What Lies Behind European Diets? A Multi-Regional Input-Output Analysis of Processed Food Consumption and the Water Footprint in the European Union

Increasing awareness of climate change impacts on natural resources has strengthened public concern and authorities' commitment to environmental sustainability and climate neutrality in Europe.

Recent literature has focused on the role of households in the European Union as drivers of environmental impact, identifying them as central actors in environmental policy design. In this context, shifts in demand, particularly those related to food consumption, contribute significantly to reducing environmental footprints and fostering the development of sustainable and resilient economies.

This provides the context for our research, which seeks to analyze the water footprint associated with food consumption in European Union households in 2018, distinguishing between processed and unprocessed foods. To achieve this, we develop an environmentally extended multi-regional and multi-sectoral input-output model for all the countries of the European Union. The study introduces a methodological contribution by disaggregating agri-food sectors into processed and unprocessed within input–output tables. This refinement allows for a more accurate assessment of the environmental impacts of consumption patterns.

The analysis examines the environmental impacts of three alternative dietary scenarios: (i) a reduction in processed and ultra-processed food consumption, replacing these products with nutritionally comparable non-processed alternatives; (ii) a transition towards the Mediterranean diet; and (iii) the adoption of nationally recommended dietary guidelines. The analysis evaluates the heterogeneous regional effects of dietary transitions on water use across EU member states.

Preliminary results suggest that reducing processed food consumption can significantly lower the overall water footprint of European diets, although impacts vary substantially across regions due to differences in production structures, trade dependencies, and consumption patterns.

Keywords: Multi-regional input-output, water footprint, sustainable consumption patterns, embodied water, processed food

JEL codes: D57, Q25, Q51

1. Introduction and literature review

The increasing visibility of the consequences of climate change on natural resources has heightened public concern and strengthened policy commitment to mitigating environmental degradation. This has led to the establishment of international agreements aimed at promoting sustainable development and achieving carbon neutrality in Europe during the second half of the century, including the Paris Agreement and the Sustainable Development Goals (SDGs) of the 2030 Agenda.

Recent literature has increasingly emphasized the role of households as significant drivers of environmental impacts, identifying them as pivotal actors in the design of environmental policies, where shifts in demand can contribute to reducing environmental footprints and fostering more sustainable and resilient economies (Vita, 2019; Behrens, 2017; Hardadi et al., 2021). In this context, consumption choices related to food have received particular attention, as the food sector represents one of the largest contributors to global environmental pressures and water use (Foley et al., 2011; Ivanova et al., 2016).

Most researches agrees that current food systems are not aligned with the SDGs and need to be reshaped to fulfil the proposed environmental requirements in order to preserve the natural environment in which we live (Green et al., 2015; Biesbroek et al., 2014; Gonzalez Fischer & Garnett, 2018).

Recent advances in the literature highlight the significant environmental mitigation potential associated with dietary transitions. Li et al. (2024) demonstrates that global shifts towards healthier and more sustainable diets could substantially reduce environmental impacts from the food system, particularly through changes in consumption patterns in high-income regions. However, dietary transitions may also involve socioeconomic trade-offs. Evidence from the United States indicates that although healthier diets can reduce environmental pressures, they may remain economically unaffordable for lower-income populations, highlighting distributional challenges associated with sustainable food transitions (He et al., 2021).

Within this context, diverse studies have explored the environmental implications of alternative dietary scenarios aimed at achieving more sustainable food systems. Vita et al. (2019) estimate that adopting a vegan diet could reduce Europe’s water footprint by approximately 24%, while Vanham et al. (2013) analyze shifts towards healthy and vegetarian dietary patterns.

2. Methodology and data

I. Methodology

To achieve our aim, we develop an environmentally extended input-output model in terms of blue water consumption (EE-MRIO). Input-output models allow us to quantify water impacts from both a production and a demand perspective (Lenzen et al., 2013). Let the world economy consist of m countries and n sectors and let the equilibrium equation be:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \boldsymbol{y}^{\boldsymbol{HH}} \qquad (1)$$

Where $\mathbf{x}$ is the vector of total production, $\mathbf{A}$ the matrix of technical coefficients whose elements represent the output of sector *i* in country *r* that is used as an input to produce one unit of product *j* in country *s* and $\boldsymbol{y}^{\boldsymbol{HH}}$ is the vector of household final demand of countries.

The equilibrium equation can also be expressed in terms of the well-known Leontief inverse matrix $(\mathbf{I} - \mathbf{A})^{-1}$, where each element captures all the production generated in sector *i* and country *r* to fulfill the demands of inputs directly and indirectly incorporated in each unit of final demand of sector *j* in country *s*:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\boldsymbol{y}^{\boldsymbol{HH}} = \boldsymbol{L}\,\boldsymbol{y}^{\boldsymbol{HH}} \quad (2)$$

On the other hand, let us consider a vector of direct intensities corresponding to a resource or a pollutant, in our case blue water consumption. This vector, indicates, for each sector and country, the pressure on a resource per unit of production:

$$\boldsymbol{c} = {}^{\boldsymbol{c}_{\boldsymbol{j}}^{\boldsymbol{r}}}\!\big/_{\boldsymbol{x}_{\boldsymbol{j}}^{\boldsymbol{r}}} \qquad (3)$$

where $\boldsymbol{c}_{\boldsymbol{j}}^{\boldsymbol{r}}$ is the water employed in sector j and country r.

Using the inverse Leontief matrix, which in our case relates the direct and indirect production needed to satisfy the final household demand of each country and sector, we can estimate the direct and indirect (or embodied) consumption associated with each final household demand through global intensity vector $\boldsymbol{\lambda} = \hat{\boldsymbol{c}}\boldsymbol{L}$[1], which shows the global blue water pressure associated with each unit of final demand for each specific product and country, thus capturing all the environmental pressure generated in the economy in the direct to indirect production incorporated as inputs to produce each unit of final household demand.

Finally, the environmental footprint associated with final household demands in a country can be obtained as:

$$\Omega = \boldsymbol{\lambda}\hat{\boldsymbol{y}}^{\boldsymbol{HH}}$$

[1] The symbol ^ denotes a diagonalized vector.

Household demand vectors incorporate information on demand volume, consumption structure, and geographical origin of goods. The vector $\boldsymbol{\lambda}$ reflects production technology and environmental intensities across sectors and countries. The scenarios analysed in this study operate on the household demand vectors $\boldsymbol{y^{HH}}$, modifying the composition of consumption according to each dietary scenario.

II. Database

As a starting point for calculating the water footprints of the proposed dietary scenarios, this study uses the multi-sectoral and multi-regional EMERGING database (Huo et al, 2024).

The EMERGING table represents the global economy across 245 regions for the year 2018. This database was selected over other available sources due to two key features essential for our analysis. First, it includes all European Union countries—our main area of interest—and second, it offers a high level of disaggregation for the agri-food sector. This granularity enhances its suitability compared to other datasets, although it also increases its complexity.

The environmental satellite accounts linked to EMERGING do not include the environmental indicator used in our analysis, blue water consumption. For this reason, we have to extend the model environmentally. To do this, the built our environmental vector, water consumption, by using environmental satellite extensions from the GLORIA database (Lenzen et al., 2022).

For analytical simplicity, the original multi-sectoral, multi-regional input-output table was aggregated to 159 regions, each comprising 78 sectors. Food-related categories were preserved in detail, while less relevant sectors were grouped. Aggregation matrices were constructed to reduce the dimensionality of the dataset while preserving consistency with international sectoral classification standards and retaining detailed information for key sectors.

For this study, information from FAOSTAT Food Balance Sheets (FAO, 2022) is employed to determine the adjustments required in current dietary patterns across countries to meet the proposed dietary scenarios. The FAO dataset provides annual per capita consumption data by food category and country, which allows the construction of baseline consumption structures for each national diet. Information on the Mediterranean diet scenario is derived from Dapcich et al. (2004) and Davis (2015), while data on nationally recommended diets are compiled from official dietary guidelines issued by authorised national health and nutrition institutions.

3. Preliminary results

Blue Water Footprint represents the amount of surface and groundwater consumed (i.e., evaporated or incorporated into a product) during the production of goods and services. It excludes water that is returned to the same watershed from which it was taken (Hoekstra et al, 2011).

Initial results indicate that households in the more developed European economies exhibit the highest per capita blue water footprints (Figure 1) result in alignment with previous studies (Li et al., 2024)

Preliminary results indicate that adopting a mediterranean diet across Europe would lead to an increase in the water footprint, with Eastern European countries experiencing the most significant rise. In contrast, the nationally-recommended scenario would reduce the footprint in the EU as a whole, particularly in more developed nations such as Luxembourg and France, where the reduction would be most pronounced (Table 1).

This analysis allows us to conclude that household consumption patterns have a significant influence on environmental footprints, which means that countries with a higher economic level have a greater importance in their diets of foods with a larger water footprint, such as dairy products and animal meat.

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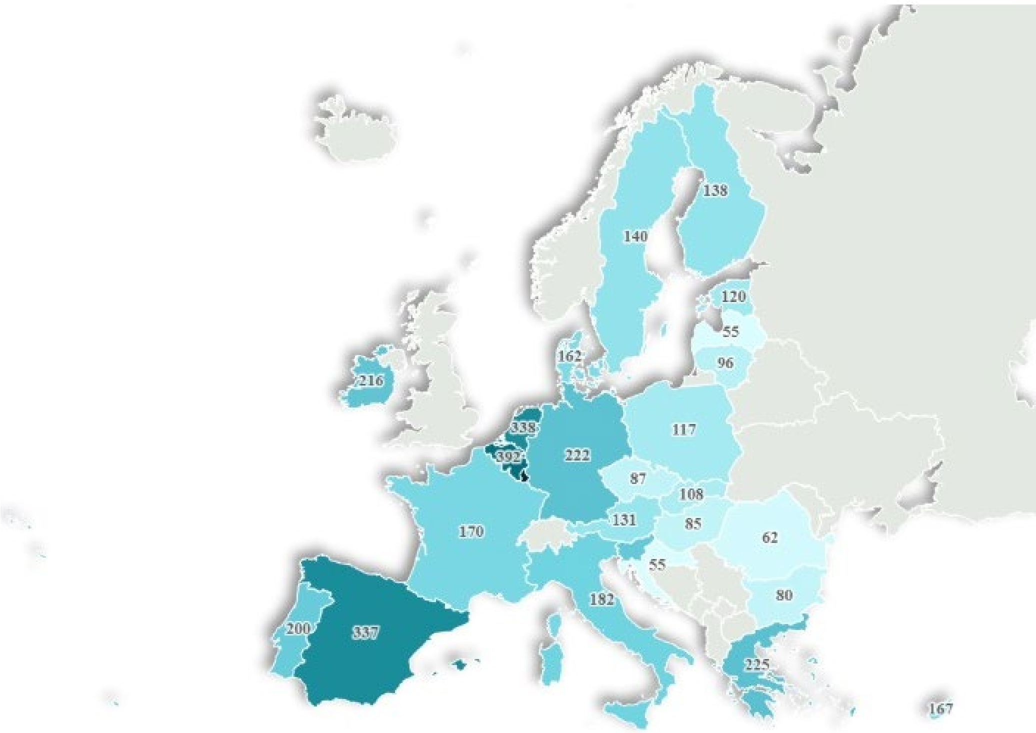
Appendix



Country	AUT	BEL	BGR	CYP	CZE	DEU	DNK	EST	ESP	FIN	FRA	GRC	HRV	HUN
m^3 per capita	131,4	391,5	79,9	167,7	87,1	222,8	161,9	120,5	336,8	137,8	170,3	225,5	55,0	85,0
Country	**IRL**	**ITA**	**LTU**	**LUX**	**LVA**	**MLT**	**NLD**	**POL**	**PRT**	**ROU**	**SWE**	**SVN**	**SVK**	
m^3 per capita	215,8	181,7	96,4	1214	55,0	54,3	337,8	116,9	200,4	62,4	140,6	206,0	108,4	

Figure 1 Blue Water Footprint per capita in 2018

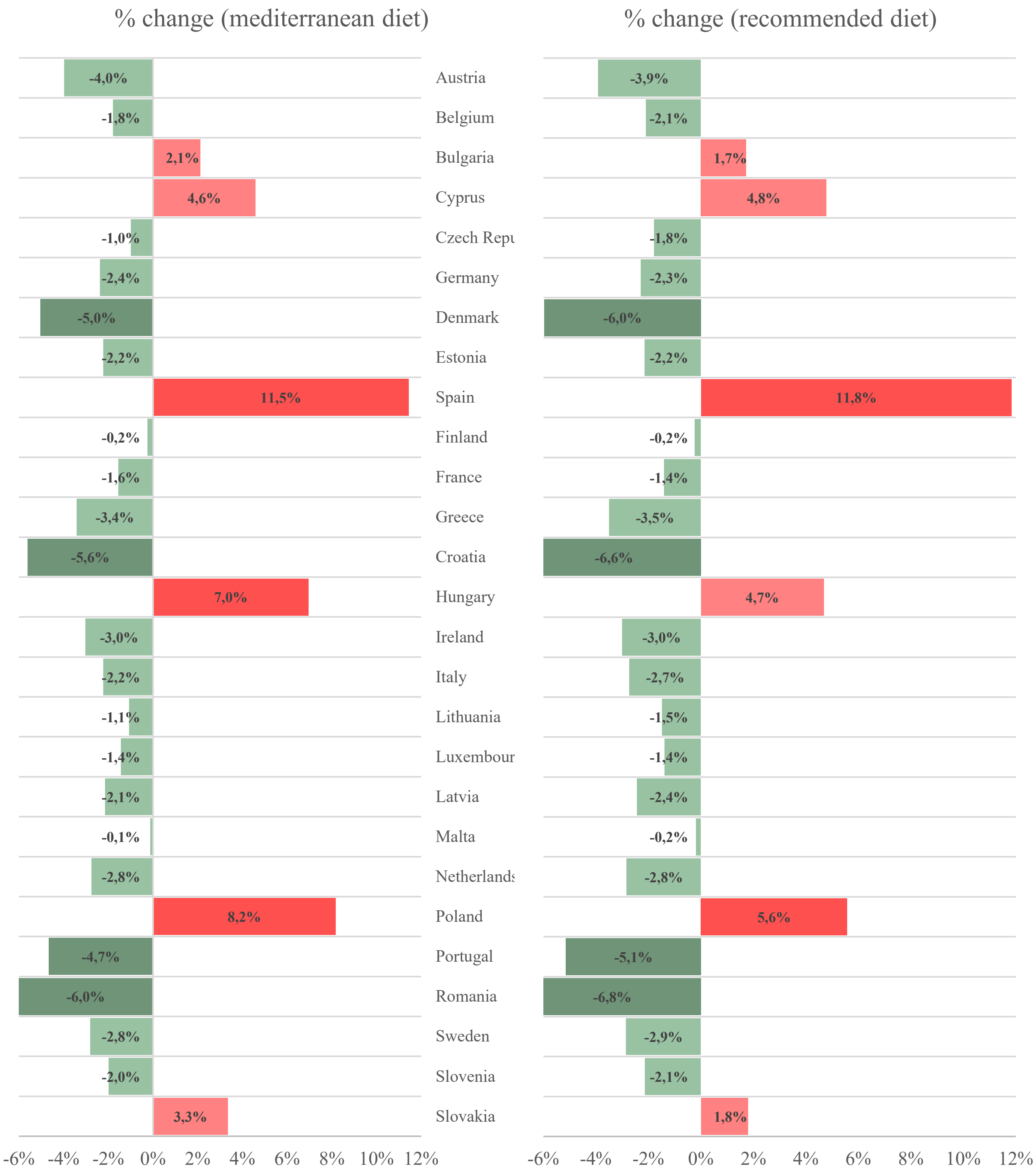


Table 1. Change in the blue water Footprint by country under each scenario.