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On Sustainable Consumption: The Implications of Trade in Virtual Water for the EU's Food Security

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Abstract: The paper addresses the sustainability of the European Union's food consumption through a water footprint assessment of selected vulnerable agricultural imports from a two-pronged perspective: (1) the degree of the EU's dependence on global green water resources embedded in the apparent consumption of selected water-intensive agricultural products and (2) the degree of commitment of countries of origin to sustainability policies. The study argues that the vulnerability of the EU's agricultural imports to water risks can be estimated based on the amount of green water consumed in producing crops in the countries of origin. The results show that the EU's consumption of agricultural goods is highly dependent on virtual water imports for all six selected vulnerable agricultural products, from the lowest footprint for bananas (5 mil. km³) to the largest for coffee (69 mil. km³). The analysis also points to a greater concern for quality issues in the countries of origin (56.53%) relative to management (26.52%) and availability issues (16.85%), but the latter are to arise in importance for sustainable production in the years to come. Our conclusions contribute to building up a responsible commitment towards (1) development of environmental policies and the design of practical measures by providing quantitative information that makes problems more clearly defined and tangible, and (2) assessing the outcome of policies and practical measures by understanding their effects on the sustainability of food consumption.

Keywords: water footprint; virtual water; agricultural trade; food sustainability



Citation: Alexoei, A.P.; Cojanu, V.; Coman, C.-I. On Sustainable Consumption: The Implications of Trade in Virtual Water for the EU's Food Security. *Sustainability* **2021**, *13*, 11952. <https://doi.org/10.3390/su132111952>

Academic Editors: Gunnar Mallon and Erik W. Meijles

Received: 1 October 2021

Accepted: 26 October 2021

Published: 29 October 2021

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1. Introduction

One of the most extolled virtues of trade consists of its role as an indirect means of optimizing domestic output. However, the criterion of specialization based on opportunity costs began to be questioned from several directions. Early criticism has shown that specialization patterns may change depending on specific characteristics of competition in the marketplace. One of the latest items added to the list of requirements for rethinking trade structures is the cost of environmental degradation. Food safety has increased lately in importance in the context of transactions that pay little attention if any to such life-threatening conditions as the presence of dioxins (in poultry), mad-cow disease, or, in some cases, genetically modified organisms (GMOs). In addition, trade has contributed to massive deforestation, acid rain, aggression towards endangered species, carbon emissions, and even global warming [1–5].

Integration of environmental issues into the mechanism of trade relationships is a two-way approach. For one thing, one must ensure fair exchanges so that flows of products obtained through environmentally friendly investments are not at a disadvantage in competition with exports from less environmentally conscious countries. For another, it is of practical concern to investigate how trade-related environmental issues affect society in general. Consumers' tastes have changed in recent times, and imports account for an ever-larger share of domestic consumption. At the same time, concepts such as "smart farming," "virtual water," and "farming 4.0" are perceived as trends in overcoming the

future challenges related to predicted shortages in agriculture output and global climate change [6–9]. This latter category of issues inspired our present examination of the impact of the virtual water trade on sustainable consumption.

By 2050, the world's population is predicted to exceed 10 billion, doubling the demand for food [10]. The food system's capacity to account for increased demand has become a critical challenge at the global level. Sustainable production and consumption in connection to water use and management are among the key objectives of the United Nations' Sustainable Development Goals (e.g., SDG 2, SDG 6, SDG 12) [11]. The World Bank has repeatedly warned of a significant stalemate in economic development due to a lack of fresh (clean) water. In some countries, the water crisis could slow GDP growth by 6% by 2050 and/or is giving rise to social unrest [12]. Likewise, the World Economic Forum [13] has been consistently listing water crises as one of the most significant global risks in terms of potential impact. According to the World Resources Institute (WRI), the "hydrological stress is the biggest crisis that anyone is talking about. Its consequences are very obvious in the form of food security, conflicts, migration and financial instability" [14]. It is estimated that by 2030, global water demand will exceed the supply of renewable sources by 56%, while the global gap between water supply and demand could reach 40% [15].

The availability of fresh water varies greatly at the territorial level. Most of the world's freshwater resources are divided into 410 basins, of which almost a quarter (90) are considered "severely stressed" (i.e., the ratio between total annual withdrawals and total annual supply available exceeds 40%) and about half are in the territory of three countries with enormous water needs and high economic activity: China, India, and the United States [14]. WRI (2019) [14] data show that 17 countries—hosting a quarter of the world's population—face "extremely high" stress levels on water resources, meaning that irrigated agriculture, industry, and municipalities use on average more than 80% of the available supply each year. Consequently, there is a legitimate interest in improving the management of water resources besides the traditional concerns related to their quality and availability. One example is deficit irrigation, a strategy that involves reducing water supply below maximum levels and allowing for mild stress with minimal yield impact. In times of scarcity of water and drought, deficit irrigation may result in higher economic rewards than optimizing yields per unit of water for a given crop. Studies prove, however, that this strategy necessitates a precise understanding of a crop's water response, as drought tolerance varies significantly by crop species and stage of growth (e.g., [16–18]).

In response to the global concerns, the EU's Industrial Strategy (2020) has underlined the importance of "reducing dependence on others for things we need the most: critical materials and technologies, food, infrastructure, security and other strategic areas" [19]. The European Council also stresses the need to "identify strategic dependencies, particularly in the most sensitive industrial ecosystems (. . .) and to propose measures to reduce these dependencies, including by diversifying production and supply chains, ensuring strategic stockpiling, as well as fostering production and investment in Europe" [20]. In the same vein, increased environmental ambition is a critical component of the EU's agri-food promotion policy of the new Common Agricultural Policy, and the Commission is drafting a contingency plan to secure the EU's food supply and security [21].

This paper aims at providing further evidence for the EU preoccupations with "strategic dependencies" by assessing the sustainability of the EU's food consumption as can be derived from a water footprint of its imports. We searched specifically for (1) the degree of EU's dependence on global green water resources embedded in the apparent consumption of selected water-intensive agricultural products and (2) the degree of commitment of countries of origin to sustainability policies. The paper is structured as follows: Section 2 provides a literature review and background on the concepts of water footprint and virtual water and the role they play in trade and in fostering sustainable consumption. Section 3 is devoted to the methodological framework. Section 4 presents the findings in light of relevant measures that might be considered to mitigate strategic dependencies and related risks. Section 5 draws together final commentaries and conclusions.

2. Virtual Water and Sustainable Consumption

2.1. The Concepts of Virtual Trade and Water Footprint

The concept of “virtual water” (VW) was introduced in the early 1990s and was defined as “the water ‘embodied’ in a product, not in real sense, but in virtual sense and refers to the water needed for the production of the product” [22]. The total trade in virtual water can be thus conceived as the hidden flow of water in all traded commodities. When awarding the Stockholm Water Prize to Professor John Anthony Allan, one of the concept’s pioneers, the Stockholm International Water Institute stated that “virtual water has major impacts on global trade policy and research, especially in water-scarce regions, and has redefined discourse in water policy and management” [23].

An accompanying concept, “water footprint” (WF), was developed as a tool to quantify virtual water use across the entire supply chain, from manufacturing to delivery to the consumer, including pollution generated in the process [24,25]. It refers to the amount of fresh water required to manufacture a product (whether food or a material commodity), transport it to the consumer, and clean up pollution caused by the product across the supply chain. For example, it takes 2400 liters of water to produce 100 grams of chocolate or 140 liters of water for a cup of coffee [26].

The water footprint is classified as **blue** (consumption of surface and groundwater (through irrigation) along a product’s supply chain or from crop growth to the marketplace), **green** (the use of rainwater (before it becomes runoff), moisture absorbed by plants from the soil, as well as moisture intercepted in the plant canopy or on soil surfaces), or **grey** (amount of fresh water required to assimilate polluted loads to achieve local water quality standards) [26]. The water footprint can be evaluated from two perspectives: Production and consumption. The water footprint of production quantifies the strain placed on local water resources and serves as a reference for judging whether they are being used sustainably. Consumption’s water footprint reflects a country’s citizens’ standard of living and lifestyle choices based on both internal and external water resources. Evaluating how much of that water footprint is contained within a country’s boundaries and how much and where it is contained abroad is a necessary first step toward measuring its external water dependence and the impact on food security.

The two concepts of VW and WF have contributed to research advances at a variety of spatial scales, for a variety of agricultural and industrial products, and to various assessment techniques [27–34]. Because of the large estimates of their WF, the analysis of agricultural products has generally taken center stage of scientific interest. Furthermore, the growing awareness of the practical impact of the two concepts resulted in the development of a new standard, ISO 14046, which quantifies the impact of water usage and promotes water management efficiency.

However, the novel conceptual framework has not been spared criticism. Merrett (2003) [35] and Wichelns (2011) [36] considered that nations import food and not real water, as the amount of water contained in traded goods is always far lower than the totality of water used in their production. Velázquez et al. (2011) [37] pointed out that unclear methodology makes the two concepts often misused even if virtual water was established as a production-oriented indicator, whereas water footprint was designed as a consumption-oriented indicator. Verma et al. (2000) [38] argued that when it comes to inter-state virtual water flows, other non-water yet ecologically relevant factors of production, such as “per capita gross cropped area” and “access to secure markets,” also have to be considered.

Nevertheless, conducting a water sustainability analysis provides explicit spatial-temporal information on how sustainable and equitable global water resources are being used for different activities. The analysis of trade flows points to a country’s dependency on the resources of other countries, as well as to the areas where water-related risks may arise. This might have economic, sustainability and food security, and in some cases, even diplomatic implications.

2.2. Virtual Water and Trade Specialization

Trade of food crops or other agricultural products, in compliance with the principle of comparative advantage, has the potential to mitigate the issues associated with water scarcity. If one considers the virtual flow of water embedded in those commercial exchanges, according to the Heckscher–Ohlin (H–O) theory of factor endowments, a water-scarce country shall import water-intensive products from a relatively water-abundant country. However, from the Ricardian perspective, even if a country is not abundant in water in absolute terms, it can still gain from trade if it exports water-intensive goods for which it has lower opportunity costs. The initiator of the concept of virtual water defines it as a descendant of comparative advantage and argues that regions with limited water resources must import agricultural commodities to meet their food demand [39].

Several studies were conducted to evaluate the relationship between water availability and virtual water trade, but conclusions are seemingly contradictory. Rosa et al. (2019) [40] and Debaere (2014) [41] support the idea that water availability impacts worldwide patterns of agricultural production and trade. On the other hand, de Fraiture et al. (2004) [42] and Kumar and Singh (2005) [43] support the idea that there is no direct link between water shortages and virtual water imports and that a variety of other factors (e.g., arable land, GDP per capita) influence agricultural trade flows. Wichelns (2004) [44] critiqued the analogy between comparative advantage and the idea of virtual water because the latter focuses exclusively on water resource endowments (i.e., only one factor of production), while ignoring the role of opportunity costs and technologies in influencing trade patterns.

In the same vein, according to Ansink (2010) [45], trade can result in water savings only if the country with a comparative advantage in water also possesses an absolute advantage in the resource. This may account for the paradoxical result of countries that are net virtual water importers despite their large water resources: They are relatively more endowed with a second factor of production—capital. As a result, they gain a comparative advantage in commodities that do not require a lot of water. Furthermore, these countries' abundant water resources are not matched by an abundance of agricultural land. Kumar and Singh (2005) [43] argued that the availability of both land and freshwater constrains agricultural productivity, hence affecting virtual water “export.” On the other hand, Reimer (2012) [46] argued that water endowments as a source of comparative advantage are frequently overlooked as a result of the high costs and trade barriers associated with agricultural trade, which fundamentally distort prices and obscure any potential comparative advantage (or disadvantage) resulting from relative water endowments. The author [46] considered that any theoretical or empirical shortcomings related to the idea of virtual water are either the result of inconsistencies with the theoretical assumptions or because reality deviates from economic theory's assumptions.

Generally, studies with a broad coverage of a larger number of countries and products have rejected the hypothesis that the scarcity of water resources is an important determinant of food imports (e.g., [43,47,48]). Yang et al. (2003) [49] tested the relationship between water resource availability and grain imports for Asian and African countries and identified a water deficit threshold below which a country's demand for grain imports increases exponentially with declining water resources, whereas above this threshold there is no systematic relationship between the import of cereals and the availability of water resources. The results also showed that GDP per capita and arable land area are very significant in explaining variations in the level of grain imports between countries with similar water resources. Yang et al. (2003) [49], de Fraiture et al. (2004) [42], and Yang et al. (2007) [50] noted, however, that the relationship between water resources and food imports still applies for countries where water resources are extremely limited. For instance, Yang et al. (2007) [50] reduced the sample to the countries of the southern and eastern Mediterranean to test in detail the water deficit and trade for various food products. They found that the decline in per capita water resources in these countries is a key factor in explaining the increase in water-intensive crop imports, namely, cereals, vegetable oil, and sugar. However, no significant relationship was found for fruits and vegetables, a conclusion

that supports the general view that for countries with few water resources it is logical to import some of the water-intensive crops consumed domestically and to export high-value fruit and vegetable crops. Similarly, using cross-sectional data from 134 countries and 206 sectors, Debaere (2014) [41] concluded that although water's impact on export patterns is less significant than that of other traditional factors of production, it is nonetheless a source of comparative advantage, with countries with more water available per capita exporting more water-intensive goods.

Wichelns (2004) [44] and Yang and Zehnder (2007) [51] considered that virtual water cannot be completely represented by the notion of comparative advantage, but neither can it be considered a simple metaphor. Virtual water is a multi-faceted concept and the challenge in conceptualizing it lies largely in the unique nature of water resources: "it originates from rainfall which is free of charge, renewable at various rates, variable in space and time, highly mobile, costly to store, almost impossible to possess by individuals, disastrous when too much or too little" [51] (p. 9).

Summing up, pooling all countries for an aggregate analysis is very likely to nullify any direct relationship between water scarcity and food imports. Moreover, the underlying issue is that the significance of other input elements in production, the different opportunity cost of blue water and green water resources (specific to precipitation-based agriculture) [52], as well as the distinction between relative abundance (as used by the Heckscher–Ohlin model) and absolute abundance (as used in water footprint analysis) are rarely considered [45]. Overlooking these facts can underestimate the water supply of a country and can distort the examination of imports of water and food, especially for countries dominated by rainfed agriculture.

2.3. EU's Virtual Water Trade in Agricultural Products

The European Water Resources Safeguarding Plan [53] presented by the European Commission in November 2012 reiterated the need to address Europe's water resource management more broadly, integrating all categories of water users, as well as the analysis of the interaction of water with other types of resources. The Plan, as well as a host of other complementing initiatives such as the European Climate Law and Water Framework Directive (WFD) or the European Green Deal, provides for a roadmap that focuses on policy actions that will improve the way current water legislation is implemented and on the integration of water policy objectives with other policies.

The risk is compounded by domestic conditions of production as well. Water scarcity and droughts are already affecting a third of the European territory, so water availability and its efficient use are issues that need to be addressed as a matter of priority [54]. The OECD (2004) [55] defines a water stress index >40% as high water stress, 20–40% as medium-high, 10–20% as moderate, and <10% as low. Cyprus is the most affected country in the EU, with a water stress index of about 66%, and other European countries, such as Belgium, Italy, Greece, Spain, and Portugal, also face a high level of water stress [14]. Hess and Sutcliffe (2018) [56] discussed the issue of the United Kingdom's reliance on other nations such as Spain for the supply of many of its fruits and vegetables (a matter that could equally apply to many other countries). As a semi-arid country, Spain is experiencing significant water scarcity, and its agricultural exports effectively allow the United Kingdom and other nations to "offshore" their environmental responsibilities.

In 2019, the EU-28's agricultural extra-community imports amounted to EUR 119.3 billion, with the top five countries of origin accounting for more than 35% of total agricultural imports: the US (11.8%), Brazil (11.6%), Ukraine (7.4%), China (6.1%), and Argentina (5.0%). In terms of product categories, the highest increases in import values compared to 2018 were recorded for vegetable oils other than palm and olive oil (+30%), oilseeds other than soya beans (+21%), cereals other than wheat and rice (+12%), fresh, chilled, and dried vegetables (+7%), and tropical fruit (+6%). In 2020, extra-EU trade in agricultural products represented 9% of the overall extra-EU international trade in goods. From 2002 to 2020, the EU agricultural trade more than doubled, at an average annual growth rate of 5% [57].

An essential yet invisible part of this trade is represented by trade in “virtual water.” An assessment of virtual water levels may be inferred from two elements: the quantity of traded products and the products’ water footprint (m^3 per unit of mass of product). For the 2006–2013 period, the EU’s total virtual water imports was $333 \text{ km}^3/\text{year}$ (green, blue, and grey components), whereas it uses approximately 668 km^3 of water for all that it produces (industrial goods included), consumes, and exports annually. Crops make for the largest share (72%), followed by industrial products (22%) and animal products (6%) [58]. These dependencies leave the European economy particularly vulnerable to a lack of water availability in countries of origin, especially for supplies of agricultural commodities.

3. Materials and Methods

The water footprint impact on the sustainability of the EU consumption of agricultural goods is gauged from the perspective of “vulnerable” imports of agricultural products. A product’s “vulnerability” is assessed against two criteria:

- Size of trade deficit (expressed in quantities), and
- Dependency on external resources of green water.

The investigation followed two working hypotheses:

Working hypothesis #1: The EU’s consumption of agricultural products depends to a considerable extent on external resources of green water.

The sustainability of the EU consumption of agricultural goods is highly dependent on water-related risks for vulnerable crops in countries of origin. The issue is further compounded if parts of these imports originate in countries that face high stress levels on water resources.

Working hypothesis #2: The state of water sustainability policies in supplying countries points to possible disruptions in the EU consumption of certain crops.

Given that the production process consumes by far the most water in crops’ value chain [25], the paper will concentrate on the risks associated with the location of production only. Although there is a general worldwide interest in water resources and water footprint studies, most nations lack a clear and long-term vision for protecting and efficiently using their region’s water resources. Their lack of commitment to promoting sustainable water use is an indicator of presumable regulatory risks in the countries of origin [59] and therefore poses a credible threat to maintaining secure provisioning and even to being counted as a responsible supplier by the increasing cohort of environmentally conscious consumers.

3.1. Methods

In addressing the first working hypothesis, we collected statistics for EU agricultural exports and imports based on the four-digit Harmonized System (HS) nomenclature retrieved from the International Trade Center (Trademap). The top five largest trade deficits were singled out. For this range of products, we identified the volume of imports per country of origin and determined water footprints of each EU member. To further assess the degree of the EU’s vulnerability, we adopted the methodology suggested in the 2020 New Industrial Strategy of the EU [16] as a combination of three complementing metrics:

- (1) Concentration of EU imports from extra-community sources

$$V1 = \sum (s_i^2)$$

where s_i is the market share of each extra-EU supplying country in total EU imports. Scores are to be normalized to lie between 0 and 1; scores close to 0 indicate a diversification of markets and scores close to 1 indicate high concentration in a few markets. To identify crops with a low diversification potential, an HHI index threshold of 0.25 is set (regarded as a high concentration in the economic literature) [58] (p. 21). Therefore, if $V1 > 0.25$, the higher the concentration, the lower the diversification of EU imports from extra-community sources.

- (2) Importance of extra-community imports in total demand

$$V2 = \text{extra-EU import value} / \text{total EU import value}$$

if $V2 > 0.5$ then the higher the importance of extra-EU imports in total EU imports.

(3) Substitutability of extra-EU imports with EU production

$$V3 = \text{extra-community import volume} / \text{EU domestic production}$$

if $V3 > 1$ then the less capable the EU is of substituting additional EU imports for EU output in the event of a trade disruption.

To reveal the products for which the EU relies most on external resources of green water, a three-dimensional chart for each product category was designed along the following variables: (1) apparent consumption in 2019, (2) import annual growth between 2015 and 2019, and (3) virtual water imports of green water. The footprint is assessed only against the green water component because it accounts for the most significant share in agricultural production (Mekonnen and Hoekstra, 2011) [25]. For each vulnerable product, the chart illustrates the way EU member states cluster in groups of countries that have a small/large apparent consumption, a significant increase/decrease in their imports of selected vulnerable products, and exhibit a large/small water footprint of their imports.

Data on green VW content were collected from Mekonnen and Hoekstra (2010) [25] and domestic production statistics from Eurostat. The trade data (in tons/year) were converted to VWF (in m^3/year) by multiplying the quantity of products traded with the global value of VW required to produce the product:

$$\text{VWF} = \text{VW}_{p,c} * Q_{p,c}$$

where $Q_{p,c}$ is the volume of imports of product p sourced from country c , and $\text{VW}_{p,c}$ is the global value of green water footprint for p .

Apparent consumption of each EU member state was determined as

$$\text{AC}_p = P_c + I_c - E_c$$

where P_c is domestic production of product p in country c , I_c is imports of product p in country c , and E_c is exports of product p from country c .

Based on the three-dimensional chart, we defined the range of vulnerabilities as follows:

- High vulnerability: countries that cumulatively meet the conditions of annual growth in imports between 2015 and 2019 higher than 0. At the level of 2019, both apparent consumption and import water footprint are above the EU average. In particular cases, even if there is a slight decrease in imported volume for the analyzed timeframe (no lower than -5%), if both apparent consumption and import water footprint are above the EU average, countries will fit into this group.
- Moderate vulnerability: countries with a 5–10% annual growth in imports (2015–2019), and both apparent consumption and import water footprint below the EU average. In particular cases, if both apparent consumption and import water footprint are above the EU average and the annual growth in imports is lower than -5% , countries will fit into this group.
- Low vulnerability: countries with an annual growth in imports lower than 5% (2015–2019), and both apparent consumption and import water footprint below the EU average.
- Lowest vulnerability: countries with negative annual growth in imports (2015–2019), and both apparent consumption and import water footprint below the EU average.

To answer the second working hypotheses, we selected 22 European and international policy papers regarding sustainable water resources (see Supplementary Materials, Table S2). We prepared a qualitative content analysis to measure the occurrence of water-related words, identify the most salient terms or phrases related to it, and examine the

meanings of these associations to gain a better understanding of international policy scope and objectives on the matter. We used Wordstat (to extract phrases) and Maxqda (to extract words) software to create a dictionary that would match the research goals by enabling the Keyword Extraction function to index data from the selected documents. Based on word- and document-appearance frequency, a dictionary of 165 terms was created on a three-code classification as defined in Table 1.

Table 1. Lexical categories.

Category	Analytic Objective
(1) Water Availability scarcity, risk, drought risk, flood risk, freshwater, surface water	Assessment in terms of water resource quantity, scarcity, flood risk, and drought risk
(2) Water Management investments, irrigation, strategy, training, infiltrations	Measure the extent to which water management practices exist and identify the type of investments, strategies, training, and infrastructure
(3) Water Quality pollution, certifications, standards	Aspects related to water quality, performance and efficiency indicators, standards, conventions, regulations, and directives

Source: Authors' work. Note: Despite not being among the most frequent terms, we opted to include a set of other relevant terms such as "certificates," "certifications," "certified," "ISO," "watershed," "erosion," "water resource development," "SDG," "fertilizer," "UTZ," "ecologic," "ISPO," "CSPO," "RSPO," "CWR," "pesticides," "nitrates," "chemical," "herbicides," "nutrients," and "contamination." The term "water" was also worth including because not all documents were exclusively about water, but also sustainability reports and entities' websites to investigate the prominence/absence of terms.

For each selected agricultural product, the first two import shares of exporting countries were singled out for analysis. The next step was to collect data on companies/clusters/cooperatives or other forms of organizations involved in exports operations from the countries of origin of selected vulnerable products. To assess the frequency of the selected 165 key terms, we mined data from 228 sources in the form of annual reports, sustainability reports, or policies (e.g., environmental, social, and governance (ESG) reports), websites, or any other form of related information made public by exporters, clusters or cooperatives, or other forms of organizations within the countries of origin covering the 2011–2021 timeline. This step was intended to shed light on how committed the exporting companies, national support institutions, or other third parties are to water sustainability policies and to classify what type of aspects are of most concern in relation to the three previously defined categories of key terms (water availability, water management, water quality).

3.2. Limits

The analysis represents a snapshot based on 2019 data (the latest available for all EU countries at the time when the analysis was performed) and therefore it cannot capture future or emerging trends. The evaluation was subject to a selected group of products and countries and thus provides an initial indication of items for which the EU may be more reliant on external water supplies only from a small number of water-stressed nations. We were confronted with a language barrier throughout the content analysis, and consequently, not all the available online reports and data were evaluated. This limit was encountered primarily for Brazil (coffee and soya bean production), and those few specific documents that were not published in English were excluded from analysis.

4. Results

4.1. The EU's Dependency on Imports of Agricultural Products

This section provides a bottom-up analysis of the EU's vulnerability and reliance on international trade in virtual water for agricultural products. It covers external trade flows

for six vulnerable crops in 2019. Table 2 integrates the results in relation to the share in the EU's trade deficit in agricultural products and the scores of three dependency indicators (i.e., V1, V2, and V3).

In terms of concentration of EU imports from extra-EU source, only imports of soya beans and cocoa beans had levels higher than the threshold of 0.25, meaning that their foreign supply can be considered the least diversified and concentrated in very few countries of origin. For soya beans, the US and Brazil were the two largest exporters and together comprised 75% of the EU's imports, whereas for cocoa beans, Cote d'Ivoire (49%) and Ghana (14%) summed up 63% of all the EU's imports. For the second indicator, importance of extra-community imports in total demand, for all selected products, the score exceeded 0.5, illustrating the large dependency for these products on sources outside the single market. As for the substitutability of extra-EU imports with EU production, for three of the analyzed products there was no domestic production in the EU, whereas in the rest of the cases the scores were larger than 1. Consequently, for all six products, the EU's capacity to satisfy the demand for these products with local production was very low or inexistent, making it extremely vulnerable to global disruptions.

The results of the shares of apparent consumption of virtual water for each EU member and each vulnerable product (see Table S3, Supplementary Materials) indicate that the EU countries with the largest apparent consumption of virtual water are as follows:

- Coffee: Slovakia, Belgium, and Latvia;
- Soya beans: Slovenia, Belgium, and Latvia;
- Palm oil: Denmark, Germany, and the Netherlands;
- Other nuts: Spain, the Netherlands, and Romania;
- Cocoa beans: Estonia, Belgium, and the Netherlands;
- Bananas: Belgium, the Netherlands, and Slovenia.

A three-dimensional chart (Figures S1–S6, Supplementary Materials) illustrates the way EU member states cluster in groups of countries that have a small/large apparent consumption, a significant increase/decrease in their imports of selected vulnerable products, and exhibit a large/small water footprint of their imports. The highest degrees of vulnerability are presented in Table 3 below. An account of the main findings shows that:

- Cyprus stood alone in a coffee (0901) cluster of the countries that are most vulnerable and highly dependent on external resources: Between 2015 and 2019 it had the largest annual growth of imports (+27%); in 2109 its apparent consumption was above the EU average, and it also had a significant water footprint of imports.
- Germany was singled out in the palm oil (1511) cluster due to its very large apparent consumption and imported water footprint and the significant drop (−18%) in import volumes (negative annual growth). Estonia differentiated itself with an atypical evolution of 454% annual growth in imports, a negative apparent consumption, and a water footprint of 726,649,973 m³/ton.
- For the other nuts (0802) groupings, the relevant finding is that most of the EU countries were part of either the group of highly or moderately vulnerable countries.
- The cocoa beans (1801) category registered the largest range of annual growth figures of all analyzed products (from −83% to +612%).

Table 2. The EU's vulnerable imported agricultural products, 2019.

Code	Vulnerable Products	Trade Deficit (Thousands of EUR)	Share in the EU's Trade Deficit for Agricultural Products	Concentration of EU Imports from Extra-EU Sources *	Importance of Extra-EU Imports on Total Demand **	Substitutability of Extra-EU Imports with EU Production ***
0901	Coffee, whether roasted or decaffeinated; coffee husks and skins; coffee substitutes	−5,350,862	11.19%	0.0728	0.59%	No EU production
1201	Soya beans, whether broken or not	−4,701,076	9.83%	0.2951	0.91%	5.84
1511	Palm oil and its fractions, whether refined or not (excluding chemically modified)	−3,894,273	8.14%	0.1864	0.73%	No EU production
0802	Other nuts, fresh or dried, whether shelled or peeled or not	−3,819,625	7.99%	0.2033	0.71%	41
1801	Cocoa beans, whole or broken, raw or roasted	−3,783,940	7.91%	0.2837	0.94%	No EU production
0803	Bananas, incl. plantains, fresh or dried	−3,384,651	7.08%	0.1123	0.80%	13

Source: Authors' work. Notes: * HHI index threshold of 0.25; ** V2 > 0.5; *** V3 > 1.

Table 3. Countries with the highest degrees of vulnerability.

Category	Coffee	Soya Beans	Palm Oil	Other Nuts	Cocoa Beans	Bananas
High vulnerability	Cyprus Belgium, Austria, Bulgaria, Estonia	Germany, Italy, Portugal, Spain, the Netherlands	Spain, the Netherlands, Belgium, France, Italy	Germany, Italy, Spain, the Netherlands, France, Belgium	The Netherlands, Germany, France, Italy, Belgium, Spain	The Netherlands, Spain, Romania, Poland, France, Italy, Belgium, Germany
Moderate vulnerability	Denmark, France, Hungary, Ireland, Latvia, Malta, Poland, Portugal, Romania, Slovenia	Belgium, Poland, Denmark, Croatia, Sweden, Ireland, Slovenia	Sweden, Ireland, Denmark, Greece, Romania, Cyprus	Poland, Austria, Denmark, Portugal, Sweden, Czechia, Lithuania, Croatia, Bulgaria, Slovenia, Latvia, Estonia	Austria, Bulgaria, Croatia, Portugal, Ireland, Czechia, Sweden, Hungary	Greece, Slovakia, Slovenia, Croatia, Bulgaria, Malta, Cyprus, Luxembourg

Source: Authors' work based on Figures S1–S6 (Supplementary Materials).

Table 4 summaries the EU countries' vulnerability in terms of green water resources from the main countries of origin. The key finding here is that Belgium, the Netherlands, Italy, and Spain qualified as highly vulnerable in five of the six analyzed products, followed by France and Germany for four products. At the EU-27 level, a ranking according to import footprint placed coffee (0901) first, followed by soya beans (1201), palm oil (1511), other nuts (0802), cocoa beans (1801), and bananas (0803).

Table 4. Analysis of EU countries' vulnerability in terms of foreign green water resources.

Vulnerable Products	Main Countries of Origin—Share in the EU's Imports of the Product	EU's Apparent Consumption 2019 (Tones)	EU's Imports Footprint (m ³)	Highly Vulnerable EU Members
Coffee 0901	Brazil—15% Vietnam—8%	2,563,645	69,149,605,347	Cyprus, Belgium, Austria, Bulgaria, Estonia
Soya beans 1201	US—43% Brazil—32%	1,795,858	43,331,034,340	Germany, Italy, Portugal, Spain, the Netherlands
Palm oil 1511	Indonesia—34% Malaysia—20%	7,067,266	43,279,377,095	Spain, the Netherlands, Belgium, France, Italy
Other nuts 0802	US—42% Turkey—13%	17,176,451	33,125,592,150	Germany, Italy, Spain, the Netherlands, France, Belgium
Cocoa beans 1801	Cote d'Ivoire—49% Ghana—14%	681,720	9,089,597,853	The Netherlands, Germany, France, Italy, Belgium, Spain
Bananas 0803	Ecuador—21% Colombia—17% Costa Rica—17%	5,532,554	5,118,596,340	the Netherlands, Spain, Romania, Poland, France, Italy, Belgium, Germany

Source: Authors' work. Note: Intra-EU trade was not included in the analysis.

A review of the EU's main countries of origin for agricultural products and their water stress level is presented in Table 5. As the scores indicate, from 12 countries of origin of vulnerable agricultural products, Turkey was the one registering a level of high-water stress

(for imports of *other nuts*), whereas the US (for imports of *soya beans* and *other nuts*) and Indonesia (for imports of *palm oil*) scored medium–high levels of water stress, and Vietnam had moderate water stress (for imports of *coffee*). The remaining countries or origin faced low levels of water stress.

Table 5. Level of water stress: freshwater withdrawal as a proportion of available freshwater resources by country (2017).

Country	Code (Vulnerable Products)	Water Stress Score	Water Stress Level ***
Colombia	0803 Bananas	2.04	Low
Brazil	0901: Coffee1201: Soya beans	3.11	Low
Malaysia	1511: Palm oil	3.44	Low
Indonesia	1511: Palm oil	29.7	Medium–high
Cote d’Ivoire	1801: Cocoa beans	5.09	Low
Costa Rica	0803: Bananas	5.45	Low
Ghana	1801: Cocoa beans	6.31	Low
Ecuador	0803: Bananas	6.78	Low
Vietnam	0901: Coffee	18.13	Moderate
Turkey	0802: Other nuts	44.57	High
US	1201: Soya beans0802: Other nuts	28.16	Medium–high

Sources: Authors’ work; *** World Bank, 2021. Note: The level of water stress is represented by freshwater withdrawal as a dimension of available freshwater resources. Water stress level is determined as the proportion between total freshwater withdrawn by all principal sectors and total renewable freshwater resources, after weighing environmental water requirements. The OECD (2004) defines a water stress index > 40% as high water stress, 20–40% as medium–high, 10–20% as moderate, and <10% as low.

4.2. Countries of Origin’s Approach to Sustainability

The selected 165 words, which were counted in 43,036 occurrences among the analyzed sources, are presented by category in Table S1 (Supplementary Materials). As the preliminary results indicate, the selected countries of origin, more precisely their exporters/clusters/cooperatives or other forms of organizations, were mainly focused on water quality issues (56.53%), followed by water management (26.52%) and water availability issues (16.85%).

Table 6 depicts a general perspective of the top 15 most intensively used keywords, which accounted for 58% to 76% of the total distribution, in respect to product and country of origin. Countries primarily focused on *water availability* issues were the U.S.—soya beans (15.36%) and nuts and dried fruits (12.97%), and Ghana—cocoa (12.80%). Regarding water management, the U.S. had the most significant degree of interest (30.99%) in the case of nut and dried fruit production, followed by Vietnam for coffee (29.95%) and Brazil for soya beans (24.4%). The leading countries in terms of water quality concerns were Malaysia (56.4%) and Indonesia (47.05%) for palm oil production, and Costa Rica for bananas (44.26%).

Table 6. Distribution of top 15 keywords, by product and country of origin (%).

Product Code/Country of Origin	Water Availability (%)	Water Management (%)	Water Quality (%)
'0901—Brazil	5.29	13.41	41.27
'0901—Vietnam	11.71	29.95	28.44
'1201—USA	15.36	19.75	26.65
'1201—Brazil	8.9	24.4	29.3
'1511—Indonesia	2.44	17.31	47.05
'1511—Malaysia	8.32	11.54	56.40
'0802—USA	12.97	30.99	29.80
'0802—Turkey	11.55	20.57	40.06
'1801—Cote d'Ivoire	7.11	23.66	38.76
'1801—Ghana	12.80	21.74	38.74
'0803—Ecuador	10.80	11.83	35.71
'0803—Costa Rica	6.97	8.25	44.26
'0803—Colombia	12.30	17.47	35.71

Source: Authors' own work.

As Table S4 (Supplementary Materials) illustrates, there was a homogenous mix of the most and least used terms within the selected documents and among the 12 countries. From an overall perspective, “certification,” “management,” “research,” “quality,” “training,” “government,” “resource,” “standards,” “risk,” “RSPO” (roundtable on sustainable palm oil), and “policy” were the most frequently used items, which prevalently belonged to the water quality category (except for “training,” which belonged to water management, and “risk,” which belonged to water availability). In contrast, the least utilized terms were “pesticides,” “droughts,” “groundwater,” “freshwater,” “nitrates,” and “contamination,” items that belonged to the water quality and water availability categories.

The European Union demonstrated a vivid commitment to building the bridge between sustainable agricultural products and active mitigation of the potential related water risks. Our findings shed light on the necessity of the EU's engagement with countries that show modest concern as regards the management of water resources.

5. Discussion

5.1. Implications for the EU's Trade Policy

The water footprint impact on the sustainability of the EU consumption of agricultural goods was investigated from the perspective of “vulnerable” imports of agricultural products. The results indicate that the EU consumption of agricultural goods is highly dependent on virtual water imports for all six analyzed agricultural products, findings that validate our first working hypothesis. Similar conclusions have been reached by the European Commission (2021) [16] and Erzin et al. (2019) [58].

In addition to previous studies (e.g., [59–61]) that have evaluated the impact of virtual water trade on the EU's food sustainability, our analysis emphasizes the degree of vulnerability in terms of the share of apparent virtual water consumption and produce results that also consider the implications resulting from decision-making at the other end of the value chain, namely, in the countries of origin. The lack of commitment in implementing water-related sustainability initiatives is supposed to give a specific indication about future product shortages once those countries' administrations strengthen their level of responsibility, especially towards the policy issues that are most sensitive in respect to international trade flows, i.e., availability and management of water resources. The findings show that this is the case for most of the exporting partners in our analysis.

Notably, medium–long-term shortages for products originating from Vietnam, the US, Ghana, Ecuador, and Turkey may represent a credible risk to EU consumption.

The overall results point to a set of policy recommendations that the European bloc should consider in terms of trade policy actions, detailed below.

- *Diversification of import markets*

In terms of concentration of EU imports from extra-EU sources, imports of soya beans and of cocoa beans were the least diversified and were concentrated in very few countries of origin. For these two crops especially, the EU might be exposed to eventual production shortages in the countries of origin, and to price volatility due to limited supply alternatives corroborated with the lack of local production. Specifically, the industries that use soya beans as key inputs and might therefore feel the impact are the food industry (high amounts of embedded soy are found in chicken breasts, hamburgers, pork chops, and salmon) and the industry of biofuels. The potential damage caused by the disruption of soybean imports is significant and could translate to a sharp decline in the production of pork, poultry, and eggs, and therefore to severe price fluctuations for pork and poultry [54]. In fact, all “vulnerable” products in our analysis are highly dependent on imports outside the single market given the insignificant local production if any, leaving the EU extremely exposed to future global shortages. Related to the wider agenda of trade policy, one may also notice that the EU’s supply might be affected by trade disputes or temporary export restrictions in the countries of origin.

- *Integrate water sustainability aspects in future trade agreements*

The EU’s 7th Framework Program for Research and Development (FP7) defined a “family of footprints”—i.e., ecological, carbon, and water footprints—that are required in any analysis of the impact of production and consumption on the environment. The cumulative expertise can lead the way for advancing water sustainability solutions on the multilateral agenda of trade negotiations. An important support for the cause might come from both China and the US. A trilateral diplomatic resolution may be credibly envisaged given their significant dependency on global water resources [25] and shared interest in food security [62].

- *Improving market access and trade facilitation instruments*

Improving market access and trade facilitation instruments that could support European companies in identifying hotspots along their supply chain and facilitate connections with foreign suppliers engaged in water sustainability strategies and water risk assessments. Both an incentive-based (as suggested, for example, in [63–65]) and a compliance-based framework ([66,67]) should guide European businesses towards a better supply chain integration that accounts for water-related vulnerabilities and risks both at home and in the production sites.

5.2. Actions for the EU’s Sustainable Consumption of Agricultural Products

The content analysis highlights the existence of precarious, incipient, or slightly moderate commitment towards mitigating water-related risks. This is a finding that points out the possibility of future disruptions in the agricultural global value chain, of which the EU members’ consumption plays a considerable role. As we have seen, their apparent consumption depends heavily on global green water resources for selected water-intensive agricultural products.

Our estimation is based on the current stream of studies (e.g., [68–71]) that highlights the increasing impact of measures related to the availability and management of water resources, as defined in Table S4 (Supplementary Materials), on future market trends. Some studies are specific about the remedies that are most needed to overcome the mishandling of sustainability goals. These are related, for example, to water management in Colombia (Torres et al. (2020) [72]), wastewater discharges in Costa Rica (Herrera-Murillo et al. (2021) [73]), employee training in Ecuador (Ramírez-Orellana et al. (2021) [74]), and

producers' certifications in Ghana and Cote d'Ivoire (Ingram et al. (2018) [75]). The interest in RSPO and ISPO certification in Malaysia for palm oil producers and the need for government involvement in addressing sustainable production are also reflected in Azis et al. (2021) [76] and Majid et al. (2021) [77], whereas Nurfatriani et al. (2019) [78] strengthened the need for sustainability-related certification in Indonesia (see our results in Table S4, Supplementary Materials). The findings for Vietnamese coffee production correlate well with recent results highlighting policy shortcomings in the fields of irrigation water systems [79–81], governmental involvement [81], and fertilization [82].

The results underscore the case of a mutual interest in preserving sustainability standards along the virtual water value chain. If this conclusion is correct, the EU should then work towards approaching its trade partners with a view to implementing issues such as:

- *Implementation of ISO 14046* in the countries of origin that, for various reasons, do not count the environmental standard among their concerns. We have identified several cases to which the line of action might be applicable, for example, Brazil and Vietnam for coffee, the US and Turkey for nuts and dried fruit, and Cote d'Ivoire for cocoa.
- *Establishing a system for renewable sources in water consumption* that has the potential to positively impact the productivity of embedded virtual water. The EU's role in providing access to knowledge and technology, together with the entire concept of smart agriculture, should be further integrated in the practice of the management of trading partners that are most deficient, such as Brazil, Vietnam, Turkey, Ghana, Ecuador, and Costa Rica.
- *Diversification of production and supply chains* for all product categories that are eligible to pose a substantial risk for future disruptions. This is mainly the case of agricultural imports on which the EU is dependent, such as soya beans, for which the US and Brazil account for 75% of imports, and cocoa, for which Cote d'Ivoire and Ghana account for 63% of imports.

6. Conclusions

Against the backdrop of a persistent stress on water demands, which embodies foremost concerns for environmental responsibility and food security, evidence is needed to reflect the degree of human uptake of critical natural resources. Companies that depend on the international supply of goods, governments, and policymakers can use such data to develop water resource conservation strategies, maximizing the economic and social benefits of water use, adapting their policies and strategies to future water needs, and even considering a potential replacement of local water consumption with virtual water trade. The virtual water approach should be encouraged to promote water savings and more conscious shopping, e.g., by renouncing the purchase of water-intensive products originating from countries with high pressure on scarce water resources, but also in respect to socio-political decision-making (dependency on food imports, geopolitical implications, food security). The water footprint analysis can provide information on how sustainable and equitable global water resources are being used for different activities, and it can help (1) to guide the development of environmental policies and the design of practical measures by providing quantitative information that makes problems more clearly defined and tangible, and (2) to assess the outcome of policies and practical measures by understanding their effects on the sustainability of water footprints quantitatively.

The EU's preemptive involvement could act as a lever to support a sustainable usage of water resources among its trading partners. The EU should further promote the Sustainability Impact Assessment (SIA), a tool that provides in-depth analysis of the potential impact of ongoing trade negotiations on the environment. The EU is thus well positioned to foresee possible risks and target specific issues at the level of each trading partner. A transparent collaboration between the E.U., national authorities, and the largest producers towards defining a coherent water sustainability policy—including the three categories of water availability, water management, and water quality—could be a head start. The

suggested policy measures to mitigate the EU's vulnerability and dependence on global water resources imply, on the one hand, the EU's support for its trading partners both in implementing the ISO 14046 standard and in building and consolidating an adequate system for renewable sources in water consumption, and on the other hand, the EU's necessity to diversify its production and supply chains.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/su132111952/s1>, Figure S1: Analysis of the EU's vulnerability regarding imports of coffee, whether roasted or decaffeinated or not; coffee husks and skins; coffee substitutes ('0901). Figure S2: Analysis of the EU's vulnerability regarding imports of soya beans, whether broken or not ('1201). Figure S3: Analysis of the EU's vulnerability regarding imports of palm oil and its fractions, whether refined or not (excluding chemically modified) ('1511). Figure S4: Analysis of the EU's vulnerability regarding imports of other nuts, whether fresh or dried, or shelled or peeled or not (excluding coconuts, Brazil nuts) ('0802). Figure S5: Analysis of the EU's vulnerability regarding imports of cocoa beans, whole or broken, raw or roasted ('1801). Figure S6: Analysis of the EU's vulnerability regarding imports of bananas, incl. plantains, fresh or dried ('0803). Table S1. Selection of international and European policy papers on sustainable water resources. Table S2. A general perspective by groups of items for vulnerable products and 13 countries of origin. Table S3. Share of apparent consumption of virtual water from virtual water imports. Table S4. Popular items within the collected data by category of product, respectively by country.

Author Contributions: Conceptualization, V.C. and A.P.A.; methodology, V.C. and A.P.A.; software, C.-I.C.; validation, V.C., A.P.A. and C.-I.C.; formal analysis, A.P.A. and C.-I.C.; investigation, A.P.A. and C.-I.C.; resources, A.P.A. and C.-I.C.; data curation, A.P.A. and C.-I.C.; writing—original draft preparation, A.P.A.; writing—review and editing, V.C. and A.P.A.; supervision, V.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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