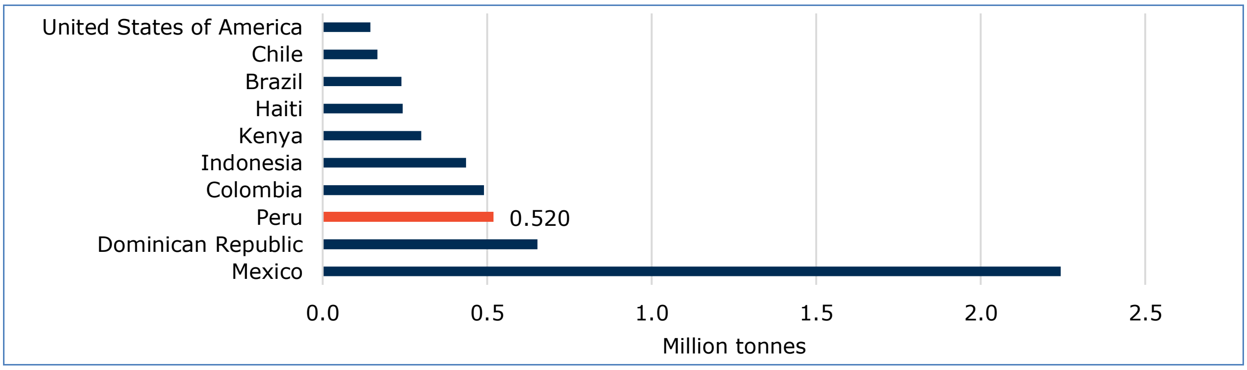
ANNEX J: CASE STUDY 9 – THE IMPACT OF THE AGREEMENT ON BIODIVERSITY – THE CASE OF AVOCADO PRODUCTION IN PERU

1 INTRODUCTION

Production of and trade in avocados is recognised as one of the fastest growing markets in the world, and European avocado consumption is identified as a key driver for this (Sommaruga, and Eldridge, 2021). Peru is one of the world's largest producers of avocados: in 2019, was the third largest one after Mexico and the Dominican Republic (Figure 1).

Figure 1: Total production of avocados by country, 2019



Source: FAO, 2020

Through the Agreement, the avocado sector in Peru benefits from duty free access to the EU market, compared to a 4% tariff which would be due without the Agreement. It is therefore interesting to study if the Agreement has led to an increase in Peruvian exports of avocados to the EU and an associated increase in production, with potential environmental implications.

This case study addresses particularly the potential impact on biodiversity. We first provide some brief background information the remainder of this introduction, then establish the current situation and recent trends of the sector (section 2). Section 3 provides the methodological model for the analysis, followed by the impact analysis itself (Section 4) Section 5 concludes.

1.1 The impacts of avocado production on biodiversity globally

Globally, avocado production can put pressure on biodiversity, by e.g., **water** and **agrochemicals** use as well as **land use change.** Regarding water use, studies indicate that avocados are among the top three crops causing water stress (Stoessel et al., 2012). Irrigation systems used for avocado productions can extract water from both groundwater and surface water, which can intensify various water related risks. These risks include aquifer depletion and reducing surface water levels in rivers, which can potentially both harm the functioning of ecosystems and negatively affect biodiversity (Verones et al., 2012). Avocados are often a mass-scale, monoculture crop, leaving the soil with less nutrients and more vulnerable to diseases, creating the need to use more pesticides and fertilisers. The use of agrochemicals is not limited to the contamination of local soils; agrochemicals also run off into surrounding water bodies and potentially into distant ecosystems. Moreover, over long periods of time, monoculture crops lead to soil depletion, taking away most of its mineral properties. The expansion of avocado production is associated with land use changes and in some countries (e.g., Mexico) with deforestation (WRI, 2020). In these cases, farmers plant young avocado trees beneath forest canopies and eventually cut down shrubs and old trees to provide more sunlight and space for these plants (UNDEP, 2017).

1.2 Avocado production regions in Peru

Avocado production in Peru is mainly concentrated in the 2,000 km dry coastal strip from Chiclayo in the north to Arequipa in the south (Figure 2). There are several major growing zones, such as:

- The **Olmos irrigated area** (Department of Lambayeque), with about 38,000 ha irrigated area (CIRAD, 2019). The average annual growth rate equalled 31.2% in this area between 2015-2019 (Peruvian Government, 2019);
- The **Chavimochic irrigated area** (Department of La Libertad), with about 75,000 ha of irrigated production (CIRAD, 2019). La liberated area is the largest area in terms of production, representing 37.7% of the national avocado production in 2019 (Peruvian Government, 2019). The average annual growth rate equals 12% over the last five years (ibid.);
- The "**coastal river valleys" of the Departments of Lima** (especially Barranca, Huaura, Huaral, Cañete, Chincha) and Ancash (Casma and Chimbote), with about 10,000-12,000 ha of irrigated production (CIRAD, 2019);
- The **Sierra**, with about 2,000 to 4,000 ha largely unirrigated (the western foothills of the mountain range, mainly in the south of the Departments of Huancavelica, Arequipa, Cuzco, Ayacucho and Ica) (CIRAD, 2019).

Figure 2: Map of main avocado production areas, Peru

Source: CIRAD (2019)

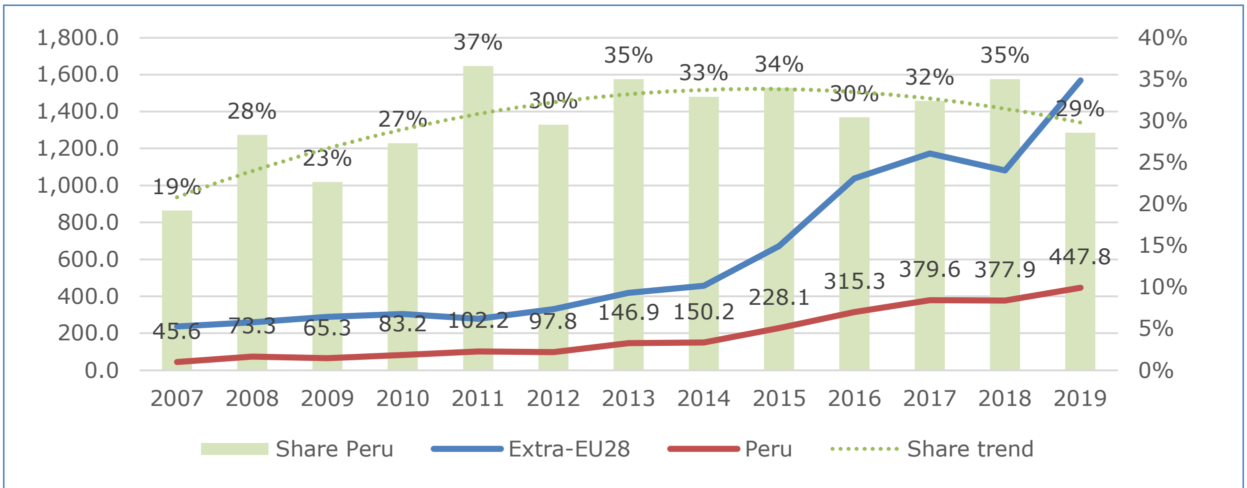
The first three areas are situated in coastal desert zones and use intensive irrigation, while the highland Sierra production area is largely unirrigated. Rainfall in the coastal production areas is low and irrigation water is sourced from rivers (and in the case of the Olmos, from the River Huancabamba, using a 20km tunnel through the Andes to the Palo Verde dam) (CIRAD, 2019). This case study focusses on large production areas such as the Olmos and Chavimochic areas and the coastal river valleys, including the Ica Valley.

2 CURRENT SITUATION AND RECENT TRENDS

2.1 Performance

Peru's **exports** of avocados to the EU have steadily grown since 2012. In 2019, fruits, led by avocados, became the largest import commodity from Peru to the EU. Between 2012 and 2019, the value of avocado imports increased from EUR 98 million to EUR 448 million (Figure 3). Over the same period, total EU avocado imports have however also rapidly expanded; the share of imports from Peru in total EU avocado imports in fact increased from 19% in 2007 to 37% and 30% in 2011 and 2012, and then remained at levels between 30% and 35% since the start of application of the Agreement; in other words, import growth from Peru was proportional, but not higher than, that of total EU avocado imports. In considering this, it needs to be taken into account that almost all EU imports of avocados are from countries benefitting from preferential access to the EU under FTAs or unilateral preferences (the only notable exception being Brazil, whose share in total EU imports is however limited at about 1.2%).

Figure 3: EU28 imports of avocados (HS 080440) from Peru vs. total, 2007-2019 (€ million)

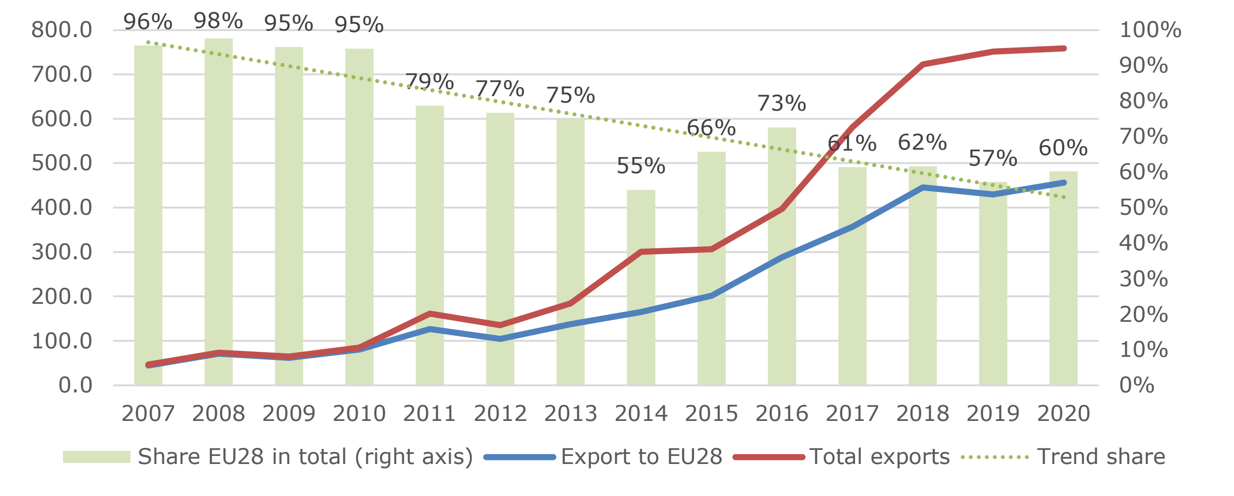


Source: Own calculations based on Eurostat COMEXT.

According to the Commission for the Promotion of Peru for Exports and Tourism (Promperu), Peru is the main supplier of Hass avocado[1] to Europe. The EU is also the largest market for Peru's avocado exports, accounting for about 60% of the total export value since the Agreement's start of application (**Fehler! Ungültiger Eigenverweis auf Textmarke.**). At the same time, that share was higher prior to the Agreement, reaching almost 100% in the years 2007 to 2010 before dropping to the current share since about 2014.

1 Hass is the most demanded avocado variety in Europe. In 2019, 95% of Hass avocado production was aimed at the international market (CIRAD, 2019).

Figure 4: Peru's exports of avocados (HS 080440) to EU28 vs. total, 2007-2019 (USD million)

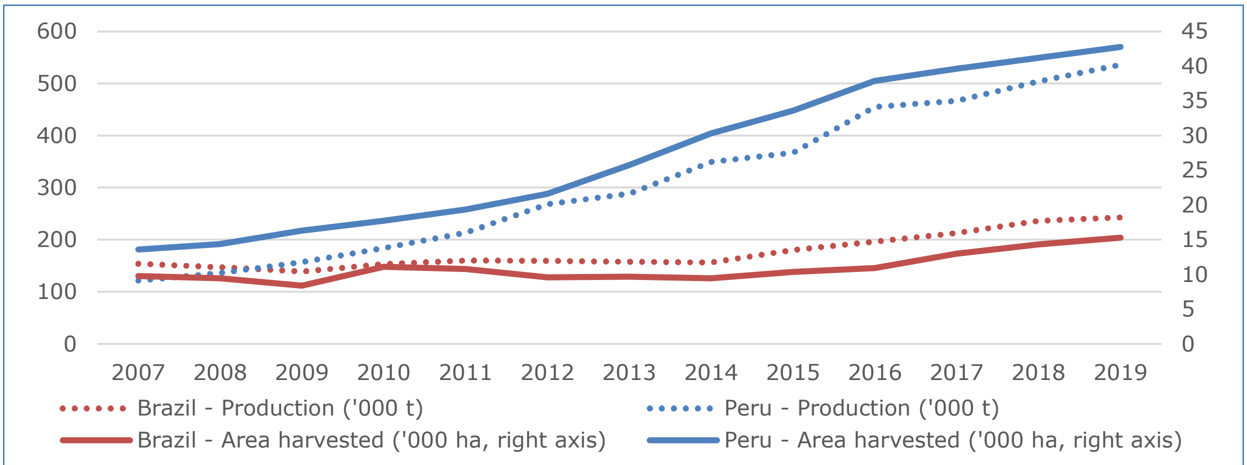


Source: Own calculations based on Eurostat COMEXT.

Figure 5 compares avocado **production** in Peru with avocado production in the largest avocado producing country exporting to the EU under MFN (Brazil). In Brazil, avocado production largely stagnated between 2007 and 2014, at around 150,000 tonnes per year, but then increased to 243,000 in 2019. In Peru, avocado production increased each year over the period 2007 to 2019, with production growth between 2012 and 2019 averaging around 38,000 tonnes per year, compared to 29,000 for the period 2007-2013; in percentage terms, the average growth rate in the Agreement period was however lower, at 10.4% per year, than in the years before the Agreement (17.1%). The area harvested has grown broadly commensurately with production.

The output performance suggests that factors other than the Agreement were the major driver of the growth in avocado production in Peru. Yet, it is also noted that Peru experienced a higher growth rate than Brazil, which may be linked to the Agreement.

Figure 5: Annual production area and total production of avocados, Peru and Brazil (2007-2019)

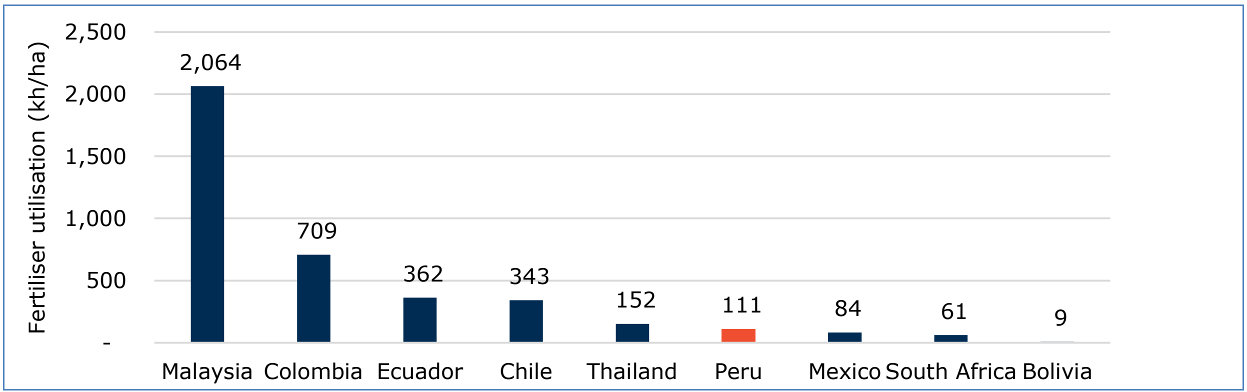


Source: FAO, 2020

In Peru, **water use** is mainly driven by agriculture (46%) and energy generation (47%), though in some regions mining accounts for a significant share of total water demand (DAR, 2017). Most of the crop production in Peru is concentrated in the arid coastal region and part of the Andean zone. Approximately 80% of water withdrawal is used for irrigation (OECD, 2017). In the coastal areas, the agricultural sector relies for 100% on irrigation and in the mountain area irrigation dependency equals 40% (Sommaruga & Eldridge, 2021). Many irrigation systems are inefficient and/or unreliable; total water use efficiency in irrigation systems is estimated to be approximately 35%, which is considered poor performance and is mainly due to leaks in the distribution systems and extensive use of unimproved gravity or flood irrigation methods, with an estimated total efficiency of 50% (ANA, 2019). In the pacific hydrographic region, 12 out of 43 aquifers are overexploited because of excessive irrigation causing deterioration in water quality due to saline intrusion in aquifers near the coast, leaving unproductive fields (OECD, 2018). In the highlands, the risk of landslides is intensified by overgrazing, bushfires, and poor soil management. Given these trends, water conflicts, water availability, and efficient water management are severe problems in Peru. While Peru is investing in technologies to mitigate these risks, these measures often increase the gap between well managed agribusinesses and smaller farmers that lack resources, knowledge, and efficiency, which results in social conflicts (FAO, 2021).

The average agricultural **fertiliser application** rate of 111 kg/ha is lower than average application rates in other countries (Figure 6) (Word Bank, 2019). However, for the production of avocados, certain levels of fertilisers and **pesticide**s are applied in Peru, which may create environmental pressures (e.g., eutrophication, acidification, human toxicity, and biodiversity loss) (Bartl, 2012).

Figure 6: Fertiliser use, Peru vs comparators



Source: World bank 2017

Globally, avocado production has been related with **land use change and deforestation**. In the Mexican state of Michoacán for instance, reports have claimed that avocado production was driving 30-40% of annual deforestation (World Resource Institute, 2020).

2.2 Governance

The **National Agrarian Policy** (PNA)[2] stipulates the long-term strategy for the agricultural sector and aims to promote the sustainable development of this sector (Peruvian Government, 2016). The PNA includes 12 policy areas including 1) Sustainable Soil and Water Management; 2) Forest and Wildlife Development; 3) Infrastructure and modernization of irrigation. For each topic, the goals and challenges are explored. For instance, for sustainable soil and water management, land degradation is mentioned, because erosion, desertification, and salinisation are identified as environmental challenges by the National Institute of Natural Resources (INRENA). Adequate agricultural water management may restore the soil quality (RVO, 2016).

The Peruvian government has put several policies in place to promote the agro-export sector. Especially, Law N° 27360 - **Law of Agrarian Promotion** (LPA) – played an

[2] Supreme Decree No. 002-2016-MINAGR

important role in the Peruvian agro-export boom, e.g. to attract business to Peru's driest areas (LNV, 2021). The law provides incentives such as tax exemptions to exporting agriculture companies (LNV, 2021). The law was enacted in 2000 and has been extended twice. The latest extension (which will last until 2031) was approved by the Congress in 2020 and includes several changes, such as a sectoral minimum wage for employees in the agricultural sector (see section 6.4 of the main report). Enabled by LPA, the private sector became the main engine driving Peru's successful agriculture export growth and diversification strategy (World Bank, 2017).

At national level, the Ministry of Agriculture and Irrigation (MINAGRI) is responsible for the agricultural sector (as shown in Table 1, together with other relevant organisations).

Table 1: Overview of important (public) organisations in relation to agriculture policies and avocado production

Organisation name	Description
MINAGRI	Ministry of Agriculture and Irrigation
INIA	National Institute of Agricultural Innovation
ANA	the National Water Authority
INRENA	The National Institute of Natural Resources
UNALM "La Agraria"	National Agricultural University La Molina
Concytec	National Council of Science, Technology and Technological Innovation
ProHass	Association of producers of Hass avocados
SENASA	The National Agricultural Health Service

Source: Based on RVO (2016)

The National Water Authority (ANA) of the Ministry of Agriculture and Irrigation (MINAGRI) is responsible for managing and monitoring national natural water resources, which includes the issuing of authorisations to water service providers for its use and distribution, as well as for the permits for wastewater discharge and reuse. The **National Water Plan**, embedded in the PNA (PNRH 2015-2035) aims to increase the crop area under **mechanised irrigation** from 2% (33 000 ha) in 2012 to 24% (602 000 ha) by the year 2035 (OECD, 2017).

In Peru, the **organic avocado** market is still a niche (FreshFruitPortal, 2021b). At the same time, **GlobalGap certification**[3] is widespread in Peruvian avocado production despite the limited size of the plantations (CIRAD, 2019), and the Government is also taking actions to implement GlobalGap certification in certain regions for the export of Hass avocados (NIA, 2019).

According to stakeholders interviewed for the evaluation, for small-scale farmers it is difficult to meet the export criteria set by e.g. the EU. Programmes or Social enterprises like Fairtraca[4] support small farm holders to meet export requirements.

3 THE IMPACT OF THE AGREEMENT ON BIODIVERSITY THROUGH AVOCADO PRODUCTION IN PERU – THE CAUSAL CHAIN

DPSIR framework - The DPSIR (Driver, Pressure, Status, Impact, Response) framework allows to interpret certain environmental indicators by establishing a causal relation between indicators and their analysed effects. The framework is often used in biodiversity analyses and the causal chain developed for this case study applies the logic of the DPSIR framework. As illustrated in Figure 3, the DPSIR framework shows the Status before the

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[3] GlobalGAp is an internationally recognized standard for farm production and includes criteria such as food safety, environment (including biodiversity), workers' health, safety and welfare, among others. See https://www.globalgap.org/uk_en/what-we-do/globalg.a.p.-certification/globalg.a.p./

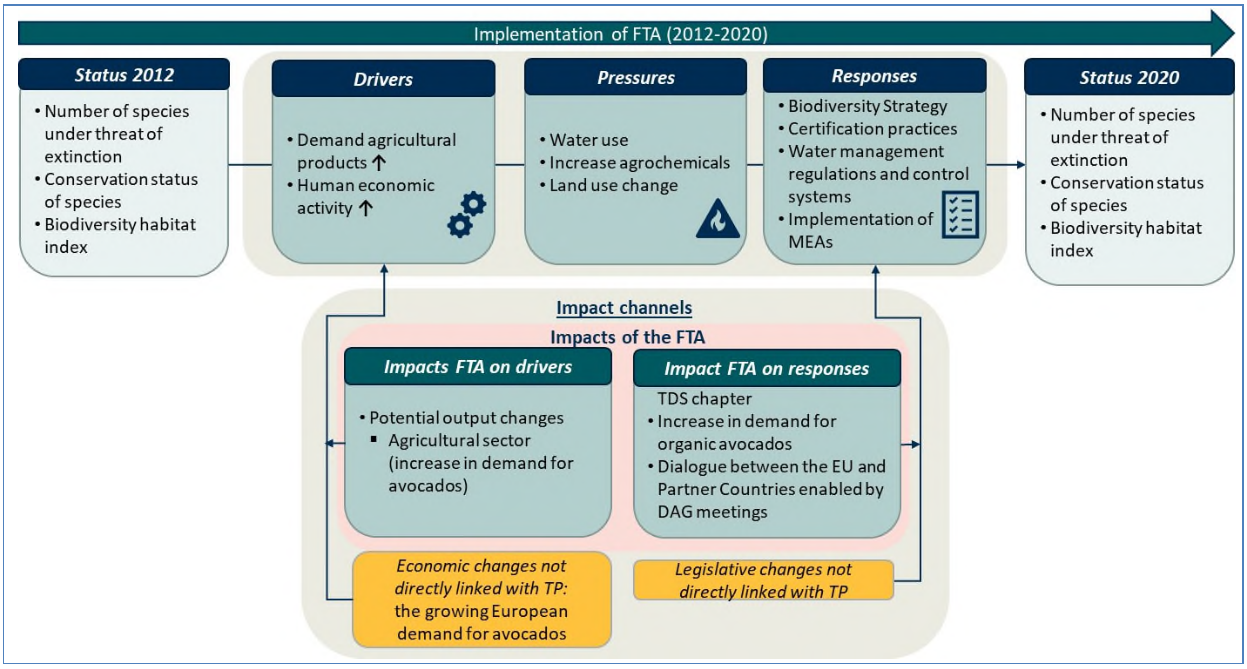
[4] https://fairtrasa.com/organic-farmer-dionisio/

implementation of the Agreement and in 2020. In the analysis (next section), the framework is applied on the biodiversity impacts of the FTA through avocado production in Peru.

1. **DPSIR** – The **Status** describes the factual biodiversity related state in a certain country or area. The state of biodiversity, and changes overtime, are measured by analysing indicators such as the number of species in different threat levels of extinction, as well as the biodiversity habitat index.[5] **Drivers** contain increased demand for agricultural products, such as avocados and increased human economic activity because of their production. A discussed in the introduction, the related **Pressures** include water constraints, land use conversion, and increased agrochemical use. Avocado production is generally associated with several key environmental **impacts**, including water resource and soil depletion, ultimately resulting in negative biodiversity impacts. **Responses** to these impacts can take the form of regulations related to water and pesticide uses (i.e., sustainable agriculture), or related to technical or efficiency improvements (e.g., in irrigation systems).

   The focus in this case study is on the key environmental pressures associated with avocado production. By identifying certain trends in e.g., water scarcity and the expansion of avocado production, certain conclusions are drawn on the biodiversity impact so far and potential future impacts of the FTA through avocado production in Peru. This is reflected in Figure 3 by emphasising the Drivers, Pressures and Responses boxes.

Figure 3: Causal chain and DPSIR for FTA's impact on biodiversity in Peru



2. **Impact channels** – The middle part of Figure 3 shows the pathways through which the FTA can affect the biodiversity status. It can do so by affecting the drivers (mainly through the economic effects on the FTA) and/or the responses (e.g., by changes in the implementation of environmental legislation, or expansion of certification practices). The provisions of the TSD chapter on biodiversity, forestry and in particular

the Multilateral Environmental Agreements such as the Rotterdam Convention are identified as the key channel through which the FTA may have affected the responses.

3. **FTA induced effects and external effects** – The lower part of the figure emphasises the role of external developments, unrelated to the FTA. It shows that developments unrelated to the FTA can also affect both drivers and responses. It also shows the key challenge in assessing the impacts of the FTA – isolating the FTA-induced impacts from external developments. In the case of avocados, a strong external effect is the growing European demand for avocados (CBI, 2021).

4 ANALYSIS

4.1 Water use in avocado production

In the **Olmos area**, avocado is the number two crop (4,200 ha) grown, after sugar cane (10,900 ha) in 2018. The avocado orchards are owned by large exporting companies, which own areas ranging from 250 to 1,000 ha per company.

The Olmos irrigation project enables the irrigation of 38,000 ha by channelling water from the River Huancabamba – which discharges into the River Amazon – to the dry coastal areas (CIRAD, 2019). The project has not reached it potential as approximately 30% of surface areas remain undeveloped due water quotas of 10,000 m^3/ha set by the National Water Authority (ANA). The undeveloped plots are used to obtain the rights for 4,000 – 5,000 m^3/ha of extra water that is required to fuel the micro-irrigation systems, **making water an important limiting factor**. By 2035, the water channelled between the Amazon and Pacific hydrographic region should increase by 50% as envisioned in the National Water Plan (cf. OECD, 2017). However, the plan also discusses the **potential negative environmental effects of water transfer**, including alteration of the ecosystem in the transferring watersheds and the risk of alien aquatic organisms to the recipient regions (OECD, 2017). The Amazon River experiences more frequent, intense, more prolonged and extreme droughts and floods as a result of climate change, which negatively affects river connectivity and aquatic biodiversity migration (Souza et al. 2019). The withdrawal of water for the Olmos irrigation project further intensifies this trend (interview data).

The extensive water use by large agribusiness enterprises **lowers the groundwater levels which has negative ecological consequences for the Bosque Seco (dry forest) in the North of Peru** (interview data). The dry forest is a unique ecosystem with several endemic species (e.g., birds and reptiles), and is a main food source for local communities and their feedstock.

The Chavimochic Special Project is a governmental initiative which aims to transfer and distribute water from the Santa River to irrigate four valleys in the Department of La Libertad (Chao, Virú, Moche, Chicama)[6], including the desert zones between the valleys (CIRAD, 2019). The Santa River is crucial for agricultural businesses in the area as **it can provide water to the agricultural sector whole year round**, turning desert areas into agriculture productive areas. Large avocado orchards (up to 2,600 ha) – mainly owned by export companies – are located in this area. In total, 75,000 ha irrigated land is available of which avocado production takes around 7,000 ha (9.3%) (CIRAD, 2019).

6 The first part was built between 1986 and 1995 and added 46,000 ha of new irrigated land (Oxford Business Group, 2021). In 2019, three of the four valleys were developed, to cover a total of 75,000 ha of irrigated land (CIRAD, 2019)

Crops are produced with pressurised irrigation systems,[7] using the newest techniques (interview data). Water use varies greatly per farm as avocado cultivation for the export market is still relatively new compared to e.g. asparagus cultivation; farmers cultivating avocados have around 12 years of experience on average, against 25 years of experience of asparagus farmers (Apaza-Tapia, 2020). Due to the irrigation of the Chavimochic area, the Santa River dries up a few times a year, losing its connection to the Pacific Ocean (interview data).

These lower water levels **negatively affect the aquatic ecosystems of the Santa River** as e.g. river shrimp rely on the connection to the Pacific Ocean for reproduction. Note that change in the aquatic ecosystem is not directly linked to the avocado production, as the lower water levels commenced after the completion of the first Chavimochic irrigation project (around 1990), before the large avocado farms settled in this area (interview data). Avocado production *could* exacerbate these pre-existing pressures.

The Chavimochic Special Project and the related expansion of agricultural areas also induced other negative ecological impacts, like **waterlogging**[8] **and salinization in the lower parts of the valley** (Vos and Marshall, 2017). Salinization lowers the soil production and negatively affects the ecosystems and the biodiversity adjacent to agricultural production areas. The region is currently investing in (costly) drainage systems (interview data).

Climate change is significantly diminishing the Cordillera Blanca glaciers which changes the hydrology of the Santa River (Mark et al., 2010). Climate change also increases the temperature, enabling small farm holders to irrigate (different) crops at higher altitudes and at the same time requiring (more) irrigation for that crop production (interview data). The reduced availability of water during the dry season, forms a threat for water supply in the Chavimochic project region, increasing the competition for water among economic sectors, political jurisdictions and upstream and downstream water users (Lynch, 2011). While the small farm holders (more upstream) the water rights of highland irrigators are defined as a share of available volume, large agribusiness enterprises (downstream) are entitled to a fixed yearly allocation of 10,000 m^3/ha, leaving small farm holders vulnerable during dry season (Lynch, 2011).

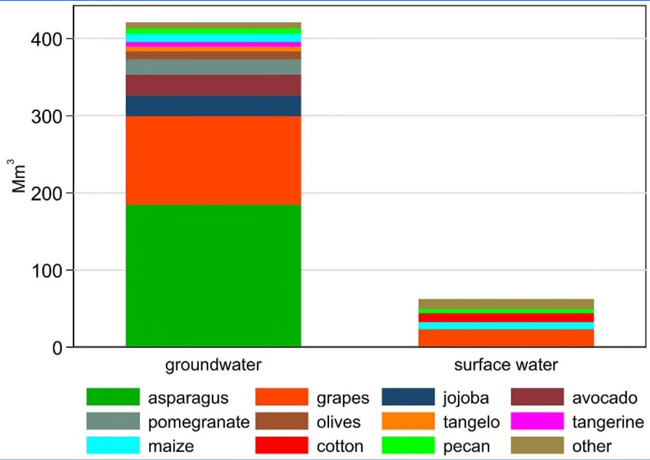
According to ANA, the **Ica Valley aquifer** has been over-exploited. If the current rate of decline in water availability continues, there could be a 76% reduction in the total area irrigated in the valley due to water scarcity within 10 years. This could lead to increased production costs resulting from higher pumping costs (ANA, 2018). Salmoral et al. (2020) estimate that the Water Footprint (WF)[9] in the Ica Valley in 2017 was 483 Mm^3, with 87% being attributed to groundwater and 13% from surface water. Avocados (28 Mm^3) have the third highest water footprint in this area, after asparagus (187 Mm^3) and grapes (138 Mm^3) (considering both water sources). In fact, **avocados grown in the Ica Valley withdraw water mainly from ground water sources** (see Figure 7), **further depleting the aquifer.**

7 In pressurized irrigation systems water is precisely applied to the plants under pressure through a system of pipes. Drip irrigation systems and sprinkler systems fall under this type of irrigation.

8 Waterlogging is the saturation of soil with water, either temporarily or permanently. This occurs when the groundwater levels are too high, which leads to salinization of the soil.

9 The water footprint represents the amount of water consumed by a nation or a specific geographical location, by sector, product or company.

Figure 7: Allocation of Water Footprint (Mm^3) by crop for the year 2017, distinguishing between surface and groundwater sources for the Ica Valley



Source: Salmoral et al. (2020)

Water scarcity in the Ica Valley puts agricultural activities in the valley under serious risk. The economic viability of pumping will also be threatened given the increased costs to abstract water. Economic feasibility studies will be needed to evaluate alternative water sources (e.g. desalination of groundwater) (Aparicio et al., 2019), but given the diversity of farming systems in the valley such initiatives would not be economically feasible for most farmers, particularly for those engaged in small-scale production.

The Agreement-induced impact on water use through its impact on avocado production is estimated **quantitatively**. Based on the data presented in the above analysis, the CGE results and water footprint data from Hoekstra et al. (as discussed in the main report), the additional water resources used in avocado production attributable to the implementation of the Agreement are estimated. Based on the CGE results, the Agreement-induced output change in the *vegetables, fruits and nuts* (VFN) sector equalled 54.8 million USD in 2020. The share of avocados in the VFN sector is calculated based on the value of production within the VFN sector (6%), and the value of avocado exports in the VFN sector (22%). This is combined with the weighted average water footprint of avocado production in the regions Lambayeque (The Olmos area), La Libertad (Chavimochic Special Project), and Ica (Ica Valley aquifer) based on Hoekstra et al (2010).[10] This estimate equals 996 m^3 water per ton of avocado. Based on this approach, it is estimated that the Agreement-induced impact on water use in Peru through avocado production in 2020 was between 4 million m^3 and 14 million m^3. This corresponds to roughly 1%-3% of water used for avocado production in Peru.

4.2 Agrochemicals use

In the **Northern production regions (Olmos and Chavimochic), there is limited use of pesticides** (interview data). This is possible due to 1) the limited number of 'host plants' for pests in the desert, 2) the climatic conditions (i.e. minimum rainfall), 3) the avocado's natural protection through its thick skin and 4) the large desert area between the Olmos and Chavimochic, preventing the transfer of pests (interview data). However, due to the strict requirements for fresh export products (set by GlobalGap and SENASA) the use of pesticides is common for the agro-export sector (interview data). In areas where rainfall is more abundant, (e.g. the Ica valley) the use of pesticides naturally increases (but still

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[10] Hoekstra et al. (2010) provide estimates of (blue, green and grey) water footprints per crop and region. Based on their estimates, the weighted average of the three main production and exporting areas was calculated. The estimates on the water footprint for avocados are: Ica 1,221 m^3, La Libertad 998 m^3, Lambayeque 927 m^3. The weights are based on the hectares of irrigated land per production zone, as listed in section 1.2 (Ica 11,000 ha, La Libertad 75,000 ha, Lambayeque 38,000 ha).

remains relatively low). **The use of pesticides is harmful to insects and reduces the biodiversity in and around the avocado farms** (interview data). Some avocado farms apply 'wind hedges' by planting trees around the production areas. In these trees birds and insects can thrive, but the absolute surface in ha of these wind hedges is low.

In the northern production areas (Olmos and Chavimochic) fertilizer use is higher than in e.g. Sierra region as the desert soil is not very fertile (interview data). Fertilizers are applied via advanced irrigation systems, ensuring their efficient use (interview data).

Export-oriented avocado farms often hold several certifications to meet the demand for certified avocados in foreign markets (Apaza-Tapia, 2020). In the **Chavimochic area**, all avocado and asparagus farms have at least one certification. These certifications (e.g. Rain forest, Tesco and Fair for Life) often include strict criteria to reduce pesticides use (Ibid), which aims to reduce harmful environmental impacts like soil and water contamination. Strict food safety criteria (from e.g. Japan and the EU) imply that no residues are permitted in the destination markets to comply with the indications on labels. (Apaza-Tapia, 2020, p. 97).

4.3 Land use change

The Northern production areas experienced land use change as coastal desert areas were turned into production sites, having a potential negative impact on biodiversity due to dry forest degradation and deforestation.

The Sierra and the Huaral regions are more traditional production areas and there is no indication that growth in avocado production resulted in land use change (interview data) with evident negative environmental impacts. It is noted that these regions host important species and are rich in agro-biodiversity, which may become at risk if many farmers shift to (monoculture) avocado farming (interview data). In these regions, including the Chavimochic region, certain crops (e.g., asparagus and peppers) are replaced by avocados to respond to the growing foreign demand for avocados. Avocado is a perennial crop and covers permanently the soil, which has environmental benefits compared to annual crops, i.e., permanent soil cover and the lack of tillage reduced e.g., the leaching of nitrogen which benefits soil production, and water and air quality (Bartels, et al. 2012). During an interview it was mentioned that **avocados are often replaced for annual crops (peppers) which positively impacts the environment.**

5 CONCLUSIONS

The demand for Peruvian avocados has increased over the past years, especially in the EU. The Agreement facilitates the growth in avocado exports, alongside several (inter)national policies and other promotion measures to support the avocado-export business, as well as the key driver: increased demand. It is challenging to isolate the effect of the Agreement from other trends. Even though the lack of detail in CGE data does not allow to identify a one-on-one causal relation between the Agreement and the growth in avocado production in Peru, it is very likely that a proportion of the higher exports is driven by the Agreement. Applying the shares of avocados in output respectively export value as estimates, between 6% and 22% of the calculated output change of USD 54.8 million in the *vegetables, fruits, and nuts* sector refers to avocados. Considering the context, in which virtually all of Peru's competitors benefit from zero-duty access to the EU market, whereas Peru without the Agreement would have fallen back to MFN treatment upon graduation from the previous GSP+ status, the output increase should however best be interpreted as an avoidance of output contraction that would have been observed in the absence of the Agreement.

The Agreement indirectly intensified the following environmental pressures:

- **Water scarcity and management:** The agricultural sector uses a substantial share of the limited water resources in Peru. In the Olmos region and the Ica valley (dominated by agro-export enterprises) water is identified as a limited factor for the avocado production. The Chavimochic area experiences growing competition for water during the dry season as climate change speeds up the retreat of the glaciers that feed the Santa River. Water stress that is further intensified by avocado production, can lead to different environmental impacts as identified in this study: lower water levels in rivers (Santa River and Amazon River) that negatively affect aquatic ecosystems and the reproduction fish and shrimp species; lower groundwater level degrading the Bosque Seco (dry forest) in the North of Peru; and the over-exploitation of the Ica aquifer. Water scarcity further deepens the vulnerability of small avocado farms as water becomes more expensive and/or large agribusiness enterprises are given priority in water allocation. In the regions in the North (the Olmos and Chavimochic region), water is applied via fast irrigation projects by channelling water from rivers to the production sites. Concerns have been expressed about the environmental negative effects of water transfer, including alteration of the ecosystem in the transferring watersheds and the risk of alien aquatic organisms to the recipient regions. In the Chavimochic region, waterlogging and salinization are identified as risks to the soil and water quality.

- **Agrochemical use & soil quality:** Avocado farms in Peru (and in particular the farms in the Northern production regions) apply pesticides. (Multiple) certifications by the Peruvian export-oriented avocado farms may further reduces the harmful environmental impacts related to pesticide use such as soil and water contaminations. The use of pesticides (though limited compared to other crops) is harmful to insects and reduces the biodiversity in and around the avocado farms. Avocado is often grown as a monocrop (especially in the Northern production areas), depleting the soil from its nutrients and thereby threatening biodiversity if agro-biodiverse farmers shift to monoculture avocado production.

- **Land use change:** The Northern production areas experienced land use change as coastal desert areas were turned into productive sites, having a potential negative impact on the biodiversity due to dry forest degradation and deforestation (in the case of Olmos). In the Sierra and the Huaral regions there has been no indication that growth in avocado production resulted in land use change with evident negative environmental impacts. In case avocado crops replace annual crops a positive impact on GHG emissions is generated.

REFERENCES

ANA, WWF, COSUDE, Universidad Nacional Agraria La Molina (UNALM), Pegasys Strategy and Development (PTY) LTD (2015). Huella hídrica del Perú. Sector agropecuario. Available at: https://repositorio.ana.gob.pe/bitstream/handle/20.500.12543/197/ANA0000013.pdf?sequence=4&isAllowed=y

Apaza-Tapia, W. (2020) Characterisation of avocado and asparagus farms in the Chavimochic irrigation project in La Libertad, Peru. DOI: http://dx.doi.org/10.21704/pja.v3i3.1342

Bartl, K., Verones, F., & Hellweg, S. (2012). Life cycle assessment based evaluation of regional impacts from agricultural production at the Peruvian coast. Environmental science & technology, 46(18), 9872-9880.

CBI (2021). The European market potential for avocados. Available at: https://www.cbi.eu/market-information/fresh-fruit-vegetables/avocados/market-potential

CIRAD, The Centre De Cooperation International En Recherche Agronomique Pour Le Développement, in collaboration with HAB, The Hass Avocado Board (2019). Country profile: Peru - Peru Making giant strides

DAR (2017) Retos y aportes para una gestión sostenible en aguas residuales. Derecho, Ambiente y Recursos Naturales. Available at: http://repositorio.ana.gob.pe/handle/20.500.12543/2806

FAO (2020). FAOSTAT – Crops. Available at http://www.fao.org/faostat/en/#data/QC/visualize

FAO (2021). Analysis of Mapping and Impacts of Climate Change and Food Security. Available at http://www.fao.org/in-action/amicaf/countries/per/en/

FreshFruitPortal (2021a). "Peru's ProHass analyzes effects of Agricultural Promotion Law". Available at: https://www.freshfruitportal.com/news/2021/03/25/peru-has-to-make-its-way-in-this-segment-prohass-on-organic-avocados/

FreshFruitPortal (2021b), "Peru has to make its way in this segment"- ProHass on organic avocados. Available at: https://www.freshfruitportal.com/news/2021/03/25/peru-has-to-make-its-way-in-this-segment-prohass-on-organic-avocados/

INIA (2019) En La Joya implementan certificación Global Gap para exportación de palta hass y granada wonderfull https://www.gob.pe/institucion/inia/noticias/108559-en-la-joya-implementan-certificacion-global-gap-para-exportacion-de-palta-hass-y-granada-wonderfull

Junta de Riego Presurizado de Chao, Virú y Moche (2016). Registro de cultivos de la Irrigación de Chavimochic. Boletín Anual. 25 p.

Kang, J. W., & Chung, I. K. (2017). The effects of eutrophication and acidification on the ecophysiology of Ulva pertusa Kjellman. *Journal of Applied Phycology*, *29*(5), 2675-2683.

LNV (2021). Recent events regarding the strikes and new agrarian law in Peru Available at: https://www.agroberichtenbuitenland.nl/actueel/nieuws/2021/01/08/recent-events-regarding-the-strikes-and-new-agrarian-law-in-peru

Lynch, B. D. (2012). Vulnerabilities, competition and rights in a context of climate change toward equitable water governance in Peru's Rio Santa Valley. Global Environmental Change, 22(2), 364-373.

Mark, B., Bury, J., French, A., J., Mckenzie. (2010) Climate Change and Tropical Andean Glacier Recession: Evaluating Hydrologic Changes and Livelihood Vulnerability in the Cordillera Blanca, Peru. Annals of American Association of Geographers, 100(4) 794-805.

Ministerio de Agricultura y Riego (MINAGRI). (2015) Analisis de Tendencias que impactan en l Agricultura. Available at https://www.minagri.gob.pe/portal/download/pdf/pnapes/actividades/comision/analisis-tendencias.pdf

Ministerio de Ambiente (MINAM). Decreto Supremo No. 002- 2008-MINAM; Estandares Nacionales de Calidad para Agua: El Peruano, Lima, 2008. www.elperuano.com.pe

OECD (2017). Environmental performance review Peru: Chapter 8 – water resources. Available at: https://www.oecd-ilibrary.org/sites/9789264283138-12-en/index.html?itemId=/content/component/9789264283138-12-en

Oxford business group (2021) Irrigation key to agricultural expansion in Peru. Available at: https://oxfordbusinessgroup.com/analysis/water-works-improvements-irrigation-infrastructure-remain-vital-accomplishing-ambitious-agricultural

Peruvian Government (2016). Se aprueba la Política Nacional Agrariahttps://www.midagri.gob.pe/portal/noticias-anteriores/notas-2016/15062-se-aprueba-la-politica-nacional-agraria

Peruvian Government (2019). Análisis de Mercado 2015-2019. Palta. Available at: https://cdn.www.gob.pe/uploads/document/file/1471795/An%C3%A1lisis%20de%20Mercado%20-%20Palta%202015%20-%202019.pdf

Salmoral, G., Carbó, A. V., Zegarra, E., Knox, J. W., & Rey, D. (2020). Reconciling irrigation demands for agricultural expansion with environmental sustainability-A preliminary assessment for the Ica Valley, Peru. Journal of Cleaner Production, 276, 123544.

Sommaruga, R. and Eldridge, H.M. (2021), Avocado Production: Water Footprint and Socio-economic Implications. EuroChoices. https://doi.org/10.1111/1746-692X.12289

Souza, C. M., Kirchhoff, F. T., Oliveira, B. C., Ribeiro, J. G., & Sales, M. H. (2019). Long-term annual surface water change in the Brazilian Amazon Biome: Potential links with deforestation, infrastructure development and climate change. Water, 11(3), 566.

Stoessel, F., Juraske, R., Pfister, S., & Hellweg, S. (2012). Life cycle inventory and carbon and water foodprint of fruits and vegetables: application to a Swiss retailer. Environmental science & technology, 46(6), 3253-3262.

UNESCO-IHE. (2010). The Green, Blue and Grey Water Footprint of Crops and Derived Crop Products. Report, Available at: https://www.waterfootprint.org/media/downloads/Report47-WaterFootprintCrops-Vol1.pd

Verones, F., Bartl, K., Pfister, S., Jiménez Vílchez, R., & Hellweg, S. (2012). Modeling the local biodiversity impacts of agricultural water use: case study of a wetland in the coastal arid area of Peru. *Environmental science & technology*, *46*(9), 4966-4974.

Vos and Marshall (2017) Chapter 8 – Conquering the desert. Venot, J. P., Kuper, M., & Zwarteveen, M. (Eds.). (2017). *Drip irrigation for agriculture: Untold stories of efficiency, innovation and development*. Taylor & Francis.

World Bank (2017). Gaining Momentum in Peruvian Agriculture: Opportunities to Increase Productivity and Enhance Competitiveness http://documents1.worldbank.org/curated/pt/107451498513689693/pdf/P162084-06-26-2017-1498513685623.pdf

WRI (World Resources Institute) (2020) Will Mexico's Growing Avocado Industry Harm Its Forests?. Available at: https://www.wri.org/blog/2020/02/mexico-avocado-industry-deforestation#:~:text=Avocado%20production%20drove%2030%2D40,local%20communities%20and%20Mexico%20City.