Energy and carbon balance of Israel's domestic and imported virtual water supply

Key findings

- The total energy use and emissions of Israel's domestic crop production (563 GWh/431 kt CO_2e) are much lower than the energy and emissions embedded in crop imports (1,796 GWh/749 kt CO_2e).
- Domestic energy use and emissions were mainly attributable to irrigation with water from alternative sources, while transport accounted for 72% and 57% of imported energy and emissions, respectively.
- Despite the transport, average greenhouse gas (GHG) emissions (CO_2e per ton of crop) of imports were significantly lower for several crops compared to domestic production.

Motivation

Every food product "embeds" a certain volume of water consumed or polluted during its production process. This has been referred to as its "virtual water" content or Water Footprint. Natural recharge from rainfall in Israel cannot meet the current water demand. One approach of dealing with (seasonally) limited precipitation is crop irrigation. Depending on the water source, water supply for irrigation can be particularly energy-intensive. The second approach many countries rely on is the import of crops. According to the Food and Agriculture Organization of the United Nation, agriculture is responsible for 69% of global freshwater withdrawals. This makes the global trade in crops of paramount importance in managing scarce water resources while reducing the impact on the climate. This study investigates the energy requirements and associated emissions of Israel's domestic crop production and imports. It seeks to contribute to Sustainable Development Goals 6, concerning better water management, and Goal12 relating to sustainable consumption and production patterns. We particularly focus on the energy used for abstraction, treatment, distribution, and reuse of water, termed "energy for water", as well as the impact transport has on emissions related to crop trade.

Methodology

Since the 2000s, Israel increasingly relies on desalinated water with its associated high energy requirements and emissions. At the same time, Israel is heavily reliant on imports of staple crops with significant emissions due to transport. The process of calculating the energy demand and associated emissions of Israel's crop consumption requires the combination of multiple datasets. In the first step, crop- and watershed-specific total blue water use of Israel's national crop consumption was quantified for the year 2010. The quantification was based on existing spatially explicit datasets of blue water consumption rate (in m^3/t) and crop production (in t) for Israeli consumption as well as irrigation efficiency factors. Total blue water use was subsequently differentiated by water source according to national irrigation mix data. In a third step, water-source-specific "energy for water" and related GHG emissions were calculated. Transport energy and GHG emissions were determined based on crop production data and transport distances.

Data requirements

The shapefile and dataset of watershed-level blue water consumption was obtained from Pfister and Bayer (2014). Crop production for Israeli consumption (Fridman & Kissinger, 2018) was provided in form of 5-arc-minute-resolution rasters. National irrigation mix was taken from Leão et al. (2018). The calculation of transport distances was based on the port location shapefile of the World Port Index. All calculations were performed in R Studio.

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Results

The total energy demand associated with virtual blue water consumption in Israel amounted to 2,359 GWh (Figure 1). 24% were attributable to domestic production (563 GWh) and 76% to imports (1,796 GWh). The import component was so high mainly due to the energy consumption related to transport (72%), compared to 28% "energy for water". Artificial water sources – desalinated sea water (49%) and domestic wastewater (33%) – were responsible for most of the domestic "energy for water". The total GHG emissions of 1,180 kt CO_2e split into 37% (431 kt CO_2e) associated with domestic consumption and 63% (749 kt CO_2e) with imports. The main difference compared to energy consumption was the lower relative importance of import transport. Ca. 49% of total energy consumption and 42% of related GHG emissions of Israeli domestic and imported agricultural blue water were embedded in cereals (Figure 2), followed by oil crops (26% energy and 27% GHG) and fruits (11% energy and 16% GHG). Wheat produced in Israel had a domestic weighted average of 524 kWh/t (energy) and 401 kg CO_2e/t (emissions). Imported wheat from Ukraine, Romania, and Turkey was only around 60-285 kWh/t and 23-230 kg CO_2e/t.

Application

Analyses of energy requirements and emissions related to virtual water imports as well as domestic crop production are of interest to policy makers aiming to strike a balance between locally produced crops and those that are imported. The trade-off analysis enabled by using this approach allows stakeholders to better address the challenges of reducing emissions while maintaining food security. Considering the increasing global importance and feasibility of energy-intensive alternative water sources, our results highlight the importance of including the energy consumption and GHG emissions related to water supply for agricultural irrigation into environmental assessments. The use of publicly available global datasets makes the approach easily replicable. However, these data often come with high uncertainty, which is the main challenge that needs to be addressed in future work.

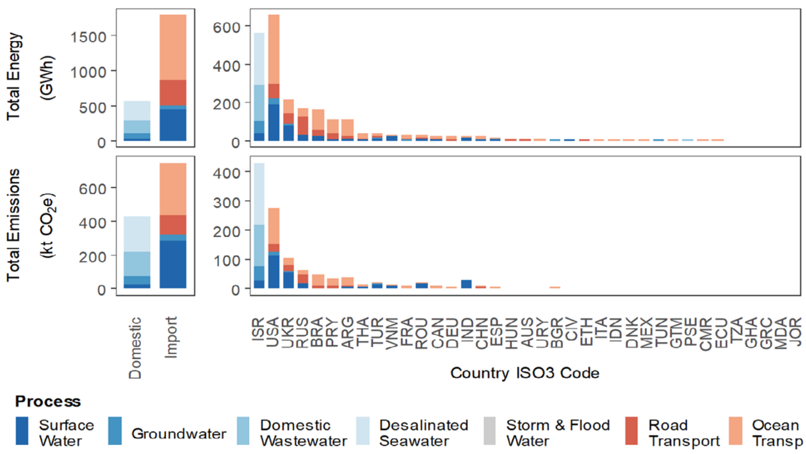

Figure 1: a) Total energy consumption (GWh) and b) total GHG emissions (kt CO_2e) of domestic and imported virtual blue water for Israel's consumption and the corresponding source of emissions

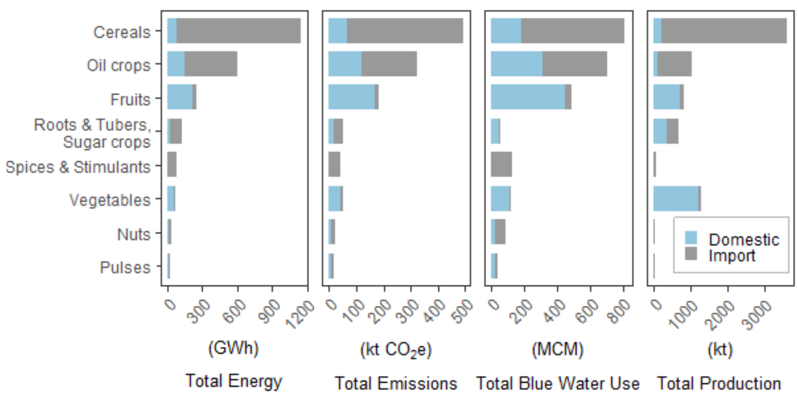

Figure 2: Total energy consumption, emissions, blue water use, and production differentiated by crop groups

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