

## Sustainable agri-food systems: the case of the avocado value chain in Mexico

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### Abstract

Achieving sustainable agri-food systems (SAS) requires the collaborative work of multiple participants. Using a systemic analytical approach, the limiting factors for the sustainable transition of the agri-food system (AS) of the Mexican avocado value chain (VC) were studied. International, national and government data sources were consulted and complemented by three case studies. Short-term policies, current VC and AS governance structures, inadequate infrastructure for the sustainable use of natural resources and insecurity limit the achievement of the SAS. Acceptable economic indicators for the sector should allow for social and environmental improvements by introducing more efficient irrigation systems and improving current working conditions.

**Keywords:** public policy; industrial organization; technological change; sustainable development; food policy.

### 1. INTRODUCTION

The achievement of sustainable agri-food systems (SAS) is a challenge on a global, national and local level (United Nations [UN], 2021). In an open economy like Mexico's, the international context influences agrifood systems (AS). Furthermore, trade openness allows connection to global value chains (VC) and drives widespread economic growth (World Bank, 2023; Banco de México [BANXICO], 2023). However, it also affects consumer diets, the environment, forms of production and, when there is no planning strategy, agricultural activities become unsustainable (Ambikapathi *et al.*, 2022; Mehrabi *et al.*, 2022; Saviolidis *et al.*, 2020).

In addition, over the last 30 years, Mexican agriculture has gone from contributing 6.8% of GDP in 1990 to 3.8% in 2020. However, in absolute terms, it has increased from MXN\$92 billion to more than MXN\$836 billion (Food and Agriculture Organization of the United Nations [FAO], 2023b). It is also characterized by increased land devoted to the production of staple crops such as corn, beans and sorghum, although it must import these and other products to meet domestic demand. In contrast, with areas up to 30 times smaller than those devoted to staple crops, malting barley, six species of vegetables and some fruit trees such as avocado, lemon and lime were among the top ten exported crops in 2020 (FAO, 2023a, 2023b and 2023c).

This allows us to identify two key scenarios for the Mexican agricultural sector: *i*) the inefficiency of sectors of national interest and *ii*) the unsustainability of commercial or export sectors (World Bank, 2020). Under current production systems, the production of strategic crops for Mexico could decrease by up to 34.5% by 2100 (Estrada *et al.*, 2022). In the case of avocados, by 2050, the most likely variations in production systems will face positive and negative changes related to temperatures and precipitation levels in the main production areas (Grüter *et al.*, 2022).

Due to the current situation of the scenarios mentioned above, actions must be proposed at the federal and territorial levels to promote gradual improvement towards efficient AS at the global level and sustainable ones at the local level (Bravo-Espinosa *et al.*, 2012; Van-Noordwijk and Brussaard, 2014), through the articulation of sustainable and inclusive value chains (SIVC) with multi-stakeholder actions (Jha *et al.*, 2014; Lucio, 2022) to promote cooperation, reduce inequalities between VC participants and strengthen the less innovative links (Hansen and Birkinshaw, 2007; Martínez and Tapia, 2020).

An AS is a group of participants that carry out activities related to VCs affected by the environment in which they operate, in which there is a constant interaction between participants, public and private organizations, infrastructure, laws and regulations, which allow for actions that impact nutrition and health, economic well-being, environmental quality and land balance and equality. If these activities do not negatively compromise the economic, social and environmental base, we can speak of SAS (David-Benz *et al.*, 2022; International Fund for Agricultural Development [IFAD], 2019; Laibuni *et al.*, 2018; UN, 2021).

Not negatively compromising the abovementioned basics includes ethical, philosophical and regulatory principles, which must be based on logical rationales supported by scientific information. It also requires maintaining, improving or recovering available natural resources, promoting improved human relations, greater equity and reducing individual and collective poverty levels as much as possible (Fernández and Gutiérrez, 2013; Haro-Martínez and Taddei-Bringas, 2014).

This research aims to identify the limiting factors of the sustainable transition of the Mexican avocado VC to provide inputs that facilitate informed decision-making for government officials, entrepreneurs, academics and society in general. The avocado sector was used as an empirical reference due to its historical, economic, social and environmental relevance for Mexico, allowing it to form part of the national and international AS.

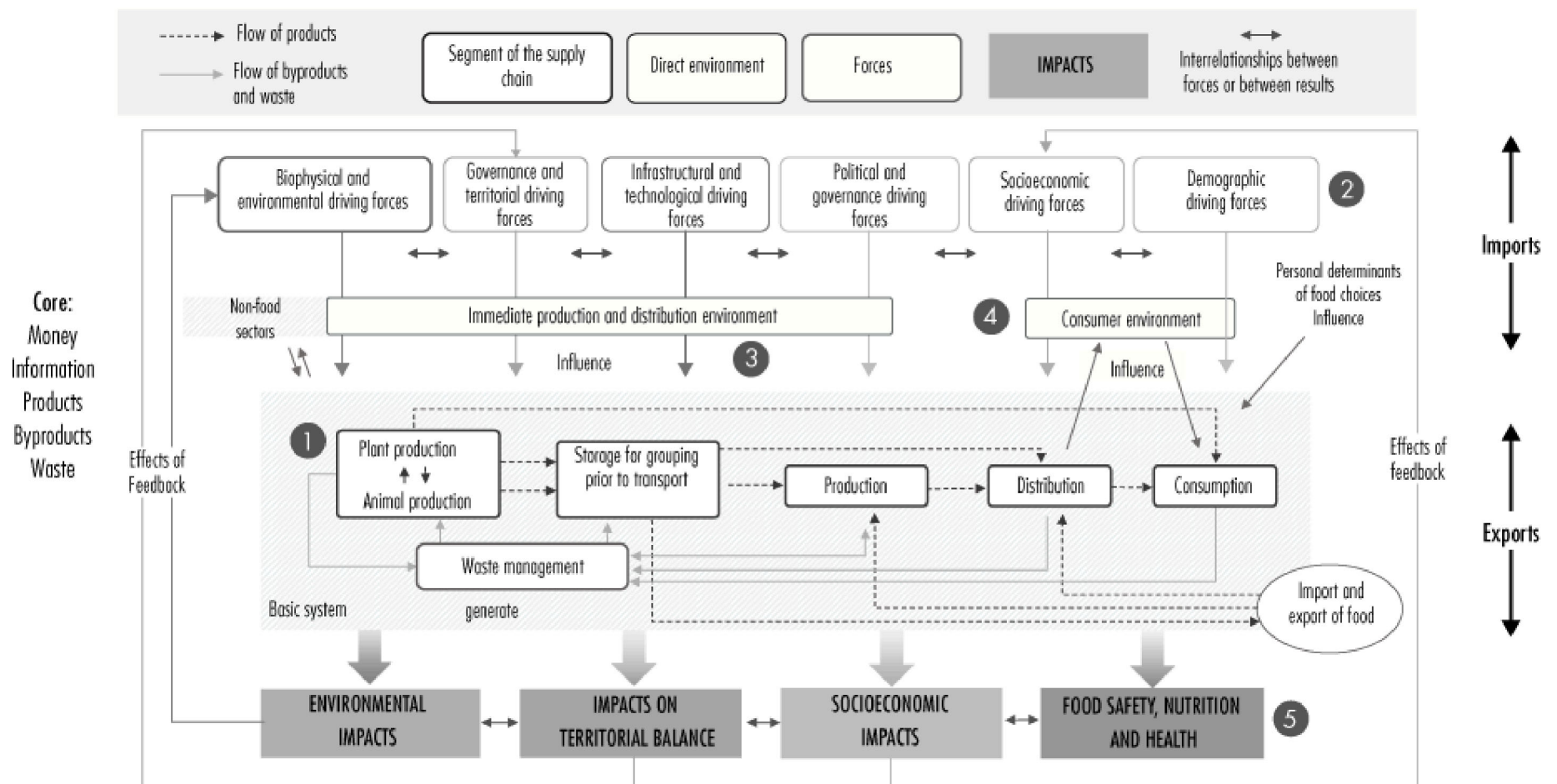
The working hypothesis indicates that the transition to SAS in Mexico is hindered by structural variables such as short-term government policies (GP), government structures with participants that favor the economic aspect over social and environmental variables, insufficient infrastructure for the sustainable use of natural resources (such as water) and the low contribution of agricultural VCs to the national GDP (FAO, 2023b; Instituto Nacional de Estadística y Geografía [INEGI], 2019a; México-Presidencia, 2019).

The article is structured as follows: after the introduction, the first section presents the methodological approach used, the origin of the information and the variables considered. This is followed by the results and a discussion based on the six driving forces analyzed. The penultimate section describes the prospects and challenges of the avocado sector and, finally, the conclusions are presented.

## 2. METHODOLOGICAL APPROACH

Five AS components were considered (see Figure 1), affected by six driving forces (endogenous or exogenous processes) developed in the paper and complemented with contextual elements to promote SIVC. This systemic approach allowed us to derive a series of action-oriented conclusions from a combined perspective of VC with AS and not from a separate perspective as other studies have done (Denvir *et al.*, 2022; Khan *et al.*, 2021; López-Sánchez *et al.*, 2021).

Figure 1. Conceptual framework of a food system



Source: compiled by the authors based on David-Benz *et al.* (2022) and IFAD (2019).

The AS methodology described by David-Benz *et al.* (2022) was used. Furthermore, to align with the SIVC approach, aspects recommended by the International Fund for Agricultural Development (IFAD) (2019) to promote SIVC were included. To meet the objective and guide the results, three multiple case studies were included, considering the elements mentioned by Yin (2001). Figure 1 summarizes the process.

The case studies were three agribusinesses located in three of the main avocado-producing states in Mexico. These companies process avocados for sale (packing) and the responsible parties were interviewed in June (State of Mexico) and July (Morelos) 2021, as well as in April 2022 (Michoacán). The states where these packing plants are located accounted for 81.9% of national production in 2021 (Servicio de Información Agroalimentaria y Pesquera [SIAP], 2023). The cases studied allowed us to understand how the VC interacts with the AS.

To complement the information, official sources from national and international organizations were consulted (see Table 1). In addition, two databases from governmental agencies exclusively related to the avocado sector were requested and accessed. The first was requested (number 0821000036221) and provided by the Agrifood Health, Safety and Quality Service (SENASICA) through the National Transparency Platform and the National Institution for Access to Information (PNT and INAI, 2021). The second was provided by the National Institute of Statistics and Geography (INEGI) and contains information from the National Agricultural Survey (ENA) in Mexico (INEGI, 2019a and 2019b).

**Table 1. Origin of the information and analytical tool used according to the driving force**

Source	Variables	Applied methodology or analytical tool	Driving force* (1, 2, 3, 4, 5, 6)
INEGI database (2019a)	Production systems	Graphical analysis	1, 3, 4, 5
	Environmental variables	Synthetic tables	
	Irrigation infrastructure	Case study	2
Packing plant interviews	Relations	Content analysis	
	Recommendations	Descriptive analysis	
		Sankey graphs	
Various documentary sources	Historical milestones	Timeline	2
	Surface area (hectares)	Graphic analysis	
	Production (tons)		
SADER and SENASICA databases (2021)	Age of plantations	Graphic analysis	2, 3, 4
	Public policies		
	Phytosanitary		
	Support and services		
Various sections of the FAO website	Agriculture (% of GDP)	Graphic analysis	5, 6
	Food security	Correlations	

Notes: \*1 biophysical and environmental; 2 governance and territorial; 3 infrastructural and technological; 4 political and governability; 5 socioeconomic; 6 demographic. Numbers do not imply hierarchy.

Source: compiled by the authors.

The SENASICA database concentrates the 2020 census for the states of interest where the campaigns against regulated avocado pests operated; the data is at the production unit level (PU). Regarding the INEGI database, the data is at the aggregate level and as a percentage (%). It includes the production of the 2019 spring-summer and autumn-winter cycles (INEGI, 2019b).

Different sources of information made it possible to apply different methodological tools to analyze each of the AS's driving forces (see Figure 1), as shown in Table 1.

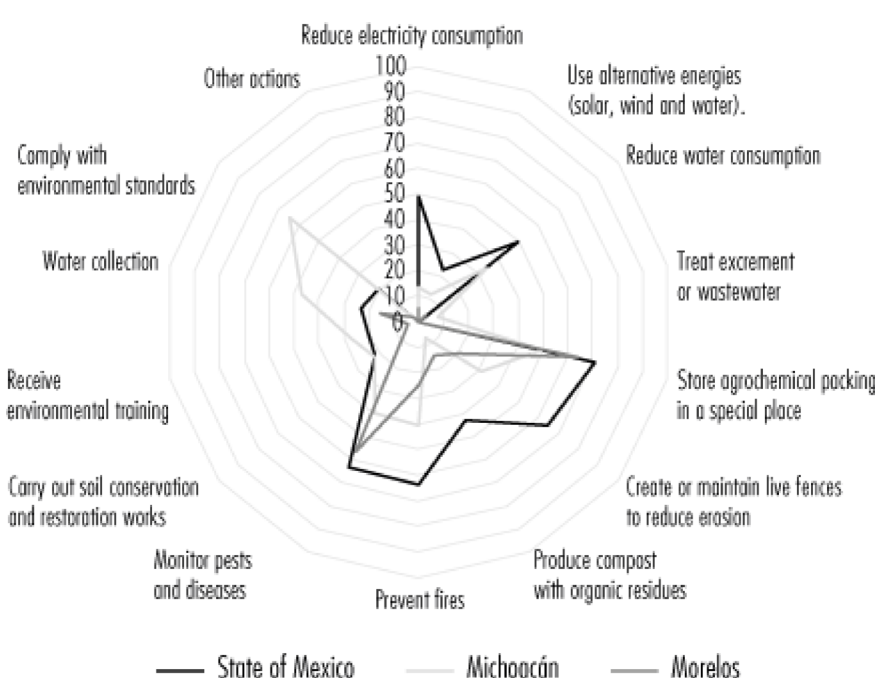
### 3. RESULTS AND DISCUSSION

To identify the limiting factors for the sustainable transition of the Mexican avocado AS, the results focused on the endogenous or exogenous processes that affect the AS of interest, classified into the six driving forces mentioned in the methodological approach: biophysical and environmental, governance and territorial, infrastructure and technological, political and governability, socioeconomic and demographic.

#### Driving forces: biophysical and environmental

Figure 2 shows some environmental improvement actions carried out in the PU where the visited avocado packing plants operate.

Figure 2. Percentage of PUs adopting actions to protect the environment



Source: compiled by the authors with data from INEGI (2019a).



Actions such as responsible water management, handling of agrochemicals, production of organic products or monitoring of pests and diseases require technological improvement in the PUs. On the other hand, actions such as fire prevention, soil conservation and training or compliance with standards reduce the impact on the environment and forests in particular, reducing the adverse effects on natural resources such as water and air quality.

Van-Noordwijk and Brussaard (2014) argue that technological improvement does not always reduce land use or save forests, including, if considerable profit margins exist, increased pressure on these natural resources. Similar cases occur in Ethiopia with eucalyptus plantations (Tesfaw *et al.*, 2021) or some coffee plantations (Jha *et al.*, 2014; Sporchia *et al.*, 2021).

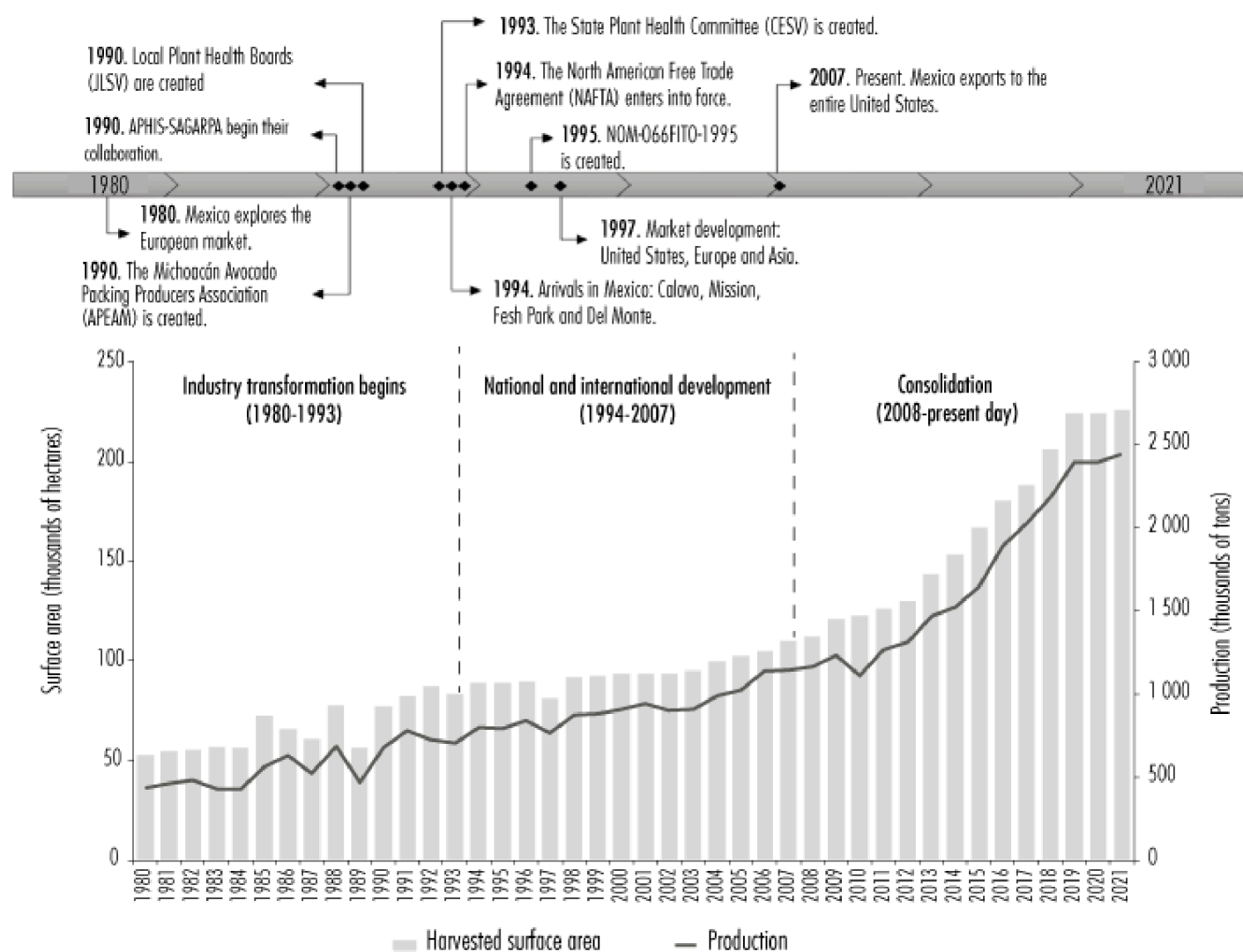
In this respect, it has been documented that the increase in avocado production in Mexico is based on the surface area, which has increased by 400% in the last 30 years (Charre-Medellín *et al.*, 2021), displacing natural areas where diverse plant species grow and endemic animals live (De la Torre *et al.*, 2018; González-Cortés *et al.*, 2012; Lucio, 2022). In Michoacán, between 2001 and 2017, 20% of deforestation was associated with new plantations of this fruit tree (Cho *et al.*, 2021). Based on the facts shown, the Mexican avocado sector is severely criticized nationally and internationally from an environmental point of view, even when the area harvested with this fruit is 31.8 times less than that harvested with corn (FAO, 2023a).

In summary, the effects of this activity on the environment are not widespread or in the main producing areas, although the change in land use due to mono-crops such as avocados affects forested areas (Cho *et al.*, 2021; España *et al.*, 2022) but does not always significantly affect soil microbiota or organic matter content (Bravo-Espinosa *et al.*, 2012; González-Cortés *et al.*, 2012). There has even been an argument about the reforestation and recovery of agricultural lands thanks to avocado plantations (Centro de Investigaciones en Geografía Ambiental [CIGA], 2011).

### Driving forces: governance and territorial

Documentary analysis and interviews revealed that producers do not dominate the VC or AS. Thus, to identify the dominant participants, the relevant historical milestones and the evolution of this activity in Mexico are shown (see Figure 3).

Figure 3. Relevant historical milestones and evolution of avocado production in Mexico (1980-2021)



Source: compiled by the authors using SIAP (2023) information and documentary review.

Until 1980, the avocado industry was linked to public research on the improvement of varieties carried out by institutional participants such as the Center for Scientific and Technological Research on Avocado in the State of Mexico (CICTAMEX) and the National Commission for Fruit Growing (CONAFRUT), which in 1970 transferred their results to Michoacán and established the first plantations with the "Hass" variety for seed collection, thus initiating the new period of transformation of this industry (Ayala and Ramírez, 2022; Martín-Carbajal and Padilla, 2008; Sánchez-Colín *et al.*, 2001) (see Figure 3).

Most of the historical events or milestones for the crop took place in the state of Michoacán (see Figure 3, upper area). In addition, Mexico's entry into world trade with the North American Free Trade Agreement (NAFTA) in 1994 favored the development of the private sector, leading to the separation of the sector into two sub-sectors: the first, producers who decided not to comply with standards and the second, producers who, with the support of international, national and state organizations (APHIS, SAGARPA, CESV, APEAM, JLSV), complied with sanitary standards (NOM-066FITO-1995) to develop markets.

There are currently 112,547 avocado PUs (111,776 are small and medium producers with PUs between 0 and 20 hectares) in the three states considered (Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food [SADER] and SENASICA, 2021).

With the arrival of transnational packing companies in Mexico in 1994, avocado activity developed in association with national producers, intermediaries and packing companies, driving the expansion of a national and international avocado sector. In the current global configuration, Mexico plays a supplier role in a VC driven by global buyers, where the link between buyers and suppliers is the packing companies, which decide what and how it is produced (Humphrey and Schmitz, 2002; Reyes-Gómez *et al.*, 2023).

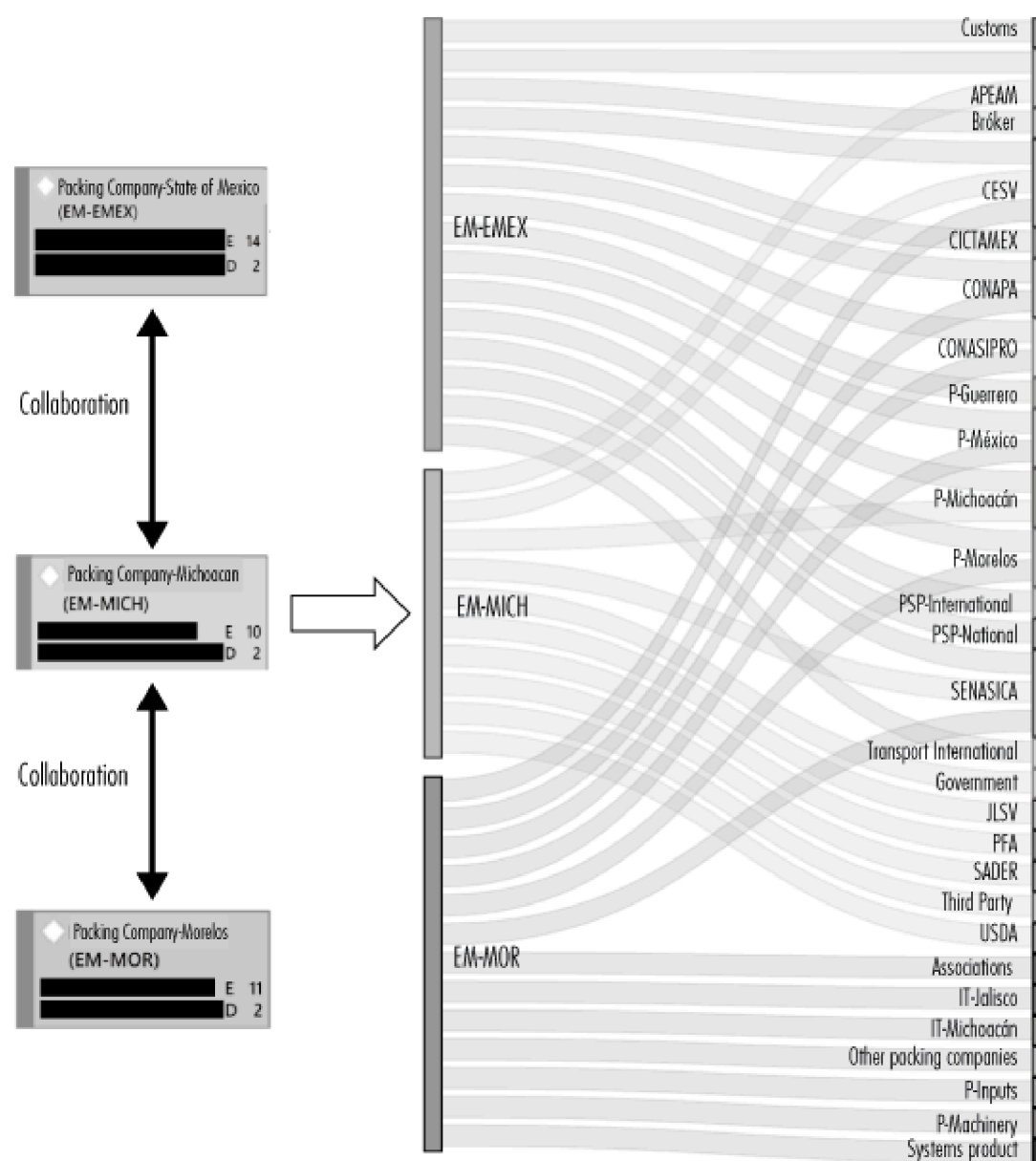
According to SENASICA and SADER (2023), there were 202 packing plants as of January 2023: 84 can export to any country in the world (and are located in the states of Michoacán and Jalisco), 92 can export to the domestic market and can export to any country except the United States (US), 26 can export to the domestic market and two are registered as industrial plants.

In short, the political conditions, the specific alignment of public and private organizations (Fontoura *et al.*, 2016), a VC driven by vertically integrated foreign transnationals seeking to achieve efficiency (Querejazu, 2020; Martín-Carbajal, 2016), which allows them to avoid sanctions due to the desired or undesired consequences of their actions (Bentia, 2021), favored the establishment in Mexico of governance structures dominated by the corporate power of these transnationals, creating institutions and altering their operations based on their interests (Hernández-López, 2012), to maintain national and international control.

Vertical integration allows packing companies to remain leaders in the VC (Reyes-Gómez *et al.*, 2023), leading to the following question: with which producers are they related in order to perform all activities in the chain? (see Figure 4).

Figure 4 shows the collaborations that the packing companies maintain with other participants who are considered links in the VC: producers (P-Guerrero, P-Mexico, P-Michoacan and P-Morelos), other local and national packing companies, and intermediaries between international buyers and sellers (brokers). The rest are public and private parties that are not considered links in the VC, but by providing inputs, technology or various services, they are considered complementary (De Janvry and Sadoulet, 2020).

Figure 4. Relationship with parties in and outside the VC



Notes: Abbreviations: Association of Avocado Producers and Packers Exporters of Mexico (APEAM); State Plant Health Committee (CESV); Avocado Scientific and Technological Research Center of the State of Mexico (CICTAMEX), National Council of Avocado Producers (CONAPA); National Committee of Product System (CONASIPRO); Producers (P-Mexico, P-Michoacan, P-Morelos); Professional Service Providers (PSP-International, PSP-National); National Service for Agri-Food Health, Safety and Quality (SENASICA); Local Plant Health Board (JLSV); Authorized Phytosanitary Professional (PFA); Ministry of Agriculture and Rural Development (SADER); United States Department of Agriculture (USDA); Technological Exchange (IT-Jalisco, IT-Michoacán); Suppliers (P-Inputs, P-Machinery).

Source: compiled by the authors using field data (2021-2022).

Some additional parties can influence the chain under analysis as much as or more than the VC links themselves (see Figure 4). These include the governments represented by USDA and SENASICA, associations such as APEAM, CONAPA, and CONASIPRO, national and international quality certifiers such as third parties and PFA, civil associations such as CIC-TAMEX, product systems and complementary parties for sanitary actions represented by the CESV and the JLSV.

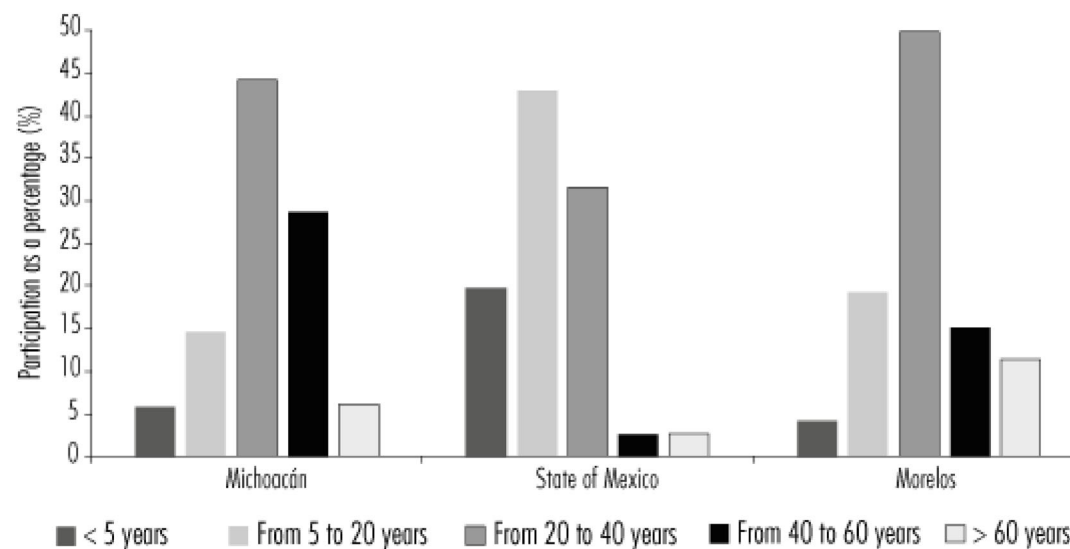
In the three cases presented, the business models were differentiated, both in terms of products and demonstrated quality, through certifications, allowing them to maintain advantages over their competitors in terms of volume, price and quality. They are responsible for ensuring product quality with their suppliers and direct

buyers. They are the link with the highest profits in the chain (40%), followed in order of importance by producers (35%), buyers and distributors (25%), and intermediaries (15%) (Franco *et al.*, 2018; Martínez *et al.*, 2013; Reyes-Gómez *et al.*, 2023; Sangerman-Jarquín *et al.*, 2014).

To implement the VC, the packing companies are clear about the importance of achieving crucial public and private partnerships, both in and outside the chain, which should be a fundamental premise for the transition to SAS. This coincides with other authors (López-Sánchez *et al.*, 2021), as it acknowledges the interaction between the socioeconomic, food, territorial and environmental dimensions and assesses the demand for new governance structures at the national, subnational and international levels (Cho *et al.*, 2021).

It was also found that the emergence of national and state leaders is influenced by experience in the activity. Figure 5 shows the current age of plantations in the states under study. This variable marks the beginning of a broad process involving VC participants interacting with other public and private participants in the AS.

Figure 5. Age of established plantations as of 2020



Source: compiled by the authors with data from SADER and SENASICA (2021).

Michoacan has the most commercial experience in avocado production (50 years) and the best organizational structure. However, three types of companies can exist in all three states (see Table 2). The number of employees, their level of education and the activities they carry out in the chain are key variables that are of attention to promote SAS (IFAD, 2019).

Table 2. Summary of cases

Characteristic	State		
	Michoacán	State of Mexico	Morelos
Type of company	Private-business	Family	Organization
Size	Not specified	150 employees	76 employees
		Primary (62)	Secondary (15)
		Secondary (61)	High school (56)
		High school (23)	Bachelor's degree (5)
		Bachelor's degree (4)	
Activities*	C1 - A - E - C2	P - C1 - A - E - C2	V - P - C1 - A - E - C2

\*Notes: C1 - Purchases; A - Harvests; E - Packs; C2 - Commercializes; P - Produces; V - From nursery.

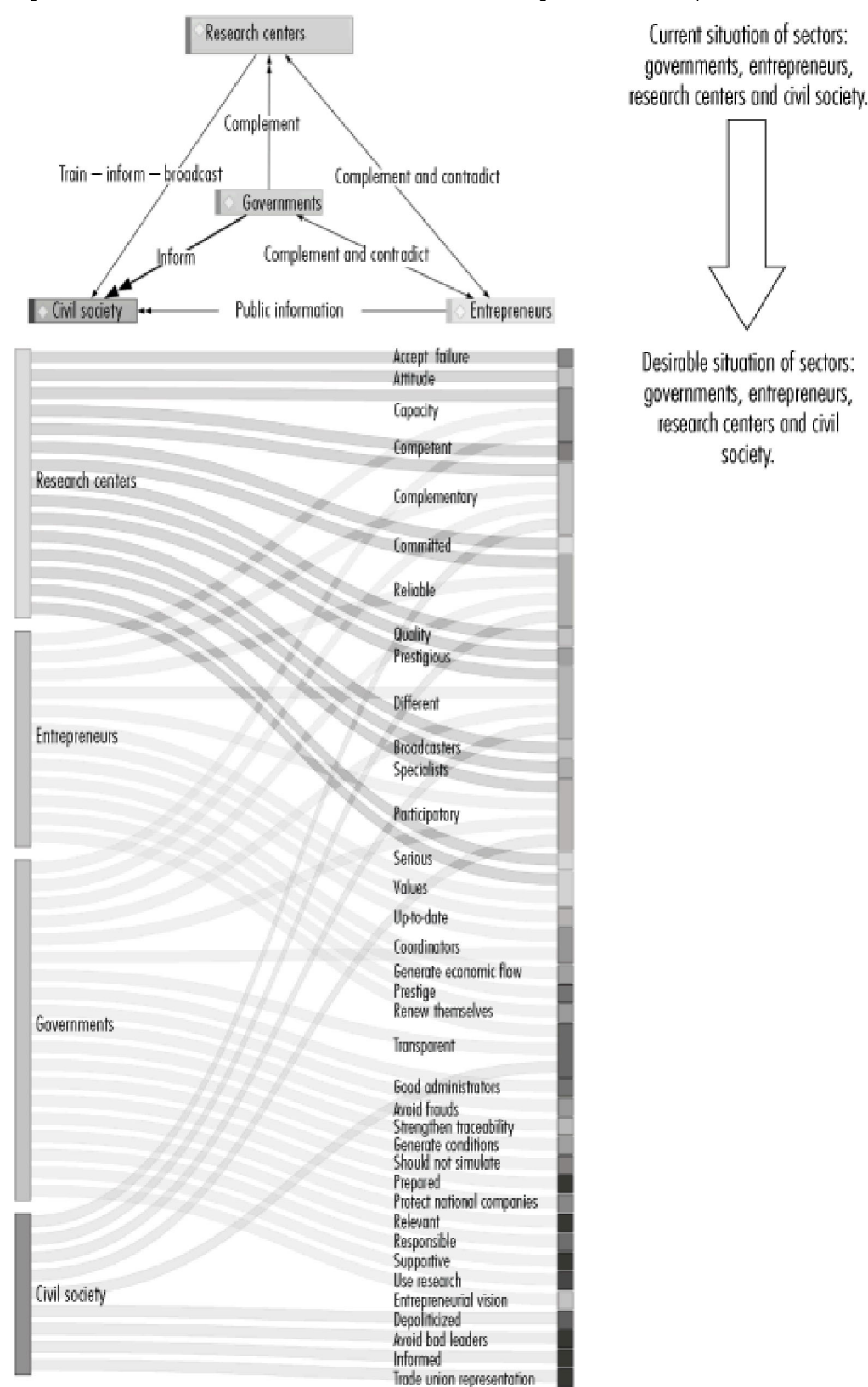
Source: compiled by the authors with field information (2021-2022).

The global influence of the sector under analysis demands the development of skills outside the AS, such as a higher level of education for agricultural employees and certifications in good manufacturing practices (GMP). This requires policies related to labor rights and the development of adequate infrastructure for their activities (Ambikapathi *et al.*, 2022; Ryan, 2023) and are justifications for promoting multi-party collaboration.

Assuming that achieving SAS will be possible to the extent that collective work is accomplished, those responsible for packing were asked what role should be played by governments through their public policies, businesses, public and private research centers and civil society to improve the performance of the VC (see Figure 6).

Figure 6. Current situation and desirable situation





Source: compiled by the authors with field information (2021-2022).

Cases of similar behavior between governments and entrepreneurs have been found in the USA (Mazzucato, 2014). Information regarding entrepreneurs exists, but it is not public. They only provide information to certifiers, large retailers or when a product needs to be withdrawn from the market (Cho *et al.*, 2021).

There are cases, such as Chile, where the government did not limit itself to being an enabling agent (Gereffi and Korzeniewicz, 1994). Joint work with leading national companies and research centers made it possible to demonstrate the technological feasibility and sustainable success of the grapevine-wine VC (Gwynne, 2012). However, transparency is a precondition for sustainable production and consumption (Mehrabi *et al.*, 2022; Saviolidis *et al.*, 2020).

Certifications are generally how packing companies demonstrate the adoption of standards based on norms, including those relating to sustainability. The number and type of certifications vary, depending on the buyer's requirements. The Mexbest-SADER (2023) platform reports Mexican packing companies that have adopted up to eight certifications to market avocados globally.

The US consumes more than 75% of Mexican avocado exports. Still, other countries in the Middle East and some European countries are seeking to achieve sustainable consumption among their populations since their purchasing power allows them to pay to consume this type of product (Arnold, 2020; FAO, 2023f).

According to the Ministry of the Economy and the Global Economic Intelligence Unit (SE-UIEG), there is a group of 15 attractive countries for Mexican avocado exports, including the Netherlands, the United Kingdom, some European countries, the United Arab Emirates and Saudi Arabia. However, although they represent an opportunity to diversify markets and trade products with sustainable recognition, Mexico is in fourth or fifth place as a supplier for these countries, surpassed by other countries such as Peru, Chile, South Africa and Kenya (SE-UIEG, 2023).

### Driving forces: infrastructural and technological

Table 3 presents the current avocado production systems by the type of production obtained in the states considered.

**Table 3. Production systems by state, figures as a percentage (%)**

Production system	State		
	Michoacán	State of Mexico	Morelos
<b>Based on chemical products</b>			
Herbicides	72.8	55.7	66.5
Insecticides	72.1	28.2	71.5
Fungicides	65.0	73.2	59.0
<b>Based on organic or biological products</b>			
Herbicides	16.6	21.0	0.4
Insecticides	17.7	41.5	9.2
Fungicides	12.6	22.9	8.9
Biological pest control	55.5	24.9	10.5

Source: compiled by the authors with data from INEGI (2019a).

The agrochemical-based production system contributes to social and economic development but is also the main threat to sustainability (see Table 3). However, stopping the use of these inputs would also be the main cause of crop losses, estimated between 20 and 40%, only in the states of Jalisco and Michoacán (Bravo-Espinosa et al., 2012; López —Sánchez *et al.*, 2021).

Sustainable adaptation based on climate-smart inputs, such as organic production and production based on biological inputs, is a viable alternative. However, it only accounts for 8% of the world's avocado production area, including countries such as Mexico, Italy and China (Gannon *et al.*, 2021; Granatstein *et al.*, 2015).

Another precondition for the sustainable use of natural resources is the infrastructure available for production, as shown in Table 4 for the avocado sector.

**Table 4. Available irrigation infrastructure as a percentage (%) by state**

Characteristic	State		
	Michoacán	State of Mexico	Morelos
<b>Origin of the irrigation water</b>			
Spring	40.3	39.8	25.8
Dam	25.1	-	-
Bank/hollow/other	23.1	14.5	24.0
River	-	47.4	27.6
<b>Type of water used</b>			
White or drinking	80.4	95.5	57.8
Treated	19.3	2.5	36.4
Not known	0.8	5.6	16.6
<b>Irrigation system</b>			
Land channel	97.0	49.2	-
Drip	18.9	29.4	-
Gate pipeline	-	24.3	74.2
Other	18.4	-	68.3

Source: compiled by the authors with data from INEGI (2019a).

The increase in surface area results in a constant demand for water, generating conflict in deciding whether to use more water for agricultural production or human consumption (see Figure 3). This situation is exacerbated in the State of Mexico and Michoacán by the use of drinking water (see Table 4).

Adequate and sufficient infrastructure for irrigation management influences the efficient use of fertilizer (Gulati *et al.*, 2012) since it can generate a high return on investment per unit of fertilizer applied, as in the case of tobacco (Sporchia *et al.*, 2021).

### Driving forces: political and governability

Table 5 shows some indicators of coverage of the plant health program to eradicate regulated avocado pests. This program is part of the most relevant agricultural public policy for the sector under study.



**Table 5. Public policies in terms of health regulations by state in 2020**

<i>Indicators</i>	<i>Michoacan</i>	<i>State of Mexico</i>	<i>Morelos</i>
Surface area where SENASICA operates (hectares)	191 024	2 590	5 795
Producer municipalities	74	18	20
Free of regulated pests	47	7	6
Subject to phytosanitary control	27	11	4
Total plantations	101 262	1 320	9 965
Commercial vegetable plantations (> 1 hectare)	48 567	674	2 617
Backyard vegetable gardens (< 1 hectare)	52 695	646	7 348
Average surface area (hectares)	1.8	3.3	1.5
Average yield (tons/hectare)	10.8	11.5	9.0

Source: compiled by the authors with data from SADER and SENASICA (2021).

Michoacán is the most representative state in terms of avocado production area in Mexico. Plant health is a common good that benefits all producers. Its most relevant contribution is its attention to backyard vegetable gardens of less than 1 hectare (see Table 5), which could become a focus of infestation by regulated pests. This would aggravate the situation in free municipalities or areas under control.

SENASICA justifies its actions under NOM-066-FITO-1995 regarding product health and mobilization both inside and outside the country (*Official Gazette of Mexico* [DOF], 1996) to guarantee its participation in national and international markets. The permanence of the program is subject to the annual budget allocated by the government in office (National Council for the Evaluation of Social Development Policy [CONEVAL]-SADER, 2021; DOF, 2020; Mexico-Presidencia, 2019).

According to the packing plant managers interviewed, the safety and other certifications that national and international buyers demand are provided by private certification companies or third-party specialists endorsed by a national or international institution, such as the USDA or SENASICA.

In the avocado sector, standards have been developed, including sustainability standards. However, poverty and marginalization persist in several producing municipalities (Vázquez-Elorza *et al.*, 2021) even with the high profitability of the activity. This is similar to the development of sustainable certifications, identified by Jha *et al.* (2014) in relation to shade-grown coffee, where it was proven to be an option to maintain biodiversity and ecosystem services, although it also failed to reduce poverty.

Historical, political, ecological and cultural conditions permitted the consolidation of the role of specific international and national VC parties in states where criminal groups are on the rise and control local economic and political life through extortion and protection rackets, increasing the crime rate in Michoacán, State of Mexico and Morelos (Ayala and Ramírez, 2022; Maldonado, 2013; Vázquez-Elorza *et al.*, 2021).

Prieto-Curiel *et al.* (2023) show that a viable way to reduce the levels of violence in the states would be to minimize recruitment for organized crime per week (estimated at 350 people). This sector is the fifth largest employer in the country, surpassing companies such as PEMEX, BIMBO and OXXO. The same number of well-paid jobs would have to be generated to achieve this, which is difficult to achieve in the agri-food sector.

Therefore, the state's capacities need to be strengthened through the availability of more communication routes to provide services, increase its presence and reduce corruption to decrease violence levels. However, poverty levels and the lack of opportunities in the producing regions increase violence (Pérez, 2018; Vázquez-Elorza *et al.*, 2021).

The shortage of skilled labor is an issue to be discussed further. In Mexico, AS accounts for the largest share of employment in agriculture and food services activities. Still, there is a shortage of developed skills in 34 of the 35 proposals by the Organization for Trade and Economic Development (OECD), considering agriculture, forestry and fishing (Ambikapathi *et al.*, 2022; Hincapié, 2015; Ryan, 2023).

### Driving forces: socioeconomic and demographic

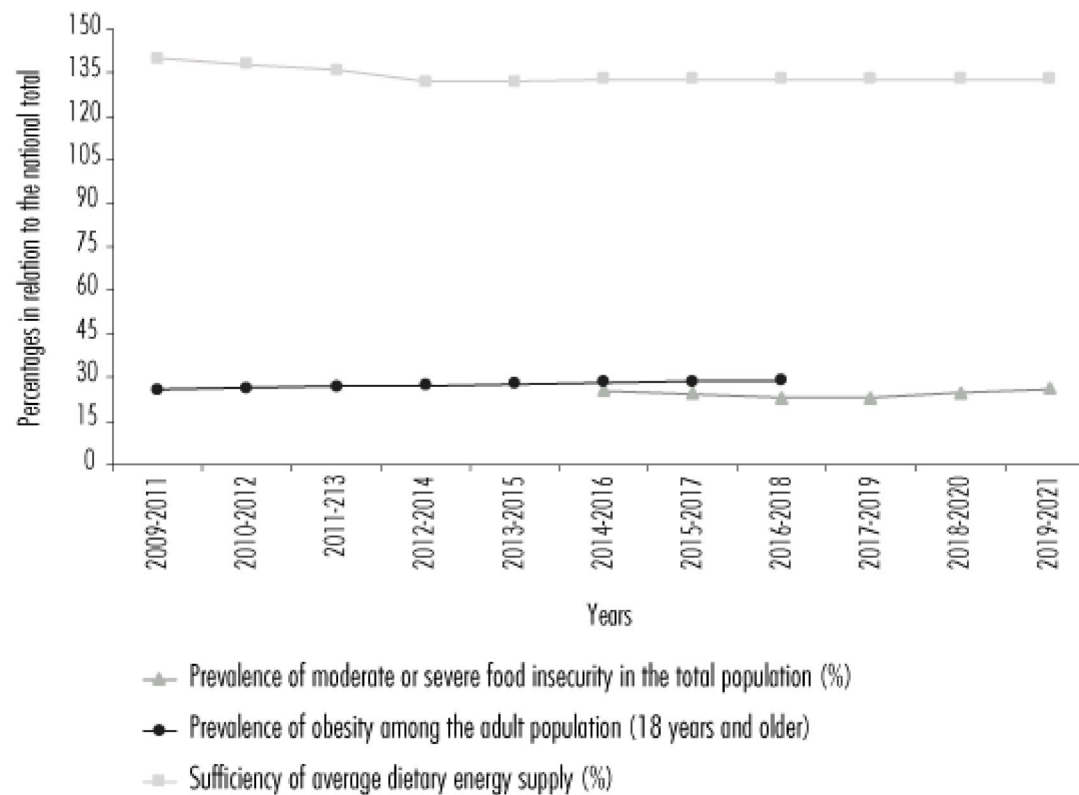
Some benefits of the avocado sector in Mexico are the creation of jobs and the reduction of emigration in producing areas. More than 40,000 direct jobs are created by this fruit tree in Michoacán, Jalisco and the State of Mexico alone. Nationwide, there are currently 251,132 hectares established, with each hectare requiring 118 day laborers per production cycle (Association of Avocado Producers of Jalisco [APEAJAL], 2020; Agriculture-Related Trusts [FIRA], 2020; National Council of Avocado Producers-National Council of Production Systems [CONAPA-CONASIPRO], 2023; SIAP, 2023). However, the socio-economic impacts have been mixed and concentrated in transnational companies (Denvir *et al.*, 2022).

Foreign transnational companies have officially participated with more than 45% of exports since 2007 (Echánove, 2008). However, their leadership began when Mexico started its internationalization process with the entry into force of the then NAFTA (see Figure 3).

Despite the above, avocado activity is considered the driving force of the economy and rural development of Michoacán's producer municipalities, where 62.7% are classified with a high to very high marginalization index (Vázquez-Elorza *et al.*, 2021), which may explain their dependence on this crop.

Furthermore, under current conditions, there is enough food to provide for the more than 130 million Mexicans, but its distribution is unequal. This is probably the reason why 24.6% of the population is subject to some level of food insecurity, and obesity rates have tended to increase since 2009 (FAO, 2023d) (see Figure 7).

Figure 7. Food security in Mexico



Source: compiled by the authors with data from FAO (2023d).

The three scenarios shown in Figure 7 are multifactorial. Some possible explanations for open economies are improvements in income to access more food, although this does not guarantee an adequate nutritional diet (Ambikapathi *et al.*, 2022; Mehrabi *et al.*, 2022), which can lead to problems of food insecurity or obesity.

According to FAO data (2023e), when correlating the ten main food groups measured by effective consumption from 2010 to 2016, a significant and strong association of obesity with the intake of meat in general, milk, eggs, corn and soybeans was observed, while wheat and avocado were the opposite case. Despite the above, and the fact that Mexico is one of the primary consumers of avocado worldwide (8.76 kg/person/year in 2020), this fruit is not part of the basic food basket, nor does it represent a sector of importance for current policies and programs (APEAM, 2021; Arias *et al.*, 2018; CONEVAL, 2021; Lema *et al.*, 2022; Mexico-Presidencia, 2019; SADER, 2023).

Achieving SAS would not be enough to solve the magnitude of the problem presented, but fruits and vegetables (such as the case addressed) could mark the beginning of a healthy diet, even though these VCs have not received adequate attention (España *et al.*, 2022; UN, 2021). For this reason, it is considered that actions in Mexico should be aimed at improving avocado distribution channels and promoting its consumption, particularly in population groups with limited economic resources and older people located in rural areas, and not just in urban areas (Rubí-Arriaga *et al.*, 2019).

In addition to the above, it is recognized that the relatively small contribution of agriculture to GDP, chains focused on economic aspects, and the triple disconnection of the AS from nature, producers and consumers are elements that prevent sustainable transition and make it difficult to implement actions suggested in theory (Ambikapathi *et al.*, 2022; Mehrabi *et al.*, 2022; Ryan, 2023; Saviolidis *et al.*, 2020).

In line with the foregoing, as an avocado-producing-exporting country, Mexico exerts greater pressure on its supply of natural resources to satisfy the demand of its consumers, as opposed to importing countries, which reduces some local environmental impacts through international trade. International trade is based on the concentration of capital, technological know-how and productive specialization of the large transnational companies established in Mexico (Ayala and Ramírez, 2022; Borrego and Allende, 2021; Martínez and Tapia, 2020).

In this context, possible solutions cannot be left to transnational corporations, whose only objective is trade. Regulatory tools are needed, such as access and transparency to the business practices of companies and stakeholders, including agricultural planning in government agendas, better governance through multi-party collaborative work and access to public information to promote responsible consumption (Cho *et al.*, 2021; Khan *et al.*, 2021).

In short, actions to achieve sustainability must start from the "bottom up" to avoid any impositions. On a national, not international, level, only the government can promote them (Hogarth, 2012) by encouraging the collaborative work of all sectors of society (see Figure 6).

#### 4. PROSPECTS AND CHALLENGES

Change in land use is the general cause of deforestation, not only the establishment of monocultures such as avocado (España *et al.*, 2022; Lucio, 2022). In a scenario of adverse climate change, maintaining the current rate of expansion, by 2050, avocado production and exports in Mexico could represent between 59 and 72% of deforestation, with severe limitations due to the availability of water (Charre-Medellín *et al.*, 2021; Madariaga *et al.*, 2021). If the necessary actions are not taken, the effects will be irreversible, as has already occurred in other countries (Madariaga *et al.*, 2021).

Given the established surface area, Mexico is likely to maintain its position as a world leader in avocado production and exports, but it must increase the adoption of production technology for the efficient use of water, with micro-sprinkler, drip and fertigation irrigation systems. This would permit improvements in nutrition and yields, maintaining or improving the current quality in relation to phytosanitary issues, a common good and a condition in which Mexico has been a global point of reference.

#### 5. CONCLUSIONS

The analyzed VC has acceptable profitability indicators but must improve the environmental and social indicators in the PUs already established. Better technological options already available and standards based on norms must be adopted, not only for the export market but also for the domestic market.

Although the environmental effects are not generalized, water management infrastructure needs to be developed through the adoption and diffusion of more efficient irrigation systems (drip and micro-sprinkler), which would improve the social and environmental perception of the analyzed sector.

At present, conventional production based on agrochemicals prevails. Due to the diversity in the size of the PU, combined production technology based on chemical, organic and biological inputs needs to be used. The destination of production will define the limitations of use between types of management and must also include the phytosanitary and safety standards in force.

Governance structures are biased towards parties that favor the financial aspect over social and environmental variables. In addition to maintaining and improving the phytosanitary element, the State should encourage new governing structures in coordination with leading national packing companies, academia and representative groups of civil society.

Mexico's standing in world markets permits a gradual transition towards sustainability while diversifying and satisfying markets that pay for this type of sustainable production. However, it is necessary to guarantee secure conditions in the production areas and prevent potential benefits from being monopolized by public or private certification organizations. Control mechanisms also need to be established to prevent "greenwashing".

The conceptual framework used in this study allowed us to present a current comprehensive overview of the avocado sector. However, the possibility of delving deeper into any specific driving force or into the six that were analyzed here is a limitation that will be dependent on the objective of the research and the availability of and access to information, which may lead to a certain imbalance in the number of variables considered in each category. It should be noted that the findings are specific to the analyzed sector and cannot be extrapolated to other sectors, chains or AS to make sweeping generalizations.

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## Informed Consent

The interviewees' participation was voluntary and with their informed consent, maintaining anonymity during the analyses presented.

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