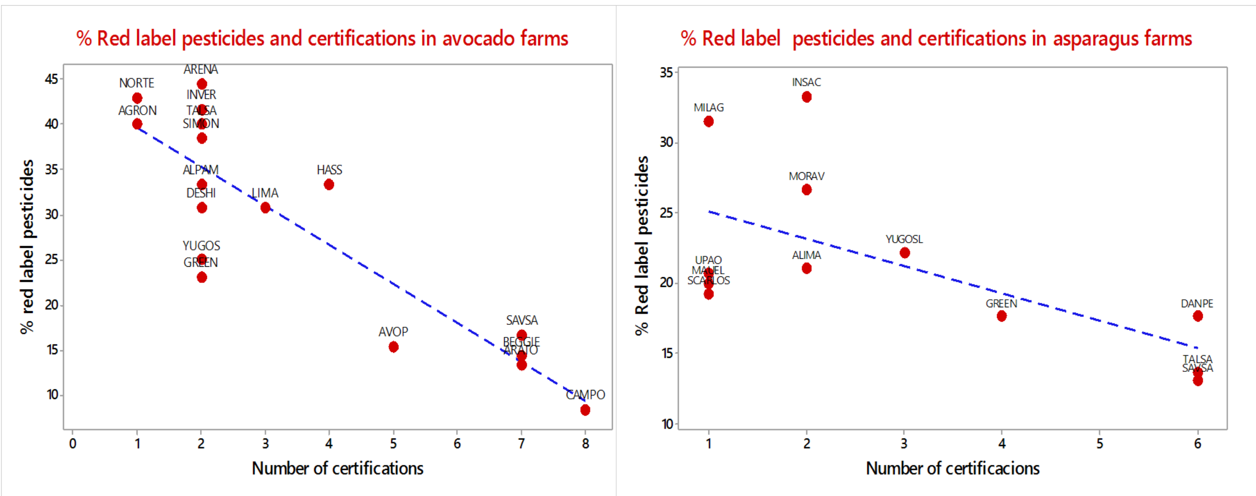

Figure 9. Relationship between the percentage of red label pesticides and number of certifications used in asparagus and avocado farms of the Chavimochic irrigation project in 2017.

Sarandón and Flores (2014) reported that modern agriculture is based on the intensive use of pesticides, resulting in numerous problems of contamination and insecticide resistance in pests. Farm certifications and market restrictions with respect to the use of certain pesticides and their maximum residue limits exert pressure on the use of pesticides by the avocado and asparagus farms. Greater care is taken in avocado than in asparagus because the avocado fruit is directly exposed to pesticides, and the high fat content of avocadoes retains lipophilic pesticides (Gilbert, García, & Molina, 2009).

Economic dimension analysis

Tables 4 and 5 show the economic indicators of the asparagus farms. Variation was observed in the yield of asparagus because the farms had different ages of asparagus and different technical management, and several farms were dedicated to green and white asparagus. The cost of cultivation also varied between farms because some farms produce fresh white asparagus, which increases their cost,

Table 4. Economic indicators of asparagus farms of the Chavimochic irrigation project in December 2017.

Farm code	Yield (kg/ha/year)	Cost (USD/ha/year)	Gross income (USD/ha/year)	Cost per kg	Net income (USD/ha/año)	Export quality (%)	Other crops[1]	Pest incidence (%)
SCARLOS	7500	5250	8325	0.70	3075	76	0	18
ALIMA	8200	6150	13120	0.75	6970	79	1	15
YUGOSL	9000	7830	12150	0.87	4320	76	1	22
DANPE	13200	8400	12880	0.64	4480	80	3	14
MAUEL	11200	4410	5175	0.39	765	84	0	14
MILAG	7800	4960	6882	0.64	1922	80	0	18
GREEN	4500	6650	12825	1.48	6175	79	2	14
INSAC	6200	5780	7480	0.93	1700	80	1	13
MORAV	9500	8500	13500	0.89	5000	75	2	22
TALSA	7500	8250	15400	1.10	7150	80	2	21
SAVSA	10000	7350	11550	0.74	4200	82	1	20
UPAO	11000	5823	7603.5	0.53	1781	83	0	23
Average	8800.0	6612.7	10574.2	0.75	3961.5	79.5	1.1	17.8

Note
[1]Only asparagus (0), other crop (1), two crops (2), three crops (3).

Table 5. Economic indicators of the avocado farms of the Chavimochic irrigation project in December 2017.

Farm code	Yield (kg/ha/year)	Cost (USD/ha/year)	Gross income (USD/ha/year)	Cost per kg	Net income (USD/ha/año)	Export quality (%)	Other crops[1]	Pest incidence (%)
ALPAM	14000	4000	24750	0.29	20750	95	0	9
BEGGIE	16700	6000	27720	0.36	21720	96	1	5
SIMON	10000	6000	16500	0.60	10500	88	1	5
ARENA	19500	7200	32175	0.37	24975	96	0	3
AGRON	12500	6000	20625	0.48	14625	85	1	7
LIMA	13300	7000	21945	0.53	14945	91	0	8
ARATO	16200	6000	26730	0.37	20730	98	1	10
YUGOS	15500	6500	24750	0.42	18250	90	0	10
AVOP	15000	6100	24750	0.41	18650	92	1	8
CAMPO	17000	6000	28050	0.35	22050	98	1	5
DESHI	16500	7000	27225	0.42	20225	93	0	10
GREEN	18000	5000	29700	0.28	24700	88	1	5
HASS	15000	7500	24750	0.50	17250	94	1	8
INVER	16000	6500	26400	0.41	19900	90	0	8
NORTE	14000	6500	23100	0.46	16600	94	0	7
TALSA	15200	6200	23430	0.41	17230	90	0	10
SAVSA	16500	7200	27225	0.44	20025	92	0	8
Average	15347.1	6276.5	25283.8	0.41	19007	92.4	0.5	7.4

Note
[1]Only avocados (0), other crop (1), two crops (2), three crops (3).

especially during harvest, but leads to higher incomes.

Figure 10 shows comparative yields (kg ha^{-1}) of both avocado and asparagus; although avocado showed higher yield, it also showed greater dispersion between farms.

The dispersion of avocado and asparagus yield was very similar (**Figure 10**), with avocado showing higher biomass yield than asparagus. Therefore, the production of avocado (kg ha^{-1}) was substantially higher than that of asparagus.

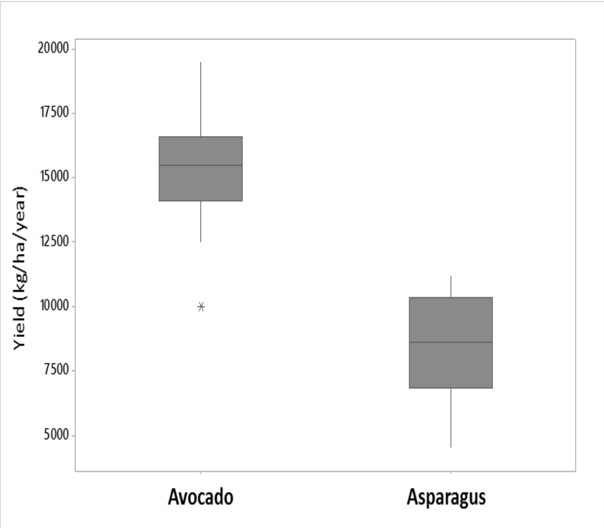

Figure 10. Yield (kg ha−1 year−1) of avocado and asparagus farms in 2017.

Larger farms showed higher net incomes, mainly because of higher returns owing to connections with the external market (**Figure 11**). Additionally, fresh white asparagus was exported, which is highly profitable, and the returns are greater than those obtained from white asparagus used for canning. Small companies do not have the logistics or connections to directly enter into exportation. Ortiz (2018) alluded to the reconfiguration of the asparagus market: fresh green asparagus companies in Peru maintain intense competition with producers in Mexico (with cheaper costs and no restrictions on quarantine and pest fumigation). This has decreased the commercial window of Peru, thus reducing prices and consequently the area of cultivation in Peru. This is why large companies that export directly have higher incomes, while companies with smaller areas suffer losses. In recent years, increase in the cost of production and reduction in prices obtained in the market have created economic problems for small companies with high costs for the cultivation of asparagus. The average incidence of pests is high, reaching 17.5%. This is mainly due to the attack of *P. longifilia*, which affects the crop and the harvest of green asparagus (Castillo, 2019). This pest causes an average reduction of 79.5% in export.

Figure 11 compares the net income of all asparagus and avocado farms. The profitability of asparagus farms was higher in the larger farms. Although avocado farms showed a similar tendency, it was not as marked; the smaller avocado farms showed high income.

Tables 4 and **5** show that the profitability of avocado was higher than that of asparagus. In contrast to asparagus, avocado growers have not diversified their crops, which explains why the vast majority of grower only produce avocado. Pest incidence was lower in avocado (**Table 5**) (7.4%), being the pests of more significant presence the scales which do not affect the yield, but the quality of exportable. Markets such as the United States and recently China require that pest damage showed be less than 5%.

Social dimension analysis

The gender distribution and ages of workers in the asparagus and avocado fields of the Chavimochic irrigation project are shown in **Figure 12.** Males showed more participation (61%) than females (39%). However, the participation of females in the Chavimochic irrigation project is higher than that reported; for example, 13% in Cañete in crops such as citrus and avocado (Collantes & Rodríguez, 2015) and 20% in Chanchamayo in the pineapple crop (Maraví et al., 2018). Relatively young adults of both genders (26–40 years old) showed greater participation than other age groups.

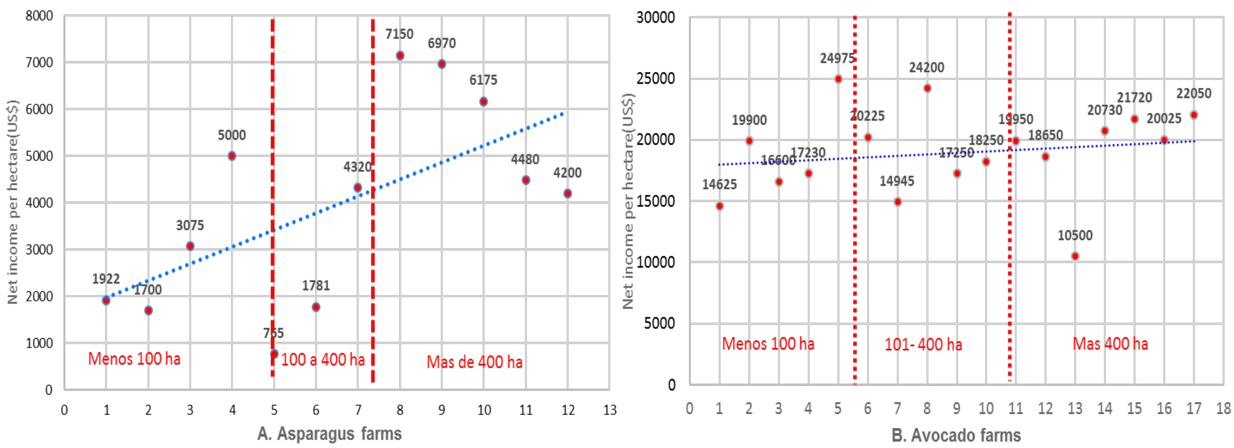

Figure 11. Net income per hectare per year from the asparagus and avocado farms in 2017. (A, B) Net income from the asparagus farms (A) and avocado farms (B).

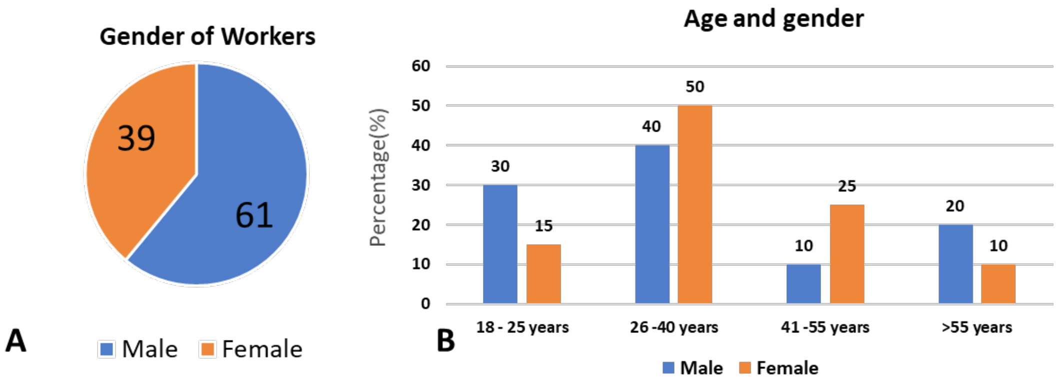

Figure 12. Gender and age distribution of workers in asparagus and avocado farms in 2017. (A) Percentage of workers by gender. (B) Gender and age of workers on asparagus and avocado farms.

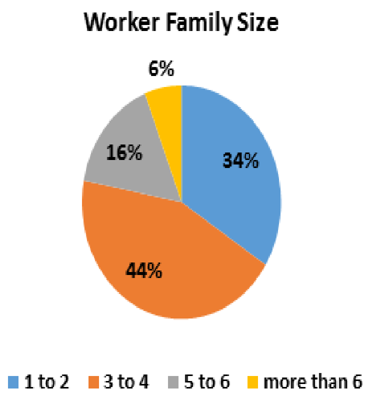

Figure 13. Family size of avocado and asparagus farmworkers of the Chavimochic irrigation project in 2017.

Figure 14 shows that everyone had access to health services, mainly in the nearest cities of Chao, Virú and Moche, which have social security health services. Additionally, water, electricity, and sewage were available to 75% of the workers. Most of the workers had their own houses.

Figure 15 shows the educational level of the personnel working on asparagus farms. Approximately 65% of the managerial personnel and farm chiefs had a master's degree, while the remaining 35% were engineers. At the plot chief level, 50% were technicians, and 34% had a professional title. Among the specialised workers, 61% were technicians. Among the workers, 71% possessed secondary education. This indicated that the higher the level of responsibility, the higher the level of education. The level of education was also related to the level of income.

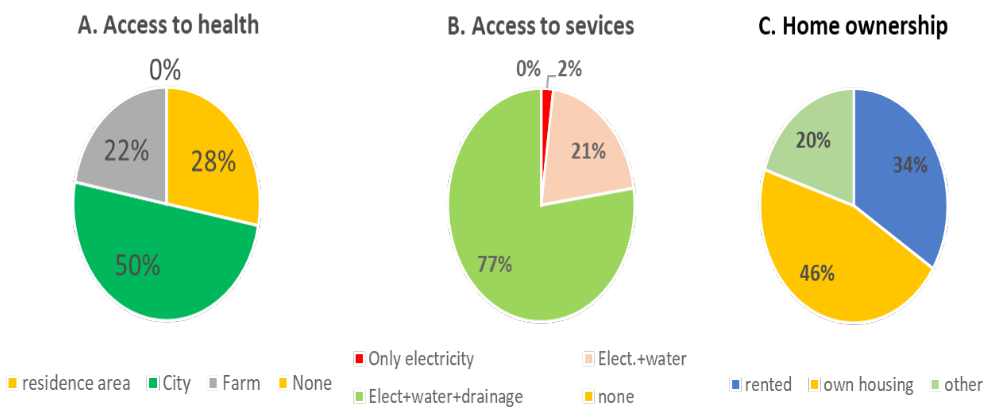

Figure 14. Access of farmworkers of avocado and asparagus farms to various services. (A) Access to health. (B) Access to services at the place of residence. (C) Home ownership of workers.

Figure 13 shows that 44% of the families of farmworkers comprised 3–4 members, while 34% of the farmers comprised 1–2 members. This shows that families of farmworkers were small in size in comparison with families in other areas such as jungles and mountains, where the families are larger in size with more than 5 members.

Figure 16 shows the wage scale of farmworkers. Workers at a higher position earned higher income, and farm managers and personnel with specialised jobs, who possessed a higher level of education, earned the highest income. Thus, at the farms, the level of income of farmworkers depends on the level of their education.

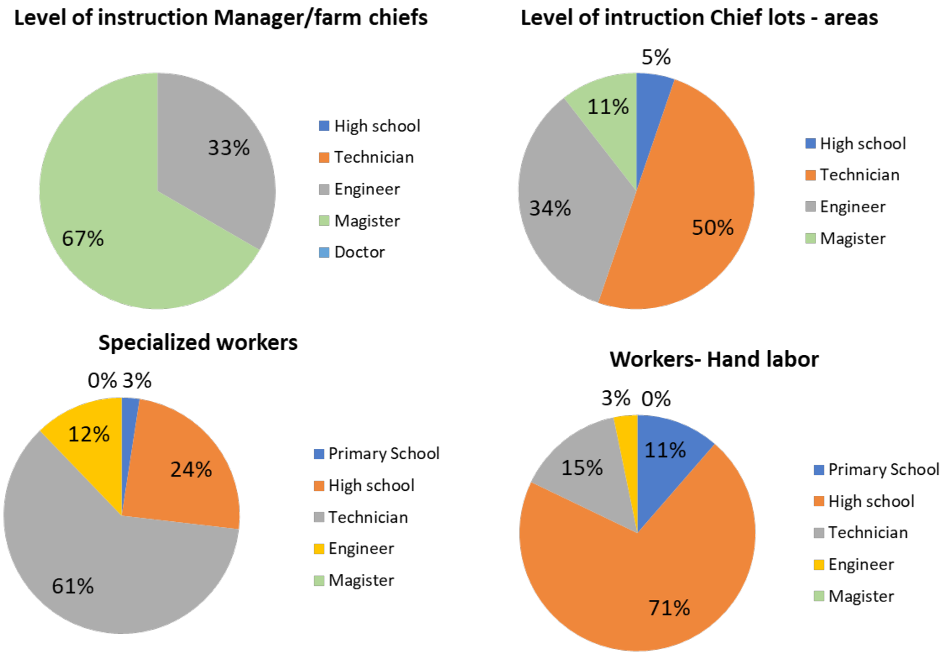

Figure 15. Level of education of the different types of workers of the asparagus and avocado fields of the Chavimochic irrigation project in 2017.

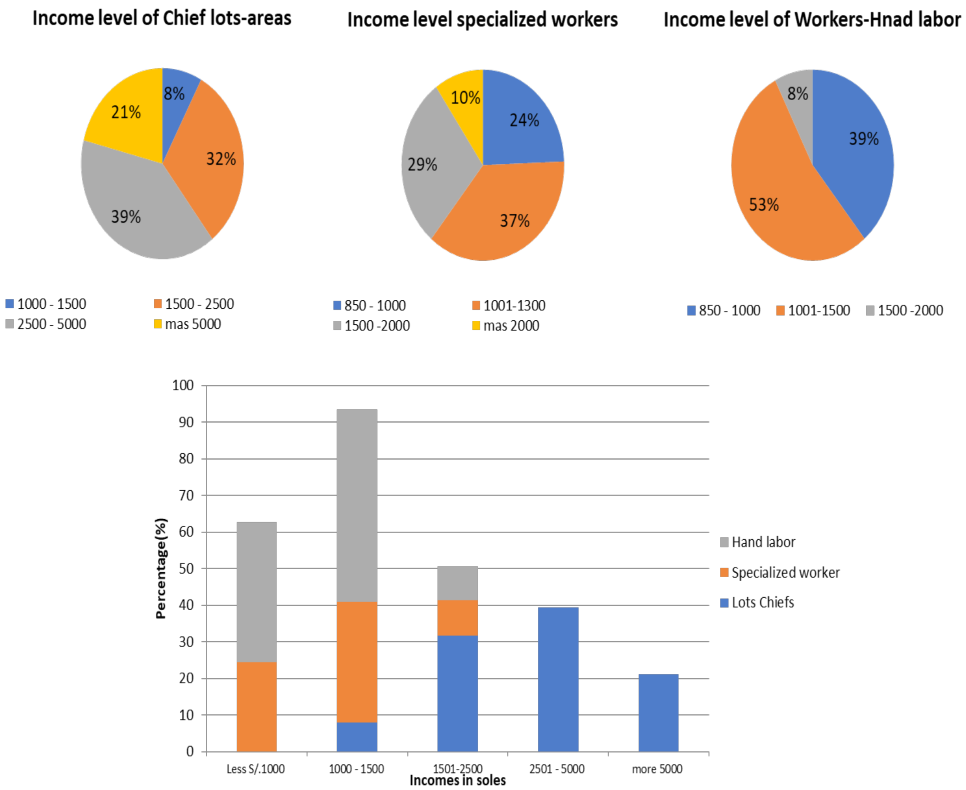

Figure 16. Income level in Peruvian nuevos soles of the different types of workers of asparagus and avocado farms of the Chavimochic irrigation project in 2017.

Conclusions

In the Chavimochic irrigation project, four groups of asparagus farms were identified, which showed a strong correlation with the type of processing, access to market, handling of pesticides and quality certifications. Additionally, three groups of avocado farms were identified, where farm size, quality certifications and crop management were the most critical factors. The income level of farmworkers showed a direct correlation with the education level. The participation of females in asparagus and avocado farms was higher than that in other agricultural areas.

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