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Environmental Pressures and Value Added Related to Imports and Exports of the Dutch Agricultural Sector

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Abstract: This study shows the environmental impacts and economic performance due to agricultural trade through The Netherlands. Using the demand-driven input–output model and the database EXIOBASE (2011), we first analysed the environmental impacts and value added directly generated abroad by the agricultural sector through imported final consumption in The Netherlands; we then compared the environmental impacts and value added generated in The Netherlands by the agricultural sector due to exports to other countries. The results show that the Dutch consumption of imported agricultural products had significant greenhouse gas emissions of 19,386 kt CO_2-eq, land use of 280,525 km^2 and water consumption of 50,373 $M.m^3$, while impacts in The Netherlands due to agricultural exports amounted, respectively, to 13,022 kt CO_2-eq, 9282 km^2 and 3339 $M.m^3$. At the same time, we found that Dutch agricultural production had a higher value added to pressure ratio than abroad. These differences highlight the great dependency of Dutch final consumption on foreign natural resources, a significant trade imbalance for environmental impacts with relatively smaller economic benefits for countries exporting to The Netherlands. With these results, we suggest that it is of great importance that sustainability policies for the agricultural sector not only address environmental impacts domestically but also impacts and value creation abroad.

Keywords: agriculture; trade; environmental impacts; economic performance

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1. Introduction

The Dutch agricultural sector drives environmental pressures beyond national borders—for example, due to the import of feed for Dutch livestock. Conversely, export countries that import Dutch agricultural produce also drive emissions and impacts in The Netherlands. With an agricultural export of EUR 95.6 billion (over 10% of Gross Domestic Product, GDP), The Netherlands is, after the US, the largest exporter of agricultural products globally. Hence, such 'impacts embodied in trade' are likely to be significant. There is no shortage of studies that have analysed the (global) environmental footprint of diets [1–5]. Moreover, the footprints of diets in The Netherlands have been researched, often as part of general analyses of the environmental footprints of consumption [6–9]. Additionally, studies have also been conducted on environmental justice and the impacts of agricultural production and consumption, and indicated how global land use and biodiversity loss are driven through trade [10].

However, to our knowledge, there has been no study that has used the Dutch agricultural sector as an entry point, as opposed to the widely used approach of analysing the global impacts of (Dutch) final consumption of food. Given the crucial role that the Dutch agricultural sector has in imports, exports and value added creation of The Netherlands, it is interesting to see how this sector drives the global footprints and value added of its imports, and how agricultural exports drive environmental and economic impacts in The Netherlands.

The objective of this study is to quantify the environmental impacts and value added created through trade from and to The Netherlands in the agricultural sector. For this purpose, we created a dashboard (see Supplementary Information, Annex I [11]) that can be used to further investigate various types of indicators also beyond the ones discussed in this study. A summary of the results given in this article, together with their visualizations, is also provided in the Supplementary Information, Annex II [11].

This article addresses the following research questions:

- What are the environmental impacts and economic benefits in The Netherlands caused by Dutch agricultural exports for final consumption abroad?
- What are the environmental impacts and economic benefits in countries from which The Netherlands imports agricultural products for its final consumption?

2. Materials and Methods

2.1. General Methods and Data

In our analysis, we investigated the direct environmental pressure and value added created per sector and per country through trade to and from The Netherlands. A footprint analysis of the total imports and exports of The Netherlands was performed, followed by a contribution analysis for sectors and regions. There are various approaches to analysing the environmental impacts of trade and of activities by an economic sector in a specific country. For example, the coefficient approach is widely used to calculate impacts embodied in imports and exports [12,13]. Such approaches use detailed import and export data from international trade databases (e.g., UN COMTRADE), in combination with pressure indicators such as litres of water or m^2 of land required to produce the imported or exported products. The disadvantage of such an approach is that it does cover the full value chains globally. For instance, imported products can contain components made elsewhere, such as in the exporting country. However, these data miss the imports and exports of services, and the indirect embodied impacts related to them. Therefore, multi-regional input–output approaches (MRIO) have become the method of choice for footprint analyses. MRIOs have as a further advantage that they contain information on value added by sector, which allows for the combined calculations of environmental and economic aspects related to the imports and exports of products. For this reason, we decided to use the demand-driven IO model [14,15] (Equation (1)) as it allows us to follow transactions and impacts across the full value chain.

$$r = \widehat{b}\mathbf{L}y \quad (1)$$

Here, r is a vector of environmental extensions (e.g., GHG emissions, land use or water consumption) and which, in mrIO, can be subdivided into regional emissions associated with given products or sectors. $\widehat{b}$ is a diagonalised vector of environmental coefficients, $\mathbf{L}$ is the Leontief inverse and y is the final demand vector.

2.2. Data

MRIO data show countries' total economy, with production divided into sectors, and consumption divided into product (and service) groups. Each sector produces an output (e.g., wheat), which is represented in monetary terms. At the same time, sectors make use of (intermediate) products to produce their outputs (i.e., inputs). Furthermore, for each sector, one can identify the direct sector-specific primary resource extraction and emissions ('Environmental Extensions' or EE)—for instance, land use by the agricultural sector, or CO_2 emissions by the energy sector. It is therefore possible to analyse how economies are interconnected. For instance, for the final demand of wheat by consumers in a given region, it is possible to analyse the contribution of other sectors across multiple regions to the production of wheat (e.g., motor vehicles from Germany used in agriculture in The Netherlands) and the environmental pressures exercised by those inputs [14,16].

Our analysis makes use of EXIOBASE V3 for the year 2011, a global MRIO database. EXIOBASE is not the only global MRIO database available, but to the best of our knowledge, it is the only one that combines product details for the agricultural sector together with a large number of environmental extensions [17]. EXIOBASE discerns more than 200 product categories and 48 countries/regions and includes around 40 types of emissions, material extraction, water use and land use by sector and region as environmental pressures. We used 2011 as the base year since, at the time that our calculation was performed, this was the latest year for which full data were available. Although this database probably is one of the most detailed in the world, import and exports in the same product category can include different products. For example, in the case of imports to The Netherlands, 'fruit' can consist of mangoes and avocados, while in the case of exports by The Netherlands, they can consist of apples. This of course means a limitation in our analysis.

2.3. Contribution Analysis

In this study, we analysed greenhouse gas (GHG) emissions, land use and water consumption next to value added as the main indicators. The analysis was divided in two steps:

1. Imported final demand by The Netherlands from other countries: we calculated the country-wise footprint of all imports for Dutch final consumption and then analysed the direct contribution of agricultural product categories;
2. Exported final demand by The Netherlands to other countries: we calculated the country-wise footprint of all exports from The Netherlands and then analysed the direct contribution of agricultural production in The Netherlands.

The direct environmental impacts and value added created abroad due to the consumption of imported products for final demand are calculated by performing a contribution analysis on the vector resulting from the following equation:

$$\mathrm{r}_{reg\_a}^{imp} = \widehat{\mathrm{b}}\mathbf{L}\mathrm{y}_{reg\_a}^{imp} \tag{2}$$

where $\mathrm{r}_{reg\_a}^{imp}$ is a vector of environmental pressures (or value added) due to the consumption of imported products in region a. The contribution analysis is then performed by isolating the values in the vector $\mathrm{r}_{reg\_a}^{imp}$ associated with agricultural production in a given region. In other words,

$$r = r_{reg\_a}^{prod\_a} + r_{reg\_a}^{prod\_b} + \ldots + r_{reg\_b}^{prod\_a} + r_{reg\_b}^{prod\_b} + \ldots + r_{reg\_n}^{prod\_n} \tag{3}$$

where r is a scalar of the total environmental pressure resulting from the sum of the direct environmental pressure due to the production of all products in all regions.

3. Results

In the next three sections, we present results concerning GHG emissions, land use and water consumption, aimed at answering our research questions presented in the Introduction section of this work.

3.1. Greenhouse Gas Emissions

Climate change is set to disrupt many aspects of the Dutch economy and society [18]. Disruptions also occur globally in the form of droughts, floods and other extreme weather events that effect the environment, society and its economic activities [19]. Because of the increasing effects of climate change, it is important to know where emissions occur so that they can be mitigated through national and international policy efforts.

3.1.1. Emissions in Kiloton

Figure 1 shows a contribution analysis of the GHG emissions due to Dutch final demand import and export. From Figure 1, we see that the total GHG emissions in The Netherlands due to the Dutch agricultural final demand export amount to 13,022 kt CO_2-eq. Moreover, 74% of these emissions are due to industries related to animal farming, while the remaining 26% are connected to other agricultural and forestry products. In particular, 48% (6281 kt CO_2-eq) of the total emissions is due to raw milk production; 16% (2043 kt CO_2-eq) to vegetables and fruits, and nuts; 11% (1395 kt CO_2-eq) to cattle; 8% (1007 kt CO_2-eq) tp pigs; 6% (781 kt CO_2-eq) to poultry; and 12% (1517 kt CO_2-eq) is due to other forms of production.

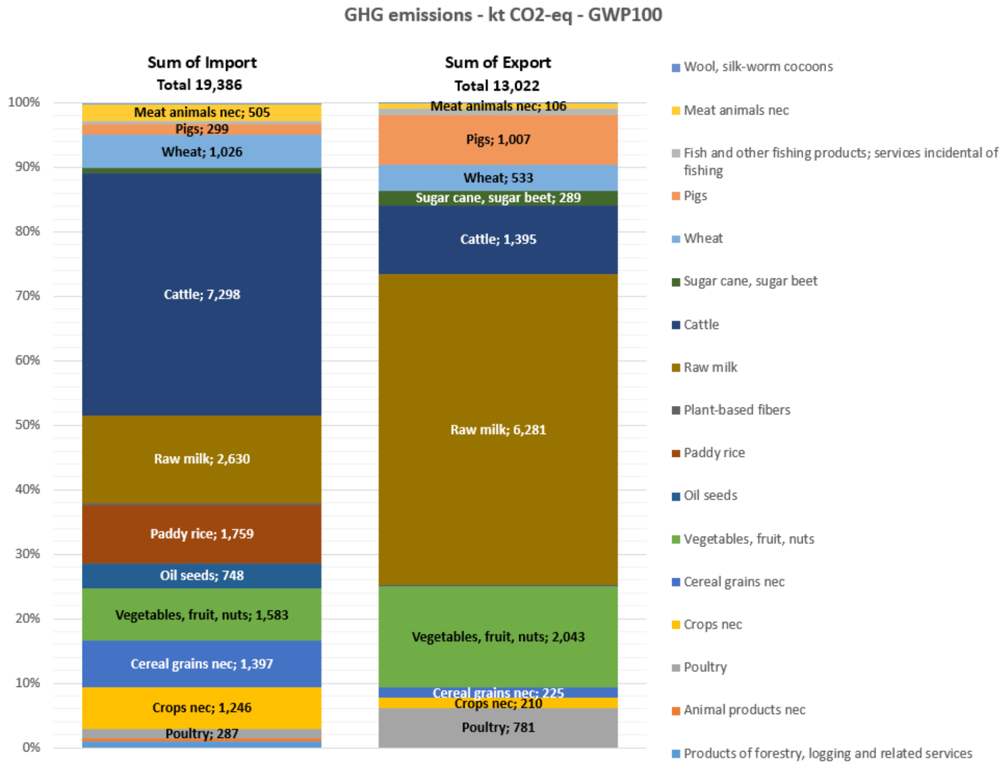

Figure 1. GHG emissions in export sectors abroad due to Dutch imports, and in export sectors of The Netherlands due to purchases abroad. Values expressed in percentage on the axis and in absolute terms inside the chart. Data: EXIOBASE V3 year 2011.

GHG emissions in other countries due to Dutch imports (19,386 kt CO_2-eq) are 50% higher than GHG emissions due to Dutch exports (13,022 kt CO_2-eq). If we account for the total carbon footprint of Dutch consumption (domestic consumption pressures 7941 kt CO_2-eq + import pressures), we see that 71% of the GHGs emitted to satisfy Dutch consumption happen abroad. In particular, 58% of this is caused by productions related to animal farming, while the remaining 42% is connected to other agricultural and forestry products. In detail, we see that cattle are responsible for 38% of import emissions and raw milk production for 14%, which combined contribute to 51% (9928 kt CO_2-eq) of the GHGs in the agricultural sector in other countries.

Other countries are chiefly considered the European Union (EU 27 minus The Netherlands) (31%), African countries (26%) and Central and South America (25%). This implies that, due to the large dependency of the Dutch agricultural consumption on resources outside of the EU, 69% of agricultural emissions may prove to be difficult to mitigate without international efforts. Furthermore, a number of countries in these regions are also identified as being most vulnerable to the effects of climate change, while also having a lower GDP, which may raise questions concerning countries' responsibility and ability to effectively mitigate emissions.

3.1.2. Emissions per Euro Value Added

The analysis of products' GHG emissions per million EUR of value added (Figure 2) shows that nearly all Dutch production is able to emit less per unit of value added in comparison with production in other countries. This is true in all cases except for the production of vegetables, fruit, nuts and fish and other fishing products. The rest of production appears to be less emitting in The Netherlands than in the countries of import. Strictly from the perspective of containing GHG emissions at the same value added level, an argument can be built in favour of outsourcing the production of vegetables, fruit, nuts and fish and other fishing products. With the same logic, it may be worthwhile to consider which products can be produced in The Netherlands. Naturally, this strategy may not be possible for all types of sub-products but it could prove to be a worthwhile investigation. In fact, this may be of particular relevance for cattle, raw milk and cereal grains, which are more highly emitting abroad relative to value added than in The Netherlands.

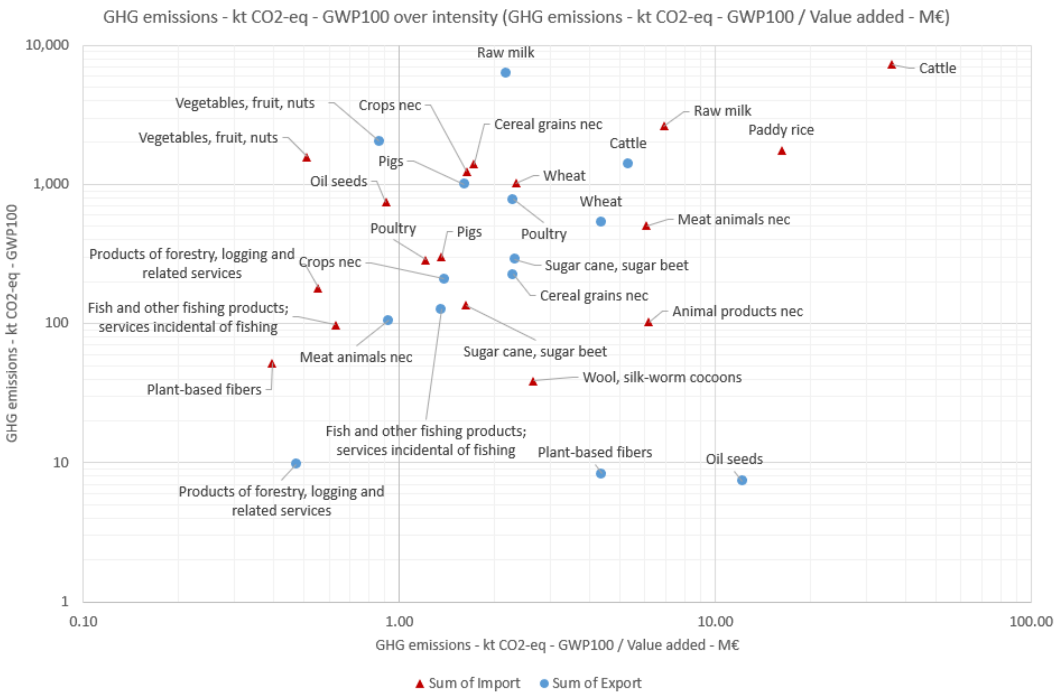

Figure 2. GHG emissions by product (y-axis) plotted against the GHG emissions intensity per million EUR of value added created by the same product (x-axis). Bottom-left corner: best; top-right corner: worst. Data: EXIOBASE V3 year 2011.

These considerations are an important contribution to the current GHG emissions and, by extension, nitrogen reduction plans in The Netherlands. Specifically, since the reduction of livestock is one of the main points of the plans [20], care should be taken to ensure that production is not simply outsourced to countries that perform the worst according to Figure 2, as this may ultimately represent a lose–lose situation where agricultural goods are produced in countries where they emit the most and that also contribute less to the global GDP. A more detailed breakdown of the geographical performance can be found in Annex I [11] of this study.

3.2. Land Use

Half of the world's habitable land is used for agriculture, resulting in disruption of ecosystems, landscape changes and loss of biodiversity (OWID, 2020). For instance, 86%

of at-risk species are threatened by agriculture [21,22]. As such, land use is an important metric to understand the disruption of the natural environment by the agricultural sector.

3.2.1. Land Use in Export and Import

The analysis presented in Figure 3 shows the impacts of the agricultural sector on land use in and outside of The Netherlands due to Dutch exports and imports. Most of the land use takes place outside of The Netherlands. In fact, Dutch exports are responsible for the use of 9282 km^2 in The Netherlands, while imports are responsible for 280,525 km^2 in other countries.

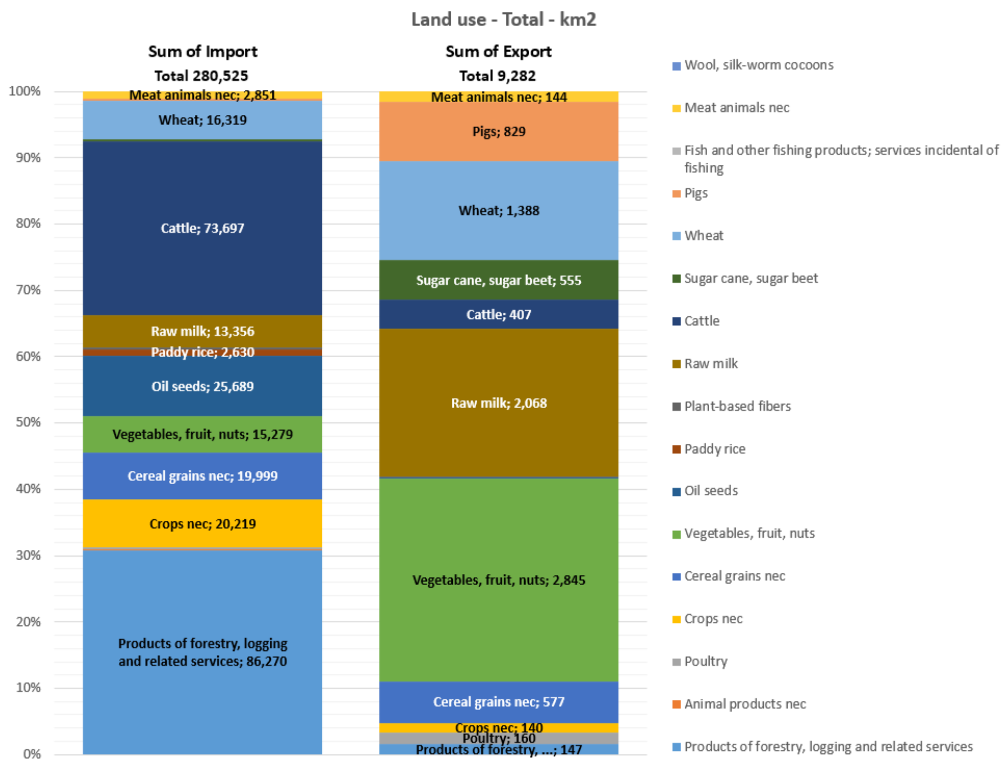

Figure 3. Land use in export sectors abroad due to Dutch imports, and in export sectors of The Netherlands due to purchases abroad. Values expressed in percentage on the axis and in absolute terms inside the chart. Data: EXIOBASE V3 year 2011.

In The Netherlands, 60% of the land use is driven by exports to other European Union member states. Animal-derived products account for 39%, while the remaining 61% is driven by non-animal farming products. The export land use is mostly driven by the production of vegetables, fruit, nuts (31%), raw milk (22%), wheat (15%) and pigs (9%). On the other hand, land use in other countries due to Dutch imports is 30 times higher than land use in The Netherlands, which shows a high dependency on foreign resources. In particular, land use due to imports takes place for 29% in Asia and the Pacific, 16% in the Middle East, 8% in the EU (minus The Netherlands), 8% in Russian Federation and 8% in Australia. Moreover, 33% (92,073 km^2) of the land use is driven by agricultural activities that do not concern animal farming directly. In fact, the most impactful products are products of forestry, logging and related services, at 31% of the total (86,270 km^2), and cattle at 26% (73,697 km^2).

3.2.2. Land Use in Relation to Value Added

Figure 4 shows that, in most cases, imported agricultural products are largely inefficient in the use of land in comparison with the export production of The Netherlands. It also implies that the issue related to land use (e.g., biodiversity loss) may be most severe in the countries of import. As previously shown, 92% of the land use due to imports for Dutch consumption occurs outside of the EU.

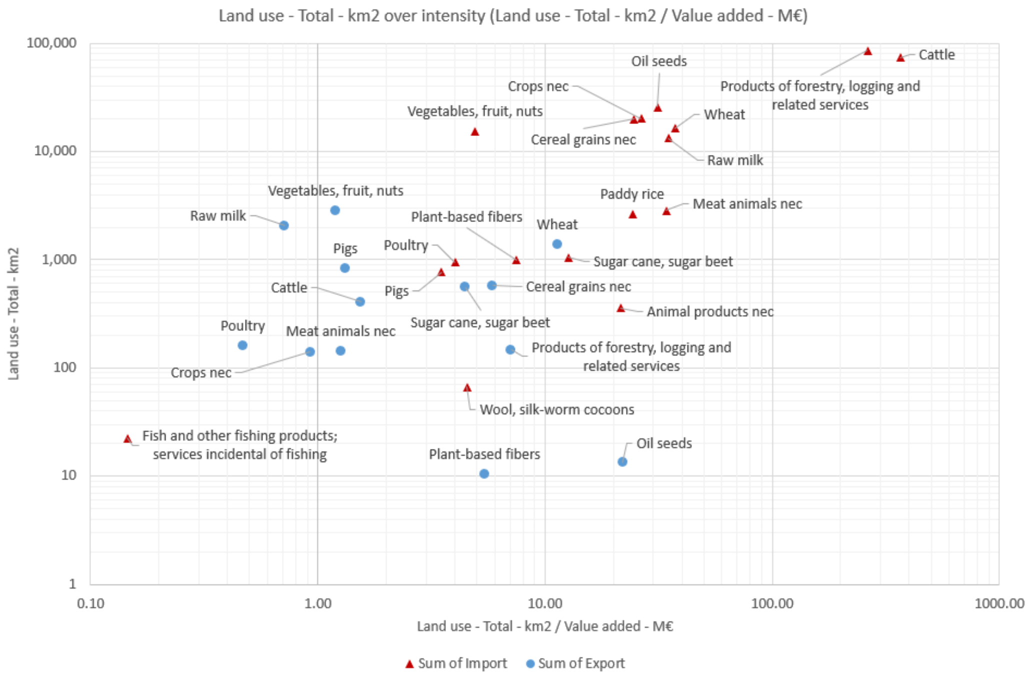

Figure 4. Land use by product (y-axis) plotted against the land use intensity per million EUR of value added created by the same product (x-axis). Bottom-left corner: best; top-right corner: worst. Data: EXIOBASE V3 year 2011.

To improve the sustainability of the agricultural sector, The Netherlands may have to employ different strategies to ensure that production uses land efficiently also abroad. Some of these strategies could be importing products from countries where land use is most efficient, redirecting some of the exports toward domestic consumption or investing in capacity building and sustainable agricultural practices in importing countries. These are important considerations to keep in mind also from an EU policy perspective (i.e., EU common agricultural policy, From Farm to Fork and biodiversity policies).

3.3. Water Consumption

Water is a crucial resource in our current world of increasing population and affluence. It is a resource that hosts 10% of all known species [23] and on which agriculture relies heavily. In fact, water withdrawal by agriculture amounts to 69% of all water withdrawn globally and 21% in Europe [24]. For this reason, it is important to understand where and how water is being consumed due to agriculture by the Dutch economy. In this analysis, we focus on water consumption (i.e., fresh water permanently used by the product).

3.3.1. Water Consumption in Export and Import

Figure 5 shows that water consumption due to Dutch exports is mainly driven by the production of crops not elsewhere classified, at 59% (1977 M.m^3), which include wheat at 17% (583 M.m^3) and vegetables, fruit and nuts at 9% (305 M.m^3). Products exported related to animal farming appear to have a small direct contribution to water consumption in The Netherlands, accounting for 4.7% of the total. Exports toward other EU member states appear to take the largest share (47%), and the rest is distributed across all the other countries and regions in minor shares.

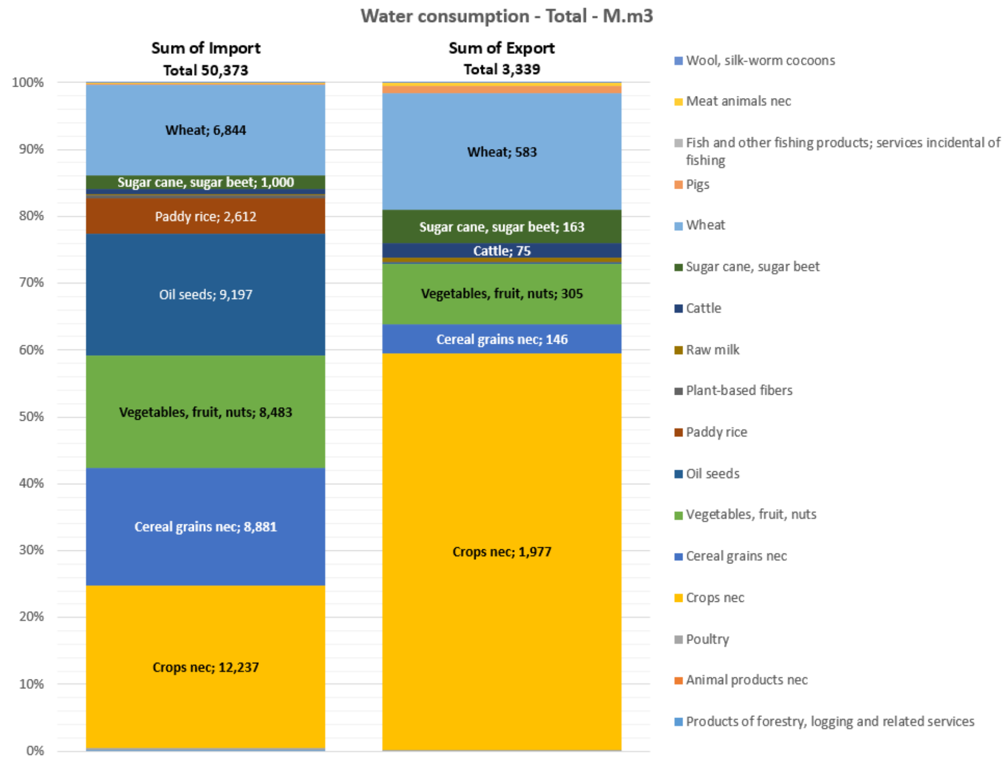

Figure 5. Water consumption in export sectors abroad due to Dutch imports, and in export sectors of The Netherlands due to purchases abroad. Values expressed in percentage on the axis and in absolute terms inside the chart. Data: EXIOBASE V3 year 2011.

Imported agricultural products have a much higher impact than exported products. Agricultural water consumption by import amounts to 50,373 M.m^3, which is 15 times greater than water consumption due to exports. In particular, 19% of the water consumption takes place in Asia, 6% in European countries outside of the EU (Non-EU + Russian Federation) and 3% in other EU member states.

The largest direct contributors are crops not elsewhere classified, at 24% (12,237 M.m^3), cereal grains not elsewhere classified, at 18% (8881 M.m^3), oil seeds at 18% (9197 M.m^3), vegetables, fruit and nuts at 17% (8483 M.m^3) and wheat at 14% (6844 M.m^3). Moreover, in this case, the direct water consumption of animal farming is marginal (1%) in comparison with the demand of other agricultural products. However, it is important to keep in mind that our analysis only considers the direct impacts of production and that one third of global cropland is used for livestock feed production [25]. For this reason, the water consumption of products related to livestock will be higher if we consider the total product water footprint.

3.3.2. Water Consumption in Relation to Value Added

The analysis of the intensity of water consumption over value added (Figure 6) shows the vast majority of products are related to animal farming as the best performer for both import and export products. The only exception is for imported cattle, which has the highest direct water consumption of all animal-based products and the worst intensity. Furthermore, generally, animal-based products for export consume less water per million EUR of value added than their imported counterparts. However, much of the production of crops is in fact destined as fodder for animal farming. Imported products of the grass family, as well as vegetables, fruit and nuts, appear to consume the greatest amount of water both in absolute terms and intensity.

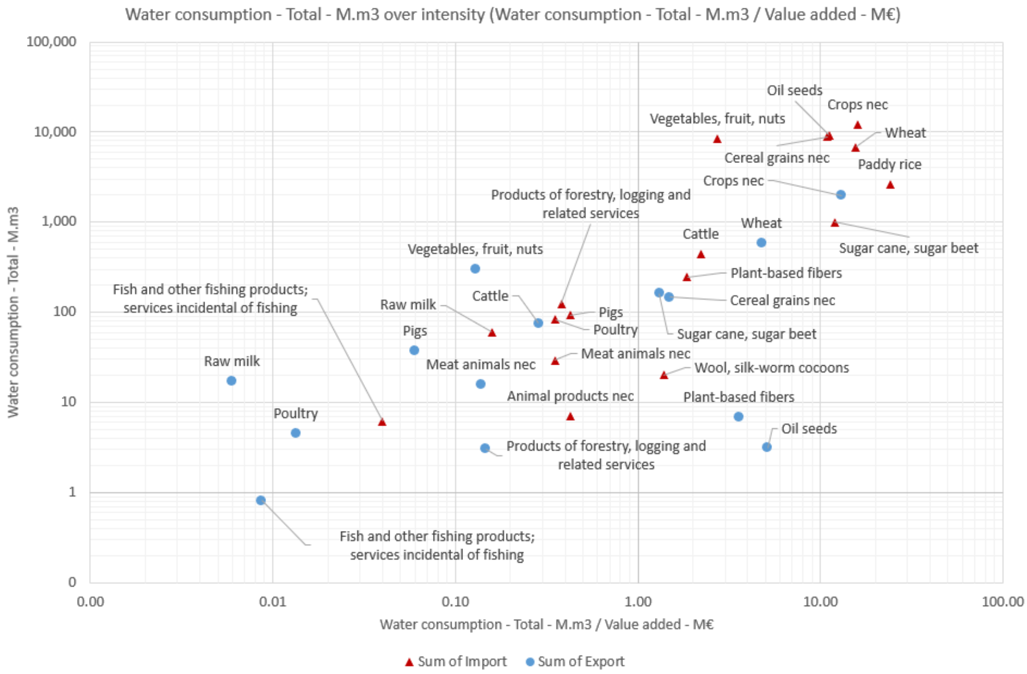

Figure 6. Water consumption by product (y-axis) plotted against the land use intensity per million EUR of value added created by the same product (x-axis). Bottom-left corner: best; top-right corner: worst. Data: EXIOBASE V3 year 2011.

Whether it is animal-based products or not, there is a clear division between imported and exported products, where the former appears to perform systematically worse than the latter. However, this is chiefly due to the fact that environmental pressures due to Dutch consumption occur in the largest part abroad, while, at the same time, The Netherlands is often one of the nodes of complex supply chains. Therefore, the graph does not indicate a higher environmental efficiency of agricultural products (to which other countries may aspire) but it is instead an indication that if The Netherlands is to implement sustainable water consumption practices, it needs to address its environmental pressures abroad.

4. Discussion

It is important to note that in the presented results, the imbalance between impacts abroad and those in The Netherlands is probably greater than represented as our chosen approach only captures direct pressures. This is very likely the case for animal products as, typically, the production of animal feed has high land use, which would not be accounted for in the direct land use of animal farming. This means that the results need to be read with care as they may lead to an underestimation of environmental pressures across the full life cycle.

In addition, it is important to recognise that uncertainties in this type of data and analysis are inevitable. This article is based on EXIOBASE [26,27]. To create this database, dozens of national input–output tables are combined—and also adjusted, since the total imports in these IO tables often mismatch the total exports per product group on a global scale. As a result, differences may exist between the national official statistics and EXIOBASE [28]. Furthermore, while EXIOBASE is one of the most detailed global MRIOs available, it contains only 15 agricultural product groups. As already noted in the Introduction, this may imply that imports and exports that, in this paper, have the same product category name in fact may consist of different products. Only higher detail in MRIOs can solve such issues.

5. Conclusions

The Dutch import of agricultural goods causes relatively high greenhouse gas emissions, and creates significant impacts related to water and land use abroad. In other words, The Netherlands drives significant environmental pressure via imports within other countries, because of Dutch consumption and production of agricultural goods. In part, it is understandable that The Netherlands creates such high pressures abroad. A densely populated country such as The Netherlands will always specialise in sectors that have a lot of value added per unit of land, while, for sparsely populated countries (from which The Netherlands partly imports), the opposite applies. However, the result is also that The Netherlands' agricultural consumption largely depends on biotic resources from abroad related to land use, water consumption and GHG emissions. This means that reducing the environmental pressures from Dutch agriculture has a clear international dimension and requires international cooperation. In this, it should be considered that countries in Africa and South America—that contribute highly to Dutch agricultural imports—have a lower national income than The Netherlands. This raises the question of whether a rich country such as The Netherlands should not take relatively more responsibility to reduce impacts outside its borders (for a more elaborate discussion on responsibility allocations, see, e.g., [29–31]).

To reduce the environmental impact of the Dutch agricultural sector abroad, various strategies can be considered. One of the options is to improve production efficiency in other countries. With regard to land use, further work could be done considering how agriculture and forestry can take place without major loss of biodiversity, something already stimulated by various certification organizations for wood products. It may also be considered to import from countries where biodiversity problems due to land use are limited or where production is already efficient [32].

Another way to reduce global environmental pressures could be to replace the imports by domestic production. For many sectors and products, Dutch production seems to have a higher value added to pressure ratio as abroad. However, such a strategy is probably not really possible. First, there are restrictions in The Netherlands with regard to the use of natural resources (particularly of land). Second, as noted above, it is likely that various groups of agricultural products in EXIOBASE will not be sufficiently homogeneous. The imports of The Netherlands, in this case, concern other products besides those covered by the exports of The Netherlands.

Given the more efficient production in other countries in terms of greenhouse gas emissions per EUR of value added, it may be considered that The Netherlands would reduce its own production of vegetables, fruit, nuts and fish and other fishery products. Finally, an important point is the large number of livestock in The Netherlands, which drives the enormous import of products for animal feed, and therefore indirectly requires a lot of land and water use. A restructuring in which, in total, a similar value added is created through livestock that is smaller in size—for example, through a higher selling price for organic meat—can offer a solution for both domestic and import-induced foreign environmental pressure. Such a restructuring will also help in solving the Dutch nitrogen crisis. However, in this, care must be taken to ensure that the kind of production now taking place in The Netherlands is not simply moved abroad. After all, our analysis shows that, often, environmental pressures per unit of value added is higher abroad, which, in this case, would lead to higher overall pressures at a global level.

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Abbreviations

The following abbreviations are used in this manuscript:

GHG	Greenhouse Gas Emissions
GDP	Gross Domestic Product
NEC	Not Elsewhere Classified

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