

3876 - Avocado Environmental Impact Study Mexico Final report

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Summary

Avocado production and exports have increased significantly in recent years in Mexico. A significant proportion of the production is exported, particularly to the United States, Europe and Japan. The state of Jalisco is the origin of most avocados exported from Mexico to Europe. There is, however, concern about the environmental impact of this industry. In this report we present an overview of the environmental impact of the avocado production in Jalisco. We highlight important ongoing and necessary sustainability interventions, and make recommendations for future action to promote sustainability in Jalisco's avocado industry.



Acronyms

APEAJAL	Association of Producers and Exporters of Avocado of Jalisco (<i>Asociación de Productores y Exportadores de Aguacate de Jalisco</i>)
APEAM	Association of Producers and Exporters of Avocado of Mexico (<i>Asociación de Productores y Exportadores de Aguacate de México</i>)
CONANP	National Commission of Natural Protected Areas (<i>Comisión Nacional de Áreas Naturales Protegidas</i>)
CONABIO	National Commission for the Knowledge and Use of Biodiversity (<i>Comisión Nacional para el Conocimiento y Uso de la Biodiversidad</i>)
CONAFOR	National Forestry Commission (<i>Comisión Nacional Forestal</i>)
CUSUR	South University Center, University of Guadalajara (Centro Universitario del Sur, Universidad de Guadalajara)
CUCBA	Biological and Agropecuary Sciences University Center, University of Guadalajara (Centro Universitario de Ciencias Biológicas y Agropecuarias, Universidad de Guadalajara)
CUCSUR	Southern Coast University Center, University of Guadalajara (Centro Universitario de la Costa Sur, Universidad de Guadalajara)
FIPRODEFO	Trust Fund for the Administration of the Programme of Forestry Development (Fideicomiso para la Administración del Programa de Desarrollo Forestal del Estado de Jalisco)
JIRCO	Inter-municipal Environmental Board for the Integral Management of the Coahuayana river Watershed (<i>Junta Intermunicipal de Medio Ambiente para la Gestión Integral de la Cuenca del Río Coahuayana</i>)
SADER	Ministry of Agriculture and Rural Development (<i>Secretaría de Agricultura y Desarrollo Rural</i>)
SEMADET	Ministry of Environment and Territorial Development (<i>Secretaría de Medio Ambiente y Desarrollo Territorial</i>)
SIAP	Agrifood and Fisheries Information Service (Servicio de Información Agroalimentaria y Pesquera)



1. Introduction

The avocado (*Persea americana*) is an important agricultural commodity, of great relevance because of its nutritional value and its application in other uses such as the oil and pharmaceutical industry, reaching very significant economic value. Global avocado production reached over 8 million tons in 2020, comprising more than 807,469 hectares (FAOSTAT data).

Per capita world consumption of avocado is rapidly growing (Arias et al. 2018). Global consumption has reached 0.85 kg/person/year, while average consumption in Europe had grown to 1.4 kg/person/year in 2020/2021, a 17% increase from 2019/2020 (CBI, 2023). Based on the average consumption in the US (nearing 4 kg/person/year) and Canada (almost 3 kg/person/year), experts expect avocado consumption in Europe will continue to grow in the coming years. In Mexico consumption is over 8 kg/person/year.

Mexico is the world's largest avocado producer. In 2021 Mexican avocado production was close to 2.5 million tons. More than half (52%) of this production is exported to 29 countries. After the state of Michoacán, Jalisco is the second largest avocado producer state in Mexico with roughly 11% of the national production. It is also the state with the fastest production growth rate.

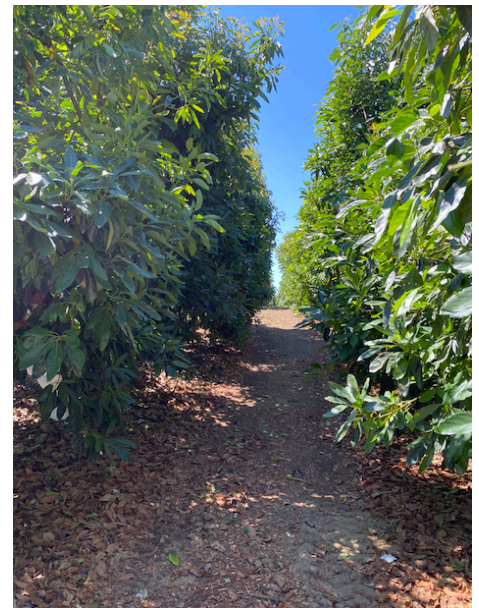
There has been an increasing trend in avocado trade from Mexico to Europe for many years. It has grown from less than €10 million in 2012 reaching a peak of € 282 million in 2019 after which it stabilized around € 244 million in 2020 and 2021.

There is widespread concern about the environmental effects of agricultural production (Wang et al. 2022). Hence, a path into sustainable production is paramount. Production is sustainable when it does not incur in environmental and social damages or costs, while producing financial benefits, thus, providing enough affordable, healthy food at minimal or no environmental and social costs.

In Europe, such concern has found its way to stricter environmental regulations and new private requirements. The European Commission is currently introducing new regulation on deforestation-free supply chains (European Parliament, 2022). Such regulation should ensure that goods placed on the EU market will not longer contribute to deforestation and forest degradation in the EU and elsewhere in the world. While avocados are not yet covered by this regulation, it is expected that they will be in the future. Environmental requirements set by the European private sector and importers are also becoming increasingly stricter, and have resulted in a plethora of environmental initiatives, private standards and certifications, with which suppliers to the European market are expected to comply (CBI, 2022).

In this report, we address important issues on the environmental impact and sustainability of avocado production in Jalisco, with emphasis on production targeted for trade to Europe, particularly to the Netherlands. We highlight current and necessary priority actions to minimize environmental impact and maximize sustainability.

In line with the available resources for the research underlying this report, we have focused on one production area only: the state of Jalisco. Jalisco was selected, as it is currently the second most important avocado producing state in Mexico, the state with the fastest growth in avocado cultivation area and the primary source of Mexican avocados exported to the European market.



2. Objectives

The Embassy of The Netherlands in Mexico commissioned this study with the aim to gain insight into:

- expected trends in avocado trade from Mexico to Europe;
- the environmental impact of the production of avocados destined for Europe;
- promising initiatives to address and minimize such environmental impact;

with a view to

- provide objective information and guidance to Dutch businesses (in particular importers) interested or active on the Mexican market;
- provide policy makers at the Dutch Ministry of Agriculture, Nature and Food Quality with insights into sustainability and tropical fruit trade;
- support promising initiatives that address and minimize the environmental impact of the avocado trade between Mexico and Europe.



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3. Methods

This study consisted of four main components: fieldwork, interviews and participatory focus groups, participation in work meetings of the avocado industry, and an in-depth literature review. All the information presented here is supported by bibliographic, videographic, and in-person interview information. All the fieldwork was conducted through a participatory approach and respecting the highest values of trust and confidentiality.

We undertook fieldwork in Jalisco in April and May 2022 with the purpose of obtaining information on the environmental impact of the avocado industry and its sustainability prospects. During fieldwork we made observations and held interviews on the socio-environmental situation in avocado production areas in Jalisco.

We also had three focal group workshops for in-depth discussion on the topic, with the participation of numerous specialists involved on different aspects of the avocado industry and on the environment and sustainability of Jalisco. Overall, we held interviews or participated in discussions with over 100 people with relevant knowledge on the objectives of this study. Information was obtained from the different components of the avocado industry in Jalisco, including large avocado producers and traders, packaging facilities, small producers, '*ejido*' (communal farmland) and private small-holder producers, producers from indigenous communities, organic producers, producers of other crops that coexist in the region, avocado producers organizations, domestic market traders, the governmental sector of the State of Jalisco (e.g. the Ministry of Environment and Territorial Development (SEMADET), the Ministry of Agriculture and Rural Development (SADER); the Trust Fund for the Administration of the Programme of Forestry Development (FIPRODEFO), or at Federal level (National Forestry Commission (CONAFOR), the National Commission of Natural Protected Areas (CONANP), and the National Commission for the Knowledge and Use of Biodiversity (CONABIO), the environmental sector from the region, certification organizations (e.g. GlobalG.A.P., Rainforest Alliance), the academic sector, civil society organizations, and other stakeholders related to the food production and environment in the study area.

In addition, we participated in four events related to the avocado industry to obtain insight on their work, and their challenges and opportunities. We also conducted an in-depth literature review on relevant topics.

4. Results and Discussion

4.1. Environmental impact of the avocado industry in Jalisco

We address some of the main environmental and social issues related to the avocado industry in the State of Jalisco, México. Jalisco, with a surface of 78,588 km², located, in western central Mexico, has great natural environmental heterogeneity, including temperate, tropical and arid areas.



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Figura 1. MAP OF MEXICO INDICATING THE LOCATION OF THE STATE OF JALISCO

4.1.1. Deforestation

Deforestation in Jalisco during the last 30 years has been significant (SEMADET 2020). Between 1993 and 2012, Jalisco lost 522,031 ha of temperate and tropical forests. Forest loss was particularly high between 2002 and 2007 when 48,618 ha/year were lost. This represented an annual rate of 3.2%, higher than the national annual average rate of 2.3%. It should be considered, however, that this is the overall state deforestation, and not necessarily related to avocado production. The main drivers of deforestation in Jalisco are extensive cattle ranching in induced and cultivated pastureland, agriculture, urban growth and land-use changes for tourism development, and mining (Secretaría de Medio Ambiente y Desarrollo Territorial, 2018).

There is contradicting information on the extent of deforestation in Jalisco for the purpose of avocado production. Many publications that argue deforestation is rampant often do not present reliable quantitative information. Several publications (e.g. WRI 2020) suggest massive deforestation, but others report more limited forest loss (e.g. SEMADET 2022).

Avocado production has not been identified as a deforestation-promoting agent in Jalisco (SEMADET 2017). Most avocado producing areas were agricultural areas on which other crops were grown before they were turned into avocado plantations. Nevertheless, although perhaps not yet a significant promotor, there has been undoubtedly deforestation to establish avocado orchards.

During fieldwork we saw recently deforested and burnt areas (approximately 1 ha) where avocado was being established. Similarly, during a forest degradation study some deforestation for avocado production was recorded (Wheeler et al. 2021). These authors established a demonstration plot network in the Sierra de Tigre region of Jalisco, in a forest dominated by pine (*Pinus* spp.) and oak (*Quercus* spp.) trees (Wheeler et al. 2021). Ten plots (25 m × 200 m; 0.5 ha per plot) were established and surveyed in 2017 and 2018. One of these plots (10%) was clear-cut (deforested) for avocado production by the time of the second survey.

4.1.2. Effects on biodiversity

There is an overlap between the main avocado production areas and the regions with the highest biodiversity in Jalisco (SEMADET, 2020). Thus, it is of great importance to provide adequate conditions for biodiversity conservation within avocado production areas and the landscapes where they are immersed.

The effects of avocado production on biodiversity are still a poorly studied issue. The following are some examples:

Amphibian and reptile fauna in avocado orchards present intermediate levels of diversity between pine forests and tropical dry forests (Marroquín-Páramo et al. 2017). There is a marked species turnover among habitats, since avocado orchards share less than a quarter of species with pine forest and less than a fifth with dry tropical forest. Avocado orchards, immersed in a landscape dominated by the original vegetation, with low levels of management and not exposed to agrochemicals (to which amphibians, particularly, are highly sensitive) showed potential to maintain several herpetofaunistic elements, including threatened species (Marroquín-Páramo et al. 2017).

Environmental heterogeneity within and between avocado orchards, including natural components, can help enhance biodiversity in agricultural areas (Fahrig et al. 2011). For

instance, even maintaining single native trees within avocado orchards, increases native bird diversity (Ruíz García, 2023, and personal communication). Linear, and preferably wider, landscape features promoting natural connectivity between natural areas also promote biodiversity within and between production areas (Fahrig et al. 2011).

Native herbaceous and woody plants should be promoted and conserved within avocado orchards in order to attract and maintain native pollinator populations. In this way, in addition of benefiting avocado production, biodiversity conservation objectives can be achieved.

Comparing conventional and organic avocado orchards, it has been found that low-toxicity insecticides, infrequent herb cutting, and the presence of forest areas in the proximity were related to high biodiversity (Villamil et al. 2018).

4.1.3. Lack of diversified agricultural management

Diversified farming systems, with greater environmental heterogeneity, increase overall species richness by 26% on average, relative to simplified farming systems, such as the typical avocado monoculture. Diversified farming systems enhance beneficial species (e.g. pollinators, natural enemies, and decomposers) abundance and richness and reduce pest (e.g. weeds, herbivores) abundance, while providing benefits for both biodiversity and agricultural production (Sánchez et al. 2022). Thus, diversification contributes directly or indirectly to production objectives. To achieve better biodiversity conservation results, however, it is required to consider the landscape context overall and not only the production unit on its own.

This is a poorly explored strategy in avocado production in Jalisco, and elsewhere, with great potential for biodiversity conservation while maintaining, and perhaps enhancing, production. It should be given important consideration in avocado production practices.

Additional management interventions to increase biodiversity within avocado orchards would be, for example, to provide natural or artificial roost sites for bats, birds and other wildlife (e.g. Weier et al. 2019). These options need to be fully assessed.

4.1.4. Avocado production water footprint

There are no published studies on the water consumption of avocado production in Jalisco. The few studies available for Mexico refer to the situation in the neighboring state of Michoacán (Gómez-Tagle et al. 2015, 2022). It has been reported that in terms of water interception, avocado plantations have similar values to native pine, oak, and pine-oak forests (Gómez-Tagle et al. 2015). Similar or better values were found in terms of water

footprint in comparison to avocado production in other countries. The mean water footprint of avocado in Michoacán was 744.3 m³/ton, below the global mean for this crop (1086 m³/ton; Gómez-Tagle et al. 2022). Crop yield was slightly higher (3.8 %) under irrigated (10.26 ton/ha/year) than in rainfed plantations (9.88 ton/ha/year). Water footprint, however, varied between years in response to rainfall circumstances.

It should be considered that competition for water resources with other sectors of society might lead to social conflict. In dry years, agro-industrial avocado production in Michoacán consumes up to 120% of the surface and groundwater volumes granted to agriculture, suggesting that other users may have limited availability of this resource for human consumption and other ecosystem services (Gómez-Tagle et al. 2022).

Water footprint calculations are often made without regards to the geographic variability of a given country or region (Sommaruga and Eldridge, 2020). Mexico is a highly heterogeneous country, with diverse ecosystems, rendering generalizations of limited value. Similarly, Jalisco is also heterogeneous and harbors diverse types of temperate, tropical and arid ecosystems. To increase the usefulness for management, water footprint estimations should be based on specific local values, and not on broad generalizations.

It is fundamental to optimize water use in avocado production in order to minimize social and environmental costs. Achieving more sustainable production methods with lower water use is crucial considering that water supplies are limited, and that the likely effects of climate change include a reduction in rainfall and water availability (Álvarez-Bravo et al. 2017). Specific research on avocado water use and its social and environmental implications in Jalisco is necessary.

4.1.5. Avocado's production Carbon footprint

Carbon footprint of the production of 1 kg of avocado in Jalisco has been estimated as 12.39 kg CO₂eq (Lomelí Rodríguez, 2020). Once carbon capture is considered, avocado production carbon footprint is reduced to 5.47 kg CO₂eq. In addition to the application of significant amounts of fertilizers and pesticides, electric energy consumption, mainly for irrigation and packing systems, were identified as the most important factors for emitting greenhouse gas emissions. Thus, management actions that can be implemented to mitigate the carbon footprint and achieve neutrality include optimizing electric energy use for irrigation systems and packing facilities using renewable energy sources. Converting into organic production would be another important action.

4.1.6. Food loss

Food loss during production and commercialization is a major social and environmental problem worldwide. Food loss values in Jalisco are lower for large producers and for products with high international demand, such as avocado (López-Sánchez et al. 2021). Smaller producers tend to have greater food loss because of lack of trained personnel and low application of technological practices or equipment. Overall, significant food loss occurs during sowing and harvesting. Pests and weather conditions were reported as the main causes of food loss, followed by improper handling of the produce during harvest and transportation, and challenges during the sale.

4.1.7. Climate change

It is expected that climate change will affect significantly avocado phenology and production in Central Mexico (Álvarez-Bravo et al. 2017, Charre-Medellín et al. 2019, 2021). This would occur in different ways affecting several components of production processes.

It is projected that by 2050, in the worst-case scenario (including an increase in temperature and a reduction in rainfall), there will be a loss of 34.8% in suitable areas for avocado production (Charre-Medellín et al. 2019). In contrast, it is likely that there will be better avocado cultivation conditions in current areas in the semi-warm sub-humid climate (Álvarez-Bravo et al. 2017).

There is concern that with commercial pressure and climate change, the sustainability of the entire avocado production system and mountain forest ecosystems may be threatened (Charre-Medellín et al. 2021). It is to be expected that water availability conditions and irrigation will also be affected negatively by climate change (Charre-Medellín et al. 2021).

It is also likely that climate change may affect the distribution of avocado pests (e.g. big avocado seed weevil *Heilipus lauri*, the small avocado seed weevils *Conotrachelus aguacatae* and *C. perseae*, the branch borer weevil, *Copturus aguacatae*, and the avocado seed moth, *Stenomoma catenifer*), compromising further the future of the avocado industry (Luna et al. 2017).

Thus, it is important to develop adaptation and mitigation interventions so that avocado production is not hampered by climate change. This includes, for instance, the development of new avocado varieties tolerant to the new conditions; for this, the conservation of avocado wild relatives is crucial. More efficient and sustainable use of water is also paramount. Systematic participatory territorial planning (such as official *Ordenamiento Ecológico Territorial* or initiatives like Rainforest Alliance's LandScale) should prioritize

conservation policies to avoid land-cover changes and establish strategies to maintain avocado crop sustainability in the long-term under climate change scenarios.

Of course, climate change is a phenomenon resulting from human activities at a global scale. So, actions developed in faraway places around the planet have effects in avocado production areas. Hence, climate change mitigation actions need to be developed also in avocado importing countries.

4.1.8. Habitat protection

Globally, an important strategy for the conservation of biodiversity is the establishment of natural protected areas or other land protection schemes (e.g. RAMSAR sites¹, wildlife management units). Jalisco has 50 spaces destined for conservation including federal, state, municipal and private natural protected areas and RAMSAR sites. They protect approximately 923,028 ha. In addition, there are eight new proposed protected areas (SEMADET 2020). Additional efforts should be made in order to comply with the goal of protecting 30% of the land by the year 2030, recently agreed by most countries (Kumming-Montreal Global Biodiversity Framework, 30 x 30). These areas provide protection to biodiversity and important environmental services that benefit society, and in particular agricultural production because of watershed protection and habitat provision for pollinators, as well as other environmental services. They also help to mitigate the negative effects of climate change.

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4.1.9. Protected areas

Jalisco has a significant system of natural protected areas and other type of land protection schemes (SEMADET 2020). There are 661,671.43 ha of federal, state, municipal and voluntary protected areas in Jalisco (roughly 8.4% of the state territory). In addition, there are plans for the establishment of 8 new protected areas. There are also 13 RAMSAR sites covering 156,157.94 ha, and 537 Unidades de Manejo de Vida Silvestre (UMA—Wildlife Management Units) covering 657,000 ha. Recently, Mexico committed to protect 30% of its land and seas by the year 2030.

¹ A RAMSAR site is a wetland site designated to be of international importance under the Ramsar Convention, an intergovernmental environmental treaty established in 1971 in Ramsar, Iran

4.2. Expected trends of the avocado trade with Europe

After years of phyto-sanitary preparations and negotiations, (parts of) Jalisco obtained access to the avocado market of the United States of America (USA) in 2022. With the opening of the borders of the USA, the world's largest avocado importer, for avocado imports from Jalisco, there is uncertainty on the expected trends in avocado trade from Mexico to Europe. Leading avocado producers indicate that they intend to continue exporting avocado to Europe and other destinations at least at a similar rate as until now, and to even increase exports to Europe. There have been, however, important efforts to export avocado from Jalisco to the United States. In all, 8,420 ha of production area and 11 packing facilities have been approved for avocado export to the USA (Portalfruticola 2022). In late July 2022, the first shipments of avocado from Jalisco to the USA were made. Since then, until early November 2022, roughly 50% of the avocado exports from Jalisco went to the USA, which may be an indication of future trends. The volume added by Jalisco avocados will help to cover the growing demand and needs of the USA market (Portalfruticola 2022).

It should be noted that avocado export regulations for exporting avocado to the USA concentrate on phytosanitary and food safety issues, and there is less consideration on the regulation or certification of social and environmental aspects of the trade (although Rainforest Alliance and GlobalG.A.P.-certified avocado has been exported to the USA; Portalfruticola 2022). Thus, once sanitary regulations are complied, it is comparatively easier to export to the USA than to Europe. In addition, it takes one day or less for land transportation from Jalisco to the Mexico-USA border, in contrast to maritime transportation to Europe, which requires between 21 and 27 days.

On the other hand, there is a history of commercial tensions between Mexico and the USA, which has sometimes resulted in the closing of the border for different products, including avocado. Thus, avocado exporters would rather not depend on a single market, and would prefer to maintain several trade options open.

On February 2, 2023, an anonymous Mexican citizen placed a legal complaint at the Commission for Environmental Cooperation (CEC) against the environmental impact of avocado production in the state of Michoacán (Commission for Environmental Cooperation. 2023). CEC facilitates effective cooperation and public participation to conserve, protect and enhance the North American environment in relationship to the United States–Mexico–Canada Agreement (USMCA). Depending on the outcome of this legal process, the amount of avocado exported from Jalisco to the USA and Canada may be affected.

Additional factors that may affect the trade of Jalisco avocado to Europe is the competition with other avocado producing countries, in particular leading avocado markets such as Perú, Colombia and Chile.

4.3. Environmental sustainability issues in avocado exports from Mexico to Europe

There are some concerns on the social and environmental impact of avocado production in Jalisco. These include: 1) land-use and land-cover changes that result in deforestation or losses of other natural vegetation types, and the consequent negative changes on biodiversity and environmental services; 2) watershed degradation; 3) potential competition and conflicts for the use of water; 4) excessive water consumption; 5) excessive use of agrochemicals; 6) siltation and pollution of water courses and water bodies. Details are presented below.

Socially, the avocado industry has a positive impact through the creation of jobs. There is, however, an unequal distribution of economic benefits in the industry, including greater uncertainty for small producers. Although there are many more smallholders, the avocado industry in Jalisco is dominated by companies that control significant production areas, and particularly, by packing facilities that control the Jalisco component of national and international commercialization. Although with different legal entities, there are enterprises that cover the production and packaging phases of the industry, and in some cases, also the preparation process of avocado oil.

Depending on the source, there are discrepancies in the estimated overall avocado production area in Jalisco. Estimates range from 27,779 ha (SIAP), to approximately 34,000 ha (estimated by APEAJAL, personal communication), or even to 56,504 ha (40,089 ha of them verified; SEMADET, 2022). Most avocado producing areas (87.1%) were historically avocado orchards or substituted other crops. It has been estimated, however, that between 2019 and 2022, 5,160 ha were deforested to place avocado orchards (1,720 ha/year). This represents 12.9% of the overall avocado producing areas in Jalisco.

It should be highlighted, that the avocado production destined to Europe has a comparatively reduced environmental impact on the issues mentioned above. Those avocado producers that participate in the European market avoid unsustainable actions that are prohibited or regulated by the different social and environmental certifications. Part of their work is documented by the different certifications offered by the governmental and private sector.

A major issue that creates uncertainty on the future environmental impact of the avocado industry in Jalisco is the recent opening of the USA market to avocado from that state. The avocado export process to the USA concentrates on plant health issues and does not consider environmental or social impacts. Hence, there is not a market-driven stimulus for avocado producers to have sustainability practices. Although, it is unlikely that well-established producers will stop exporting avocado to Europe, there is a distinct economic stimulus for all producers to export avocado to the USA, attracted by this important and profitable market, which may potentiate the increase in production area in Jalisco at a faster rate, with no consideration for sustainable practices.

As a consequence, depending on the growth rate of avocado production, and the trade patterns with different countries, there could be a significant change on natural vegetation cover (e.g., deforestation) to cope with the avocado demand of the US market, the European and Asian market, as well as the domestic market.

As avocado or other crops already occupy most flatlands appropriate for avocado production, it is likely new areas may be established on slopes. This may facilitate watershed degradation with negative consequences down slope, as well as on watercourses and water bodies found below.

Although avocado orchards have greater water consumption than native temperate forests in west-central Mexico, there is significant seasonal rainfall in avocado producing areas in Jalisco. Thus, as yet there are no documented cases of water shortages resulting from water use for avocado production. There are, however, localized conflicts for access to water that need to be resolved by negotiating agreements between the parties involved or by the authorities. If deforestation increases as a consequence of unregulated growth of avocado production at the expense of native forests, it is likely the water conflicts, and even shortages, will exacerbate.

It has recently been documented that certain practices, such as leaving original trees within avocado producing areas, have positive effects on bird communities (Ruíz García, 2023). It is necessary to expand these studies to understand the effects of avocado production on biodiversity and environmental services such as pollination. There are other topics that require specific quantitative rigorous studies in Jalisco. One example is the use of agrochemicals and its consequences for humans and domestic and wild animals.

4.4. Environmental awareness and insufficient coordination in sustainability initiatives relevant to the avocado industry of Jalisco

In this section we address the level of environmental awareness of the avocado industry in the state of Jalisco, and some of the leading initiatives promoting sustainability, and their current status.

4.4.1. Environmental awareness in the avocado industry of Jalisco

There is consciousness and concern in the avocado sector about the possible (negative) environmental impacts of the industry. This is particularly notorious with large companies that comply with governmental and private certifications. As a consequence, they reduce their environmental impact. Undoubtedly, some of them undertake sustainable practice as part of their ethos and not (only) out of commercial interest.

Nevertheless, it is necessary to undertake more ambitious and effective sustainability practices that incorporate the diverse social sectors in the region with a landscape perspective of the territory. Some of the areas for improvement are outlined below.

The organic avocado production sector explicitly attempts to reduce its environmental impact by limiting or eliminating its use of agrochemicals to reduce damage to the land, and the environment in general. Some of them also have reforestation practices with the purpose of reestablishing or maintaining appropriate environmental conditions.

It is necessary to invest in sustainability actions that focus on these issues in an integral comprehensive way. This includes investing in engagement to generate further awareness in the avocado sector, particularly in those producers and traders that are not aware or concerned about the environmental impact of the industry.

4.4.2. Need for more coordination in sustainability efforts in the avocado industry of Jalisco.

Most avocado producers in Jalisco work individually, concentrating on their production areas and, the few packaging facilities. Some of them, the minority, have good agricultural practices, organic, social and/or environmental certifications (e.g. GlobalG.A.P., Rainforest Alliance, SENASICA). However, the Association of Producers and Exporters of avocado of Jalisco (APEAJAL) promotes and develops sustainability activities within the industry in Jalisco, especially in the southern region of the state.

Among the activities developed by APAJEAL there is a reforestation program. As part of this program, they have a tree nursery for 100,000 native tree saplings to be used in the region. With a co-management agreement with Jalisco's Trust Fund for the Administration of the

Program of Forestry Development (FIPRODEFO), half of those saplings are currently used for reforestation programs at Bosque de la Primavera, a natural protected area in the outskirts of Guadalajara, where there is no avocado production. APEAJAL has an annual call that invites the local population to acquire tree saplings to reforest their land. In addition, Patronato del Nevado de Colima y Cuencas Adyacentes A.C., and Parque Nacional Nevado de Colima have important tree nurseries which they use to reforest areas in the protected areas under their responsibility, but also provide saplings to other people in the region. Unfortunately, there is no coordination between these initiatives, and most people that participate in these programs work individually without a landscape or regional perspective.

There are other initiatives in the region that contribute to reduce the environmental impact of the avocado and other food production industries (such as berry production), and other human activities in the region. These include natural protected areas of federal, state and municipal character. Jalisco has an important system of protected areas, which in general have a good conservation condition. In addition, there are currently plans to establish eight new protected areas in the state. Also, in Jalisco there are diverse governance and social participation organisms. Notable among them are the *Juntas Intermunicipales* (Inter-municipal boards)—such as the Inter-municipal Environmental Board for the Integral Management of the Coahuayana river Watershed (JIRCO) —, and at least two *Comisiones de Cuencas* (Watershed Commissions) that seek to promote sustainability in different regions of the state. Finally, the State of Jalisco government, through the Ministry of Environment and Territorial Development (SEMADET) and Ministry of Agriculture and Rural Development (SADER), provides strong leadership on environmental and agricultural issues.

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It would be of common interest and benefit those collaborative initiatives were developed to minimize the environmental impact of the avocado industry. Currently, most intervention initiatives are isolated, which minimizes their potential positive effect. A more ambitious vision that incorporates the social sectors of the region is necessary to allow for greater sustainability benefits. In that sense, official regional land use plans (*Programas de Ordenamiento Ecológico Territorial*) are an important normative tool with such purpose. Robust participatory land-use plans provide certainty to the different social sectors in the territory, and help conservation and sustainable development by minimizing conflict and maximizing consensus between the different social sectors. There are several initiatives of this type in the state, such as the Ordenamiento Territorial para la Región Cuenca Alta de la Costa Sur (Gobierno del Estado de Jalisco, 2023). A parallel initiative, with similar purpose, is the LandScale initiative of Rainforest Alliance, which is developed in the Tapalpa region, also with the participation of the governmental sector and civil society (Rainforest Alliance, 2022).

The government of Jalisco, through its Ministry of Environment and Territorial Development (SEMADET), has an initiative to promote 'Zero Deforestation Value Chains'. This scheme has been successful in the case of agave production for tequila, in which case it is promoted in partnership with the private sector, in particular the *Consejo Regulador del Tequila* (Tequila Regulatory Council). As part of that initiative, monitoring ensures that no areas are deforested to establish agave plantations, and no permits are issued for agave production in deforested lands. A similar program is required for avocado, although there are several issues that need to be worked out for such a scheme (e.g. determination of the baseline year, a self-regulating body, enforcement capabilities, continued funding for the deforestation monitoring program, including remote sensing sources, enough staff for ground-truthing).



5. Facing the future of avocado production with a sustainability vision

What is currently being done to address and minimize the environmental impact of the Mexican avocado trade with Europe? To what extent is this successful? What are the most promising (or needed) initiatives and who are the most important stakeholders in this field?

There are, at least, the following initiatives that are of environmental and social importance for avocado production in Jalisco (Table 1).

Table 1. PROMISING OR NEEDED INITIATIVES TO ACHIEVE SUSTAINABILITY IN THE AVOCADO INDUSTRY IN JALISCO, INCLUDING SOME OF THEIR BENEFITS AND SOME OF THE MOST IMPORTANT STAKEHOLDERS IN EACH CASE

Initiative	Benefits	Stakeholder
Regional land-use plans (Programas de Ordenamiento Ecológico Territorial; Rainforest Alliance's LandScale).	Sustainable land-use, biodiversity conservation, sustainable development.	(Federal-level) Ministry of Environment and Natural Resources (SEMARNAT), (State-level) Ministry of Environment and Territorial Development (SEMADET), Municipalities, Rainforest Alliance, sectorial representatives, Civil Society Organizations.
Natural Protected Areas (Federal, State, Municipal, Areas Voluntarily Destined for Conservation)	Protection of natural vegetation cover; watershed management; protection of water resources; biodiversity conservation. There are proposals by SEMADET for eight new protected areas in Jalisco. In addition, Mexico has recently committed to the Montreal Global Biodiversity Framework, in which 30% of the land and sea should be protected by 2030.	National Commission of Natural Protected Areas (CONANP), SEMADET, Board of the Nevado de Colima and Adjoining Watersheds (Patronato del Nevado de Colima y Cuencas Adyacentes A.C), Academia (e.g., Universidad de Guadalajara various campi—CUCBA, CISUR, CUCSUR), Civil Society Organizations.
Watershed management actions	Maintenance of good water and soil quantity and quality; erosion control.	Comisiones de Cuencas (Watershed Commissions), landholders, academia, private sector.

Promotion, regulation, and enforcement of Zero Deforestation Value Chains	No deforestation resulting from avocado production (and other crops).	SEMADET, SADER, avocado producers.
Reforestation and restoration programs. There are several governmental and private <u>reforestation</u> programs. It is necessary to transform these programs in more ambitious <u>restoration</u> programs, increasing the number of tree species used, using appropriate native species for each region's environmental conditions; considering in each case the seasonality, and using spatial designs to maximize connectivity and natural area size; facilitating conditions to attract more species.	Increasing natural vegetation cover; biodiversity and environmental services restoration; watershed and water management.	National Commission of Natural Protected Areas (CONANP), Board of the Nevado de Colima and adjoining watersheds (Patronato del Nevado de Colima y Cuencas Adyacentes A.C), Academia (e.g., Universidad de Guadalajara—CUCBA, CUSUR y CUCSUR), Civil Society Organizations.
The promotion and follow-up of good agricultural practices, organic, social and environmental certifications.	Better sustainability practices in avocado production and packaging areas.	Certification organizations, avocado producers and packers.
Reduction in the use of agrochemicals.	Minimize water and soil pollution; minimize impacts on human and animal health.	Organic avocado producers, other avocado producers.
Social organization to optimize costs and reduce vulnerability in trade processes.	Reduction of costs; successful commercialization.	Small land tenure (e.g. <i>ejido</i> (communal land) avocado producers, potentially organic avocado producers, and other avocado producers.
Climate change friendly and renewable energy for irrigation, agricultural processes, and packaging facilities.	Reduced greenhouse gas emissions.	Avocado producers, avocado packaging facilities.

Conservation of avocado's wild relatives.		Avocado producers, CONANP, botanical gardens, Academia (e.g., Universidad de Guadalajara campi—CUCBA, CUSUR y CUCSUR), national and international Civil Society Organizations.
Reduction in maritime transportation time between Mexico and Europe.	Minimize energy and environmental costs of transportation; increase in commercial ('shelf') life for avocado.	United Producers of Mexico, shipping companies, avocado producers and traders.

5.1. Necessary management interventions to minimize the environmental impact and maximize social benefits of the avocado industry

The following topics are important interventions to minimize the environmental impact of the avocado trade:

There are diverse initiatives that can benefit from support or collaboration with the Dutch Embassy in Mexico, or other parties such as the Mexican government, the government of the State of Jalisco, international cooperation agencies, national and international non-governmental organizations, and academia, among others (Table 2).

Table 2. EXAMPLES OF INITIATIVES THAT CAN BENEFIT FROM SUPPORT OR COLLABORATION WITH THE DUTCH EMBASSY IN MEXICO, OR OTHER PARTIES.

Initiatives	Support/collaboration needed
Support and collaborate on initiatives to maximize sustainability benefits with a regional, landscape and watershed perspective with the participation of the different social sectors of the region, including the different land management strategies (e.g. Ordenamiento Ecológico Territorial, Rainforest Alliance LandScale, natural protected areas).	Funding, technical support and collaboration.
Assist capacity strengthening in organic production good practices.	Funding, technical support and collaboration.
Provide financial, subsidies or other support to small avocado producers for good agricultural practices, organic, environmental and social certifications.	Funding, subsidies, and other support.

Provide support to fill knowledge gaps on diverse issues on avocado production sustainability.	Funding, technical support, and collaboration.
Support and collaborate on the Net zero deforestation avocado value chain.	Funding or support to obtain remote sensing products, perform ground-truthing, and perform enforcement.
Initiatives to support governance and organization of producers (particularly, for smallholders and organic producers).	Funding, technical support and collaboration.
Provide follow up and support to pilot initiatives to have direct, regular and swift maritime transportation between Mexico and Europe.	Support facilitating contact between shipping companies and avocado producers and traders in Mexico and Europe.
Provide support for the formulation of a Conceptual Note for the Green Climate Fund (GCF) to attract significant climatic funding to promote a sustainable avocado production model with a landscape and regional perspective.	Funding, technical support and collaboration.

5.1.1. Net Zero deforestation avocado value chain

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It is of great importance to establish a functional system for a net zero deforestation value chain in Jalisco (and elsewhere). The monitoring system developed by SEMADET may allow assessing land-cover changes every three months. There are, however, several caveats. First, it is essential to determine and formally agree (or decree) a baseline year for the process. SEMADET has proposed to use the year 2016 as they have compatible data from that year; this coincides approximately with the five-year period for the prescription of crimes in Mexico. Based on the Sustainable Rural Development Law (Ley de Desarrollo Rural Sustentable), it could be argued that legally 2018 is the year that should be considered in Mexico. On the other hand, based on the European Union Green Deal (Pacto Verde), the year 2020 could be used. Of course, avocado producers who are willing to deforest land to establish avocado production areas would likely argue for the most recent possible date. Second, it is paramount that institutions such as Servicio de Información Agroalimentaria (SIAP) and Asociación de Productores y Exportadores de Aguacate de Jalisco (APEAJAL) update their records of individual and total area of avocado production, hopefully eradicating or at least reducing the inconsistencies in the various data sets. Third, to follow the example of the agave/tequila industry, by establishing a self-regulatory body that allows enforcing, with the governmental authorities, the follow up of land conversion and the implementation of restrictions for establishing avocado fields in deforested land. Fourth, it

is also important to socialize the monitoring system, so that avocado producers perceive it as a useful tool for the industry, and not simply as a policing mechanism.

As mentioned above, SEMADET could update land-cover change data every three months. They need, however, support in at least three critical components: 1) funding to support further personnel to ground-truth data in a timely manner; and 2) the current subsidy from the government of Norway to use the Planet system (a high resolution remote sensing data) expires in 2023, so there is a need for a renewal or a new subsidy; and, 3) a recognition that the crop was not established in deforested land would be granted through a certification (tentatively called 'Biosello').

5.1.2. Certifications

Social, environmental, organic and good agricultural practices certifications help to minimize social and environmental impact of avocado production and trade. These good practices on their own, however, are restricted to packaging facilities and to the particular production areas, which are in the largest cases less than a few hundred hectares. This area is not enough to sustain viable populations of most fauna and flora species or to secure other environmental services. Therefore, it is imperative to have a regional land-use plan in which connectivity of natural areas within avocado production areas and other areas is implemented. This would provide greater opportunities for the conservation of biodiversity and also of valuable environmental services, such as water, pollination, and carbon sequestration, important for agricultural production and society overall. Support of these types of initiatives by participants in the avocado value chain would provide important environmental and social benefits, and would help secure avocado availability in the long-term.

Unfortunately, certifications have a financial cost that is argued to be out of reach to most small and medium-sized avocado producers. Some of them have suggested that a good way of increasing the availability of avocado for export, while promoting the sustainability of the avocado industry, would be to help producers with certification costs or to provide subsidies to producers that cannot afford certifications.

5.1.3. Organization of small and medium landholders and enterprises

There is a very significant agricultural surface in Jalisco under the control of numerous small and medium-sized landholders. For most of them it is difficult to have access, individually, to international markets. There are, however, community organization initiatives in Jalisco, such as in the locality of Telcruz, where producers work together to increase their capabilities in several aspects of production and commercialization processes. This includes obtaining more affordable and logistically efficient access to buy products (e.g.

agrochemicals), and the reduction in their vulnerability in the sale of their produce to intermediaries. There are still major challenges for them, including easy access to packing facilities.

Supporting market entry to Europe for small and medium landholders and enterprises would facilitate the growth of the European market for avocados from Jalisco, by significantly increasing the supply.

Several factors have been identified as key for the success of producer cooperatives in Jalisco. These include leadership; member knowledge and continuity; effective communication; member satisfaction; training; and government support (Romero Paz, 2016). In contrast, the following challenges have been recognized: poor understanding of cooperative principles among members; low enthusiasm for attending training; individualistic members with limited trust between them; lack of member commitment and participation in their cooperative; lack of young people joining the agriculture industry (including cooperatives); and no clear public policies regulating the agricultural sector (Romero Paz, 2016).

A major operational challenge for small and medium enterprises is having suitable access to packaging facilities and commercialization. The creation of shared facilities for small and medium enterprises has been identified as a strategic intervention to increase avocado supply while providing social and economic benefits for small and medium-sized landholders (Waldhauer et al. 2015). In fact, during fieldwork several small producers expressed their interest in having packaging facilities together with international enterprises.

5.1.4. Group certifications

There are claims from small and medium avocado producers in Jalisco that the cost of certifications is out of their reach, or they just assume it is. Some of them, willing to certify their production practices, have proposed the reduction in costs and fees of certifications or the granting of subsidies with that purpose. An alternative option would be to have group certifications (such as those already available with GlobalG.A.P.), which may allow small and medium sized avocado production enterprises to be certified, and ideally work in collaboration to maximize positive environmental contributions. In any case, a better socialization of certification processes and costs is desirable so that producers are aware of the realities and benefits of certifications.

5.1.5. Organic agriculture

Organic avocado production has diverse environmental and health advantages over conventional production (e.g., Villamil et al. 2018, Supicic, 2021). Although there is a growing global trend in the consumption of organic and healthy food products, the organic avocado market is still poorly developed. Thus, it is advisable to promote a greater consumption of organic avocado. Organic avocados, however, are between 11-20% more expensive than conventionally produced avocados (Hecteman 2019). In fact, only a few (4) organic initiatives were identified in Jalisco during fieldwork, and all of them were small or medium enterprises. They are in several stages of the process, but some already have various certifications.

The overall demand for avocados is higher than its supply, thus there is a limited stimulus to convert conventional avocado production into organic. The high profitability of the conventional avocado trade inhibits the development of a greater organic avocado industry. A promotion of organic avocado production and consumption, paying preferential prices in comparison to conventional avocado, - at least until a significant proportion of the overall production is organic - would be an important sustainability contribution helping to reduce the use of agrochemicals.

5.1.6. Tree nurseries

An essential component in reforestation and restoration programs is to have efficient tree nurseries that provide enough native tree saplings in terms of quality and quantity. There are several initiatives of tree nurseries in the avocado producing area in Jalisco. They concentrate in producing seedling of native trees to be used in the reforestation projects in the region. Their efforts need to be supported and enhanced.

5.1.7. Reforestation and restoration initiatives

Reforestation initiatives to recover or enhance forest cover in the region should be promoted and supported.

Reforestation should be embarked using exclusively tree species native to each particular region and environment, emphasizing the importance of using local germplasm. These efforts should consider the spatial arrangement of reforestation initiatives, promoting the reestablishment of structural and functional connectivity, and maximizing the size of natural areas.

Reforestation is not enough. These initiatives should have a landscape and regional perspective, attempting to restore functional and self-sustaining environments which may

help overall regional biodiversity to thrive including the environmental services they provide, such as viable wildlife populations, pollination and, hydrological services.

Current efforts concentrate in reforesting relatively small surfaces within avocado production areas. An effort to coordinate reforestation and restoration efforts with native species within and between production and natural areas should be enhanced and given top priority. The support in financial, organization and other terms of the Dutch Embassy, the Mexican and Jalisco governments, international, Dutch, and Mexican non-governmental organizations, in coordination with avocado producers and organizations, would be an important contribution to sustainability of the industry. One of the benefits would be the reduction of the carbon footprint of the industry.

5.1.8. Environmental heterogeneity enhancement within avocado plantations

Monocultures minimize biodiversity and functional environmental services (Sánchez et al. 2022). Thus, it is imperative to increase environmental heterogeneity, using native species following natural patterns, within avocado plantations. This should include numerous trees, ideally promoting connectivity through wide corridors, but also the use of other native plant species that attract pollinators of many different kinds. This is a management practice that has been documented to be of great importance in other agricultural products, such as coffee and cacao plantations (Tscharntke et al. 2012). These agricultural practices help to reduce soil erosion, enhance natural pollination, conserve biodiversity and, maintain other environmental services.

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5.1.9. Regional land-use plans (Ordenamiento Ecológico Territorial)

Robust participatory regional land-use plans will help to provide certainty to the use of land, maximizing consensus within and between social sectors and minimizing conflicts. These normative tools should have a watershed perspective in addition to structural and functional connectivity considerations. They should facilitate sustainable development and long-term biodiversity and environmental services conservation. The government of Jalisco has been updating existing official regional land-use plans, and this process should be continued and enhanced. These official normative tools can be complemented and enriched with civil society efforts such as the LandScale program, which already covers 196,000 ha in the Tapalpa region (Rainforest Alliance, 2022), and which should be expanded to other regions in the state.

5.1.10. Conservation of Avocado's wild relatives

Mesoamerica is the center of origin, diversity and domestication of avocado and its wild relatives (Goettsch et al. 2021). As a safeguard against the effects of global change on the

avocado industry it is important to invest significant efforts on the conservation of avocado's wild relatives. These species (e.g., *Persea hintonii* in Jalisco; *P. albida*, *P. chamissonis*, *P. cinerascens*, *P. longipes*, *P. pallens*, *P. rufescens*, *P. schiedeana*, elsewhere) are a source of high genetic diversity, provide essential ecosystem services, and are progressively more important for food and nutrition security and sustainable and resilient agriculture (Goettsch et al. 2021). Additionally, it should be considered that at least 9 avocado wild relative taxa (60%) are threatened with extinction (Goettsch et al. 2021). Hence, *ex situ* propagation practices under controlled conditions, such as in botanical gardens, and *in situ* protection within natural protected areas, and perhaps (depending on sanitary conditions) within avocado production areas, should be considered.

5.1.11. Natural Protected Areas

Natural Protected Areas provide safe havens for biodiversity, and they conserve environmental services important for the avocado industry, such as water, erosion control, and pollination. Thus, it is important to support the conservation management of existing protected areas and to maximize the area under private or public protection. Mexico has signed the Kuning-Montreal Global Biodiversity Framework, committing to protect 30% of land and seas by the year 2030.

5.1.12. Further studies

There is a lack of robust scientific information on numerous sustainability issues of the avocado industry in Jalisco. It would be of great benefit for the industry to invest resources to obtain such information so that management decisions can be made based on strong evidence. Some issues of critical importance include long-term studies on the effects of avocado production on water availability and quality, biodiversity, environmental services, and carbon storage. Also, further research is necessary on considerations for increasing environmental heterogeneity in production areas as a mean to attract and conserve significant biodiversity. Additionally, a permanent monitoring program of the social and environmental effects of the avocado industry should be implemented.

5.1.13. Capacity strengthening

A common recommendation proposed by people who were interviewed during this study is the need to support additional capacity building on the different aspects related to the avocado industry value chain, and sustainability. Some of the opportunities for improvement have been highlighted above. Training on sustainability issues at all levels, for people along the different components of the avocado value chain is paramount.

In terms of production surface, the vast majority of avocado producers are small and medium-sized landholders. As might be expected, they may have less economic and organizational power, especially when they work individually.

Thus, it would be beneficial to the avocado industry to promote the organization of these producers. This would increase the amount of avocado available for trade to Europe. An important area of opportunity is to empower small and medium-sized enterprises within a fair-trade framework.

5.1.14. Long-term funding for environmental and sustainability projects

It is necessary to provide long-term funding to sustain these social and environmental initiatives and to maximize their benefits. There are several initiatives that should be supported. Some of these initiatives are promoted in Jalisco by APEAJAL, and to a lesser extent by APEAM, with the direct support of avocado producers in the region. There is also the Patronato del Nevado de Colima y Cuencas Adyacentes A.C. (the Board of the Nevado de Toluca and adjoining watersheds), a not-for-profit organization that supports conservation initiatives, including tree nurseries and reforestation initiatives in the Nevado de Colima region.

These initiatives and the resources they require, however, are never enough and can benefit from additional funding and support. This is an area of opportunity for people and organizations interested in supporting the sustainability of the avocado industry. An important step in that direction would be to finance the participative formulation of a Conceptual Note for the Green Climate Fund (GCF) to attract significant climatic funding to promote a sustainable avocado production model with a landscape and regional perspective.

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5.1.15. Transatlantic transportation

Swift and efficient low greenhouse gas emission transportation between Mexico and Europe is an important initiative that supports both avocado exporters and importers, benefiting the entire industry.

5.1.16. Net Zero carbon emissions avocado industry

It is important to reduce, and ideally eliminate, the climate and environmental footprint of the avocado industry. Environmental management practices that have been recommended in the above lines in this section contribute to a net zero carbon emissions industry, helping to reduce its climate change footprint. In addition, it is important to incorporate renewable energy in all segments of the avocado value chain eliminating fossil fuel energy, from production, to packaging, to trade, to consumption. Some of the benefits of these

interventions are local, as highlighted above, but others are global contributions to mitigate climate change.

Although many initiatives have already taken place, Astier et al. (2014) argue that there is still room for improvement regarding the reduction of non-renewable energy inputs and greenhouse gas emissions. They emphasize that farming systems must be oriented towards two things: (1) "decreasing the amount of fossil fuel inputs through reducing fuel consumption, using more efficient vehicles, reducing the number of agricultural practices and switching from synthetic to organic fertilizers"; and (2) "making more efficient use of fertilizers and pest control products" (Astier et al., 2014).

Some Mexican food producers and exporters are investing in water and energy efficient systems, in reducing food loss, in order to contribute to sustainability. Water and energy consumption in the Mexican agricultural sector, however, have significant governmental subsidies, which reduce incentives to invest in sustainable technology and practices.



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6. Final remarks.

Anywhere in the world, agriculture, when it affects natural habitats, has by definition a disturbance effect on the environment, particularly on biodiversity, soils, water, and other natural elements. There is an effect of scale, in which the larger the area is affected, the greater the environmental impact. This does not refer to the single production unit, but to the overall production area.

Jalisco's avocado production destined to Europe has a relatively reduced environmental impact. Avocado producers and traders that participate in the European market avoid unsustainable actions that are prohibited or regulated by the different social and environmental certifications. Part of their work is documented by the different certifications offered by the governmental and private sector. That does not mean that certified avocado production areas have a positive effect on the environment. It means that they are less damaging than non-certified plantations. In this report we have highlighted the necessary actions to achieve sustainable avocado production in Jalisco, limiting or avoiding negative environmental impacts (Tables 1 and 2). It is paramount that all these management interventions are undertaken by the overall avocado industry, together with other sectors of society, as soon as possible.

Given the rising economic stimulus to produce and export avocado, there is a distinct risk that serious environmental damages, including significant deforestation, may occur in the future. It is imperative to have a fully operative and functional zero deforestation scheme, along with more sustainable water consumption systems, the increase of environmental heterogeneity within avocado plantations, and the switch to organic production and to a Net Zero carbon emissions avocado industry, including energy efficient maritime and land transportation. This should be supported by social, environmental and good agricultural practices certifications (individual or groupal), and complemented with other environmental interventions such as restoration programs, regional land-use plans, the protection of natural areas and the conservation of avocado's wild relatives. Transversal initiatives such as capacity strengthening and significant long-term funding for environmental initiatives are also imperative.

Since there are few studies in Jalisco on the various potential disturbance factors of avocado production, it is necessary to perform detailed studies on the various types of disturbances. They should include a permanent monitoring program of the effects, trends and performance of the avocado industry.

Jalisco has all the elements to transform into an example in avocado sustainability production. Some of the main areas of opportunity have been highlighted in this document.

The transition towards sustainability in food production systems is not simple. It requires the participation of diverse stakeholders, investing efforts in policy, regulation, research, and the investment in environmental, social, and financial efforts. The role of the Dutch Embassy promoting and facilitating the process along other key institutions is of paramount importance.



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