Impact of the implementation of the African Continental Free Trade Area (AfCFTA) on virtual water trade flows

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Abstract

Through the network of international trade in agricultural goods, water resources are virtually transferred from the country of production to the country of consumption. The volume of agricultural products traded on the global market, and the water embedded in them, has grown rapidly, marking the importance of food security and (other) issues related to this trade in goods. Introduced in 2019, the African Continental Free Trade Area (AfCFTA) is expected to increase trade within the African continent, improving its capacity to ensure food and nutrition security. This project aims to study the effects of AfCFTA implementation on virtual water trade involving the African continent, using the MAGNET computable general equilibrium (CGE) model. We calibrate the baseline with the virtual water trade matrices developed within the CWASI project, and then develop an AfCFTA scenario under the assumption of continent-wide tariff liberalization. The following paper reports on the first phase of our project: the study

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of virtual water flow trends both on a global scale and in detail for the state of Burkina Faso and West Africa, as a region subject to strong water-related climate events. Historical trends in Burkina Faso's virtual water fluxes reveal a significant increase in water exchanged through primary agricultural products. However, this increase is not due to an increased demand for water by crops but is the result of an intensification of the trade network over time and an increase in the quantities of products traded.

Keywords: virtual water trade, agricultural trade, global trade network, African Continental Free Trade Area

1. Introduction

Over the last decades, scholars and policymakers have been using the concept known as virtual water to study how the water resource moves around the globe embedded in goods and services that exploit it in their production processes. The progressive scarcity of water requires understanding the increasing complexity that characterizes its mobility patterns, the water use practices associated with them, as well as traditions and social conventions related to it, such as diets [9]. In this context, trade assumes a primary role: food imports and exports are two of the main strategic development tools that countries use to maintain food security and improve their income. Furthermore, one-fourth of the food produced for human consumption is traded internationally [3], and global and regional trade agreements are the preeminent legislative devices to regulate and generate trade links and flows [8].

Recently implemented as of 2019, the African Continental Free Trade Area (AfCFTA) is anticipated to increase trade within the African continent. In particular, an increase in inter-regional agricultural trade is expected, and, therefore, an improvement in the continent's efficiency in assuring its food and nutrition security. Moreover, the livelihoods of 60% of the active population currently employed in agriculture worldwide are foreseen to raise (ILO, 2019)[1]. In this work, we investigate the implications of the implementation of the AfCFTA on the virtual water trade network, namely the water embedded in agricultural products. In particular, we focus on the impact of AfCFTA on the Economic Community of West African States (ECOWAS)

[1] `https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_203469/lang--en/index.htm`

with a focus on Burkina Faso. The Economic Community of West African States (ECOWAS) is the main regional economic community in West Africa. Its contribution to the acceleration of the integration process of the continent is likely to have a considerable impact on areas such as trade, free movement of goods and persons, and monetary matters[2]. As trade links between ECOWAS members and other regions strengthen and ECOWAS intraregional trading patterns shift, we observe corresponding changes in virtual water flows and water footprints in accordance with variations in import-export values, and agricultural production.

Using the MAGNET model [16], a computable general equilibrium (CGE) model calibrated to the latest database produced by the Global Trade Analysis Project (GTAP)[3], we aim to study the effects of the implementation of the AfCFTA. We adopt an extension of the model which contains additional details on the water for irrigation and the differentiation of irrigated and rainfed land. As an economy-wide model with full intra- and interregional economic interlinkages, MAGNET is uniquely positioned to take into consideration all the different inputs and outputs that influence the behavior of virtual water. We intend to model a baseline scenario according to the second shared socio-economic pathway (SSP2), and use the virtual water trade data collected within the EU-funded CWASI project[13] to calibrate the baseline. The adjustment of MAGNET with this database is a major innovation as, to our knowledge, no other CGE model has been calibrated against such a detailed database. In this adjustment step, we compare the

[2] https://www.tralac.org/images/docs/13173/implications-of-ecowas-potential-expansion-and-\the-afcfta-egm-concept-note-uneca-may-2018.pdf

[3] https://www.gtap.agecon.purdue.edu/databases/v10/v10_doco.aspx

base year (2014) of the virtual water flows modeled by MAGNET with the calculated flows in CWASI. We then adjust the virtual MAGNET water flows based on the data in CWASI through adjustment rates derived from the base year comparison. Starting from this calibrated baseline scenario, we develop an AfCFTA implementation scenario under the assumption of continent-wide tariff liberalization. Our overall aim is to provide new insights into irrigation water as a scarce resource on the African continent, the consumption patterns that drive the use of water for irrigation, and how these patterns of consumption might change with the implementation of the AfCFTA.

Consequently, our work consists mainly of three steps: (i) investigating the historical trends of virtual water flows of primary agricultural products using the CWASI database; (ii) comparing these trends with the baseline simulation data and adjusting the exogenous parameters in MAGNET to calibrate the model to the virtual water growth paths; (iii) developing an AfCFTA scenario under the assumption of continent-wide tariff liberalization.

This preliminary draft is intended to illustrate the first step of this research, and then to be updated in the following steps of the research.

2. Virtual water trade: historical trend

The first phase of this work provides an analysis of the historical trend in virtual water flows using the virtual water matrices developed within the EU-funded CWASI project. The CWASI database contains over 30 years of virtual water trade (VWT, m^3) and 50 years of water footprint (WF, $\frac{m^3}{ton}$) related to agricultural products. The water footprint data includes only primary products while the trade matrices also include derived products, for a total of 290 different goods. The structure of the database is mainly based on some inputs provided by FAO such as production in tons, bilateral trade matrix, yield, and hectares cultivated. The other key input is the water footprint data are provided by Water Footprint Network, which published a large dataset of WF for several primary and processed agricultural goods having crop and animal origin [7]. This database, called WaterStat, includes average values over the period 1996-2005. Therefore, from here the CWASI dataset assumes that the time-variability of the water footprint, not detailed in WaterStat, is mainly explained by a ratio of agricultural yields [13]. The resulting time-varying WFs are then applied to the FAO datasets on agricultural production, country exports, and reconstructed detailed trade matrices, thereby forming the CWASI database. The virtual water content can be quantified in terms of a green water component and a blue water component, according to whether the water is contributed by rainwater, or by surface and groundwater used for both irrigation and food processing [14]. As we are interested in investigating the virtual water flows resulting from an irrigation process, we will only consider blue water flows in this analysis. For each food product, the CWASI database returns the country-specific blue water share as the ratio of the blue virtual water content to the overall virtual water content, both values averaged over the period 1996-2005. Then, we applied this fixed share to the time-varying overall virtual water content, which was calculated through the fast track approach [15]. This is an approximation thus does not take into account any significant changes in irrigation water supply from the averaged period of 1996 - 2005 [11].

In this work, we grouped the 239 countries into 17 regions (as shown in Figure 1). This regional aggregation mainly refers to the economic (regional) agreements existing in Africa as well as major external trading routes and partners. To exemplify the consequences of the AfCFTA implementation in the exchange of virtual water for agricultural trade, we focus on the Burkina Faso (BFA) case. The BFA's agricultural sector contributes to 30% of its Gross Domestic Product and is the main source of income for the rural population [2]. Moreover, about 80% of Burkina Faso's population is involved in agriculture [1]. Furthermore, Burkina Faso, similar to other countries in the West African region, is subject to intense droughts and floods. These climate-related events threaten food security and agricultural production, mostly because farmers depend primarily on rainfall to produce staple crops and other cash crops (e.g., cotton). To better assess food supply risks and water use practices, we consider the entity and the sources of virtual water flows in the food trade involving this West African country. We focus on the first eight sectors (as shown in Figure 2) according to the GTAP database. In the CWASI database, these same sectors cover a total of 167 primary crops for the production side, and 120 primary crops for the trade (the complete list is in the Supplementary Material 1).

Although most of the water used in agriculture comes directly from rainfall (green water), the volume of water extracted from rivers, lakes, and aquifers

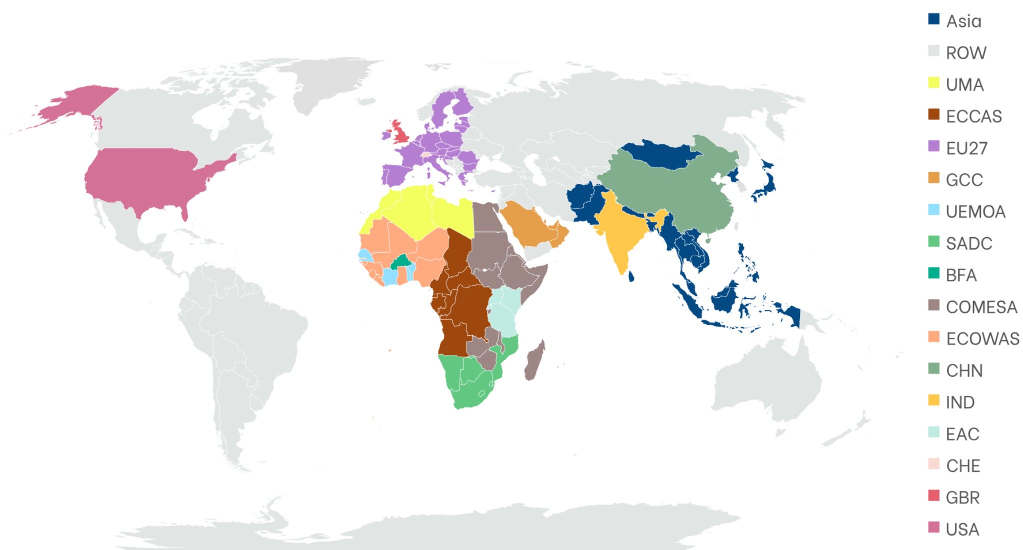


Figure 1: Map of the 17 regional subdivisions considered in this work. Burkina Faso (BFA) is highlighted and kept separate among the African states.

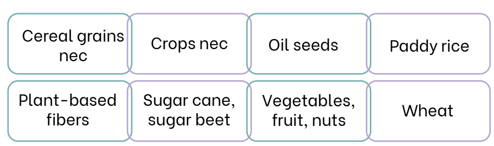


Figure 2: The first eight agricultural sectors according to the GTAP database considered in this analysis. In the CWASI database, these sectors cover a total of 165 crops.

for irrigation (blue water) plays a key role due to the amount of food it helps to produce. In fact, while the amount of irrigated land represents the only 20% of the total land globally devoted to agriculture, the food resources produced on such land adds up to 40% of the global agricultural production [4][10].

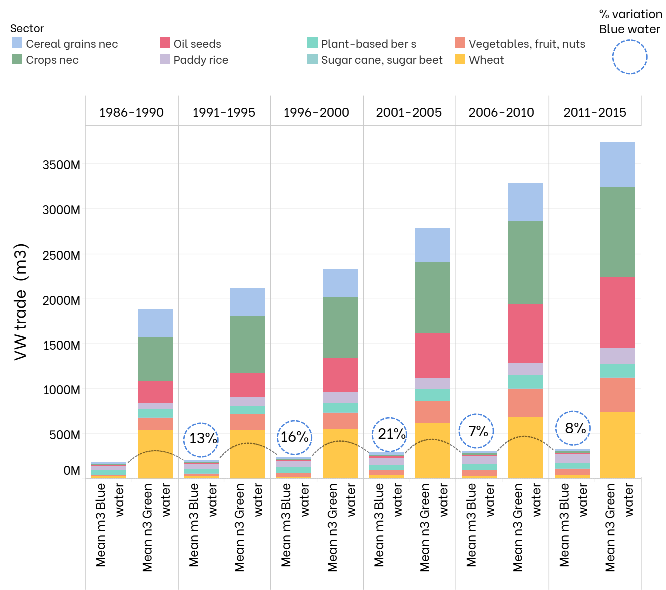


Figure 3: Virtual water annual values (in cubic meters) involved in the global food trade. Annual values are averaged over five-year intervals, and green and blue components are highlighted. Colors correspond to the different agricultural sectors, while percentage values refer to increments concerning the previous five-year period.

In this work we conduct a double analysis: we take into account Burkina Faso data, but also worldwide data as a benchmark. Figure 3 shows the temporal behavior of the green and blue water components involved in the global food trade. Two details are evident: (i) the higher amount of green water concerning the blue one, and (ii) the strong time increments of water volumes.

Since MAGNET mainly considers water from irrigation, we focus only on the average growth of the blue component. Figure 3 shows, within the dashed circles, the percentages of change between the 5-year intervals considered. The largest inter-period variation is from the years 1996-2000 to 2001-2005

(21%).

We only select the blue water shown in detail in Figure 4, where two panels are represented.

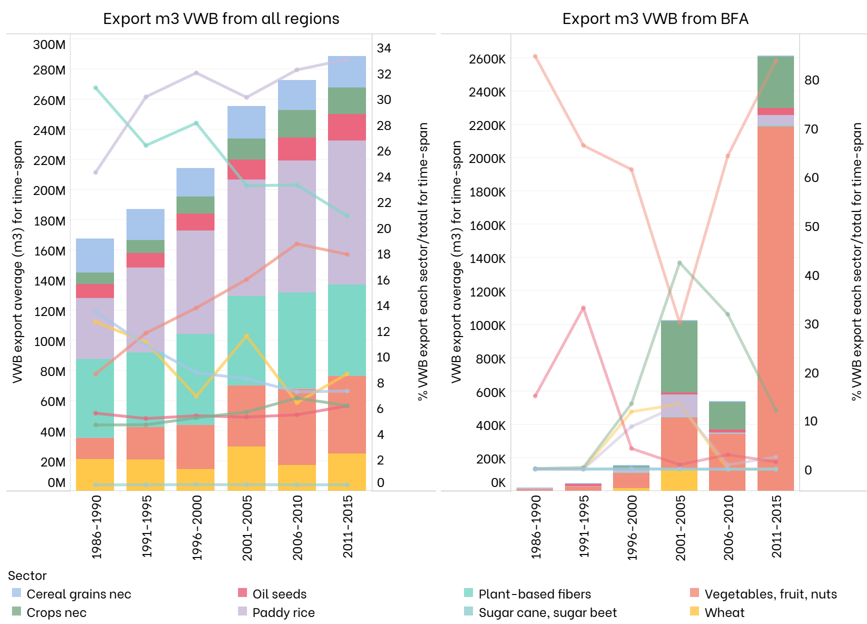


Figure 4: Comparison of the annual blue virtual water export (averaged on five-year periods) by all regions considered in the analysis for each time interval (left panel) and by Burkina Faso alone (right panel). Colored lines report the percentage variation of blue water exports for each sector on the total amount of water (from all sectors) exchanged for each period considered[4].

Figure 4 shows the blue VW exports of the regions considered in the

[4]Note that the line close to zero represents the percentage change in cubic meters of blue water in the Sugar cane, sugar beet sector compared to the total cubic meters in all sectors. This percentage is very small (<0.05), but still above 0.

analysis (see Figure 1) and of Burkina Faso. The percentages corresponding to each agricultural sector are reported. The global data (left panel) shows that (i) the rice sector is the most important in terms of blue water exports, (ii) the fruit and vegetable sector has experienced the strongest growth over time (orange line). Moreover, the strong volatility of virtual water leaving BFA through its exports is evident, marked by the large variations experienced by the percentages of virtual water change for each sector out of the total virtual water exported. Nevertheless, the dominant sector is vegetables and fruit, which not only represent the largest volume of exports on average but also show strong growth over the last decade.

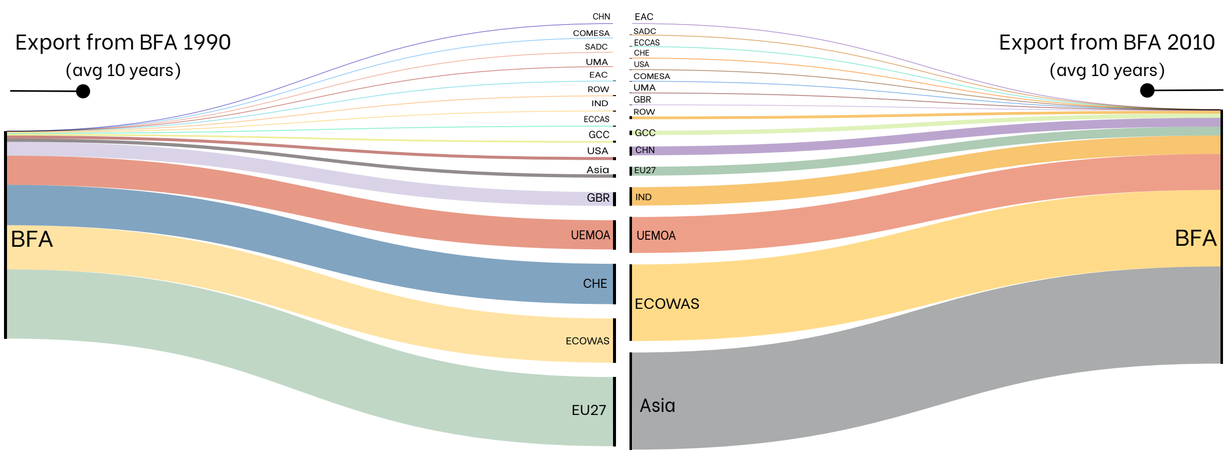


Figure 5: Time-averaged blue water flows (in m^3) exported by Burkina Faso. On the left are the averages of export flows for the period 1986-1995. On the right are the averages of export flows for the period 2006-2015. The colors define the different export destination regions.

In Figure 5 we show Burkina Faso's main trading partners. The graph illustrates the first and last ten-year periods of our analysis, so we can see how the network topology has changed and grown over time.

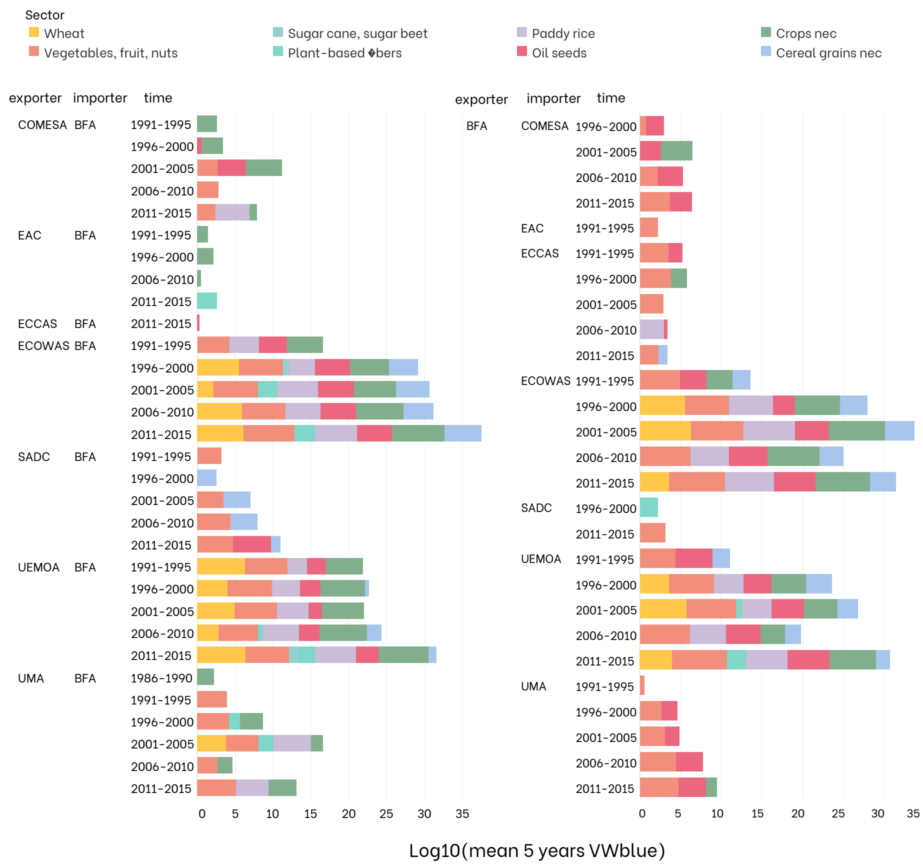


Figure 6: In the left panel, Burkina Faso's time-average virtual blue water imports from the 8 African regions; in the right panel, time-average virtual blue water exports from Burkina Faso to the same 8 regions. Colors distinguish agricultural sectors, while each bar is the time average (on a logarithmic scale) of virtual water every 5 years considered (1986 to 2015).

Specifically, while in the 1990s, the largest trading partner was Europe, in the period 2006-2015 this role was filled by Asia (note that China is not included, but considered as a separate state). Interestingly, among African regions, the largest partner in both periods is the Economic Community of West African States (ECOWAS), of which Burkina Faso is a member.

To better investigate intra-continental trade, Figure 6 illustrates in more detail all imports and exports involving Burkina Faso and African regions. On the left, we find the blue water imports entering Burkina Faso from each respective African region listed in the first column. On the right, the exports in cubic meters of blue water from Burkina Faso to each African region are reported. Here again, it is confirmed that the largest African partners are those belonging to the Economic Community of the West African States.

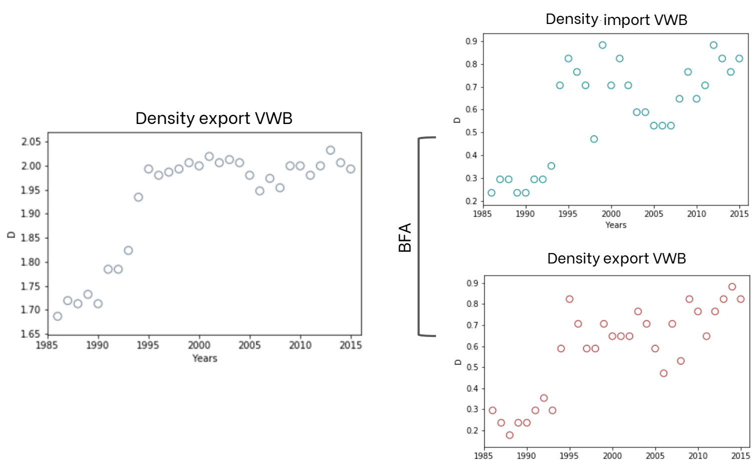


Figure 7: Density of the VW export network (from 1986 to 2015). The left panel refers to links regarding all regions, while the right panel to VW export and VW import network for Burkina Faso ($D_{BFA} = \frac{M}{(N-1)}$).

Previous analyses show that blue water flows appear to be increasing in both Burkina Faso's imports and exports. Both the number of actors involved in the network and the number of links play a substantial role in this trend. Given the number of nodes (N, equal to the number of countries involved), trade network density ($D = \frac{M}{N(N-1)/2}$) is calculated as the ratio between the number of existing links M and the number of all possible links between nodes. Figure 7 shows the density of the network increases after 1994, the year of the Uruguay Round when the growth rate of the countries involved in the network starts to grow due to the spread of trade agreements.

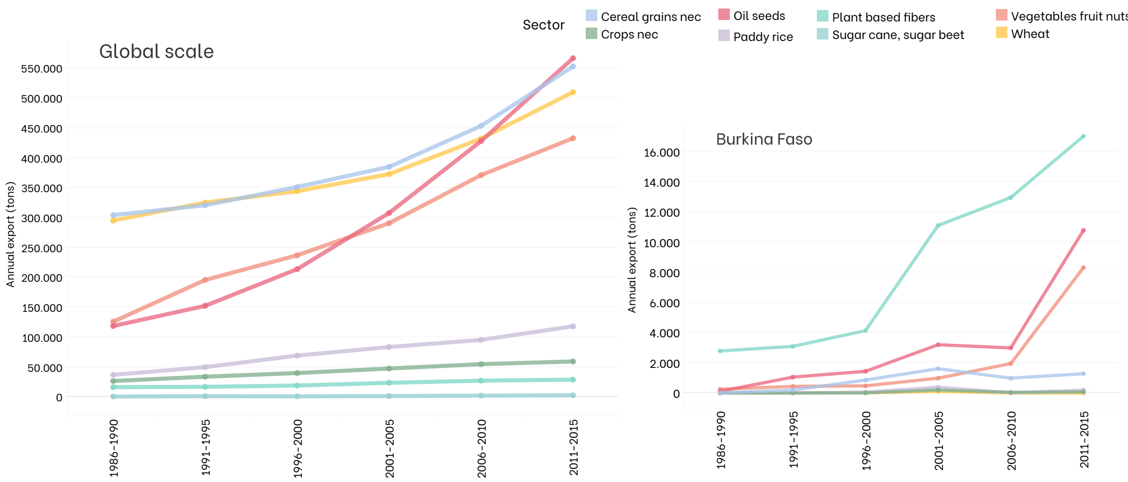


Figure 8: Five-year-averaged annual tons exported for each agricultural sector. The colors identify the different sectors. The left panel shows data about the global scale (considering all 17 regions under analysis as exporters). The right panel refer to Burkina Faso only[5].

Moreover, the increase in virtual water exports on a global scale is mainly

[5]Note that the lines close to zero represent the exports of some sectors such as sugar cane, sugar beet, which are very small compared to the exports of other sectors. The value is small, but still above 0.

due to the growth in tons of products exported over the periods considered. Figure 8 clearly shows the trend for each agricultural sector considered. E.g., wheat increases from an average of 295.000 tons of exports in the first five-year period to an average value of about 510.000 tons, in the last one. The right-hand side of the figure shows the same selection but only for exports from Burkina Faso. Again, relevant increases are evident, such as in the Plant-based fibers, Oilseeds, and the Vegetable and fruit sector. Unsurprisingly, the sector that stands out from the others in terms of exported tonnage is plant-based fibers, as this sector includes an important export product for Burkina Faso: cotton lint. Eight sub-Saharan African countries, including Burkina Faso, are among the top 20 cotton exporters in the world [12].

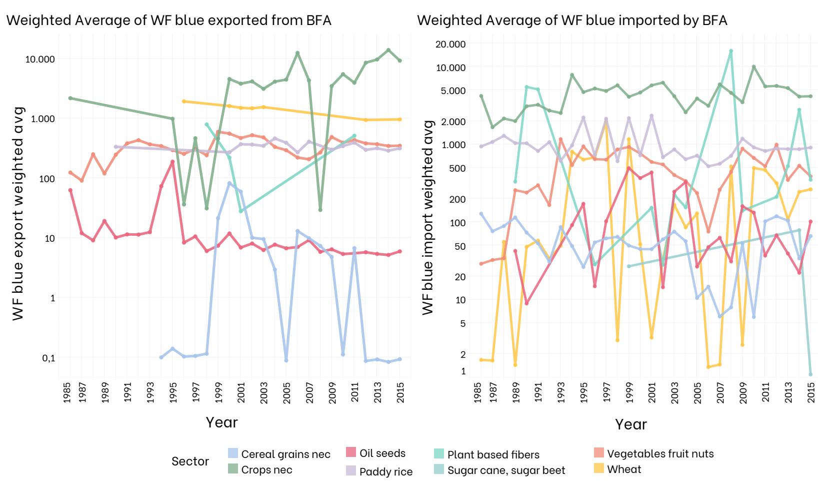


Figure 9: Burkina Faso water footprint's weighted average (m^3/ton) for exports and imports. Each sector is highlighted by different colors. The weight is the percentage of blue water exported (imported) by each product compared to the total blue water exported for the whole sector.

Another important factor to investigate is whether the growth in blue water exports is due not only to a general increase in exported tons but also to an increase in blue water-intensive products trade. To shed light on this point, we examine the cubic meters per ton for each agricultural product in the analysis (hence the water footprint) and analyze the time series of the unit of water per ton. Since we consider 8 different sectors in the analysis, we have averaged the value of the blue virtual water content for each set of products.

As our focus is Burkina Faso, we estimated the average water footprint of its annual exports and imports. For this purpose, we have calculated the weighted average of each product's percentage of virtual blue water exports over the whole sector, assigning a higher relevance to those products for which more blue water is exported overall. Figure 9 shows the time series of these averages. As we can see, there are strong fluctuations, due to the absence of certain export values for different years and specific sectors (as shown in Figure 17 in the Supplementary material). What stands out in Figure 9 is that both panels get the same information: no specific trend can be identified for the blue water footprint of the Burkina Faso crop trade.

For a better overview of the time pattern of WF, Figure 10 shows the same weighted average estimate but on a global scale. The average water footprint weighted on virtual water export rates is stable over time. Consequently, we can say that the increase in exported/imported blue water for all regions and for Burkina Faso alone is mainly due to both the increase in network density and the increase in the quantities of exported/imported products in tonnes of the existing links. Therefore, there is no increase in blue water-intensive exports/imports.

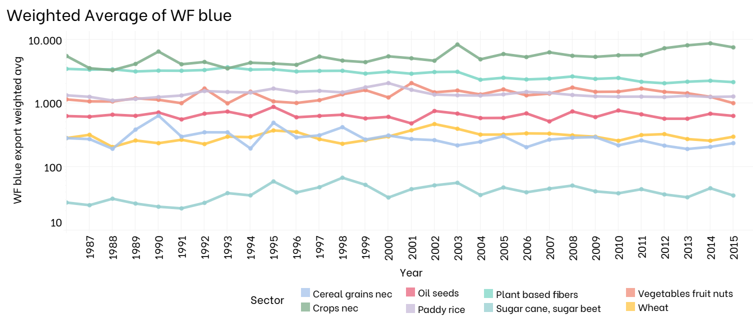


Figure 10: Global water footprint's weighted average (m^3/ton) for exports. Each sector is highlighted by different colors. The weight is the percentage of blue water exported by each product compared to the total blue water exported for the whole sector.

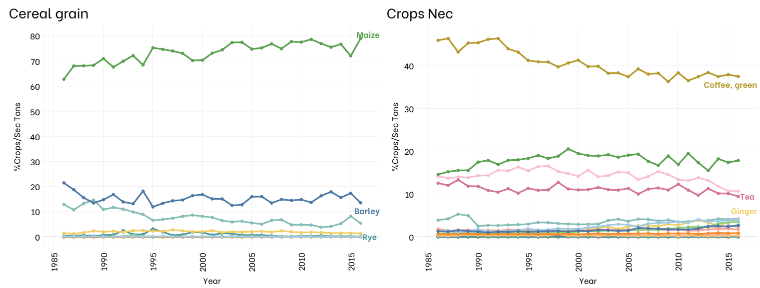
3. Export and production composition global and local scale

To better investigate the use of water in exports both on a global scale and considering Burkina Faso alone, we investigated the composition of each sector in terms of volume of virtual blue water or tons exported. For this purpose, Figure 12 illustrates the two sectors that differ the most in terms of composition[6].

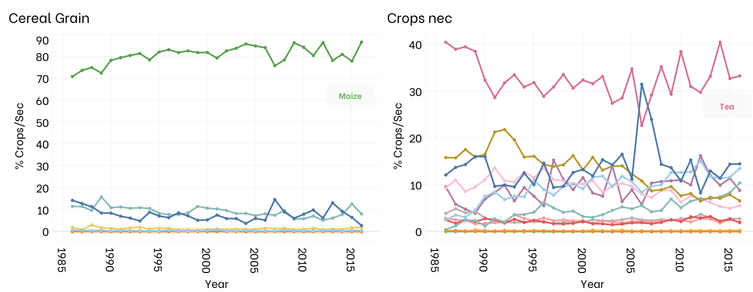
Comparing the two graphs of each panel in the Figure 12 we can identify some similarities and some marked differences in the composition of exports depending on whether we consider the quantity exported in terms of tonnes or virtual blue water.

For example, the most exported crop in terms of both tons and water is maize, which covers an export range of 70-90% of the total cereal sector.

[6]For example, the rice or wheat sectors are excluded from these graphs as they only cover one product each.



(a) Tons

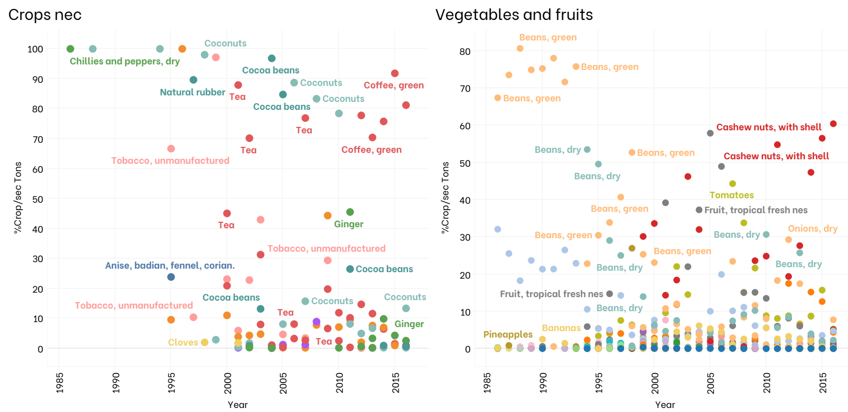


(b) VWB

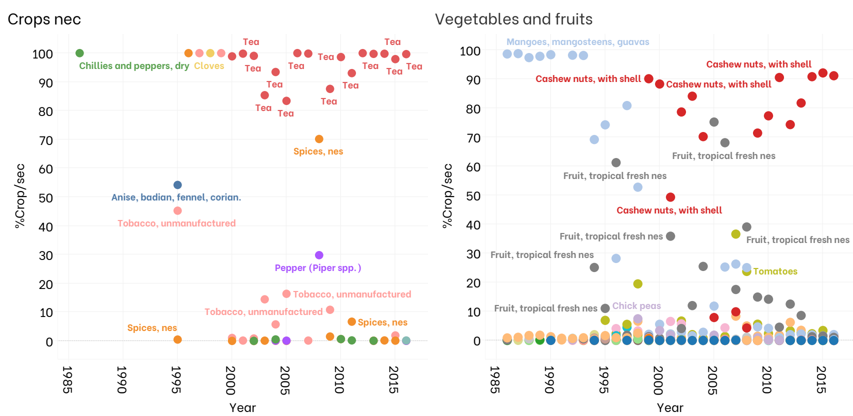
Figure 11: Composition of global exports relative to two specific sectors (Cereal Grain and Crop nec). The data of each product out of the total of the sector considered are reported both in terms of tons percentages (a) or blue virtual water percentages (b).

If, however, we look at the Crops sector, we see that in terms of quantity the most exported product on a global scale is Coffee green, but in terms of quantity of blue water, we observe the predominance of Tea.

If we compare the compositions of two specific sectors also with regard to Burkina Faso's exports, we see similar trends to those found on a global scale. In the last few years available to the CWASI database (2015 and 2016) we see that in terms of tons exported the most characteristic crop is Coffee, green, which disappears in the graph showing the composition in terms of



(a) Tons



(b) VWB

Figure 12: Composition of BFA's exports relative to two specific sectors (Cereal Grain and Vegetables and fruit). The data of each product out of the total of the sector considered are reported both in terms of tons percentages (a) or blue virtual water percentages (b).

virtual blue water (b). This is due to the fact that the water used for the production of Coffee, green is all water derived from precipitation (green water) and therefore not accounted for in the blue virtual water. As far as the Vegetable and fruit sector is concerned, we can observe an important quantity in terms of tons of Green beans exports, until about 2004. After this date, the most important export seems to belong to the category of Cashew nuts. Also in terms of water quantities, we can see that practically the entirety of exported virtual blue water was composed of Mangoes until more recent years when Cashew nuts dominated.

4. Comparison CWASI vs MAGNET

Looking at trends over time with MAGNET projections (2020-2030). As a first step, we calculated 10-year averages of the blue virtual water data in the CWASI database. For this purpose, we calculated the average VWB exported for each sector every 10 years, adding the projections obtained from MAGNET for the years 2020 and 2030. The historical data reported

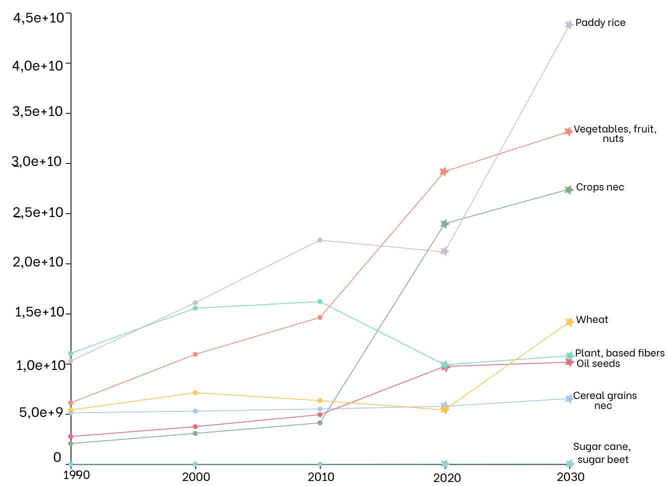


Figure 13: Time trend of 10-year averages of virtual blue water exports on a global scale (highlighted with point shape) with the addition of MAGNET projections for 2020 and 2030 (marked with star shape).

in Figure 13 refer to ten-years averages - i.e., data corresponding to 1990, 2000, and 2010 refer to 1986-1995, 1996-2005, and 2006-2015 averages - while points corresponding to 2020 and 2030 refer to MAGNET projection.

We then graphed the data for the 10-year averages, obtaining Figure 13. From the graph, we can see that for some sectors such as Cereal grains nec, the slight growth reported in the years 2020 and 2030 of the data from MAGNET is in line with the trend detected in the CWASI database. The same is true for the Sugar cane, sugar beet sector, with very small values, compared to the scale. Some sectors, on the other hand, seem to be experiencing excessive growth compared to the trend observed in the years 1990, 2000, and 2010, such as the Vegetables and Fruit sector or the Crops nec sector.

Comparing data from the two different data for one specific year, 2014. Since the two databases, as already mentioned, only have data from 2014 in common, we have graphically analyzed the differences between the two virtual blue water values. Figure 14 shows the blue virtual water exports from CWASI data (on the x-axes) and from MAGNET (on the y-axes) both for 2014. The colors highlight the 8 different sectors into which we have categorized primary agricultural products.

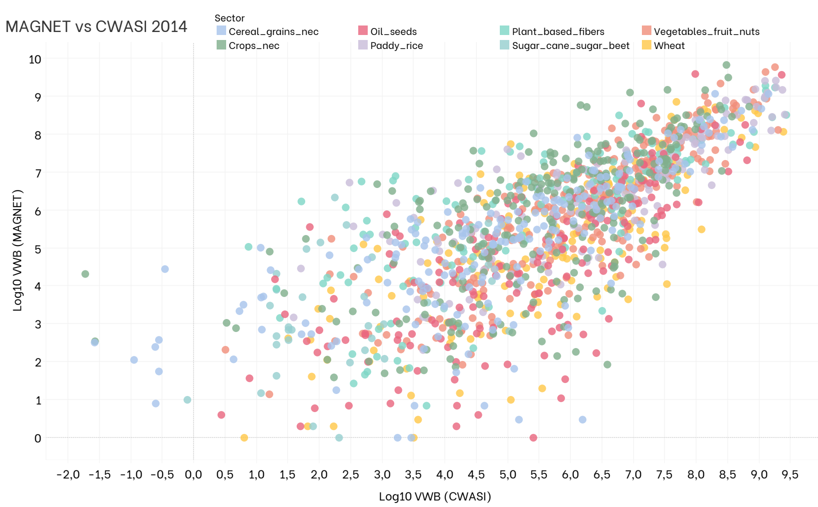
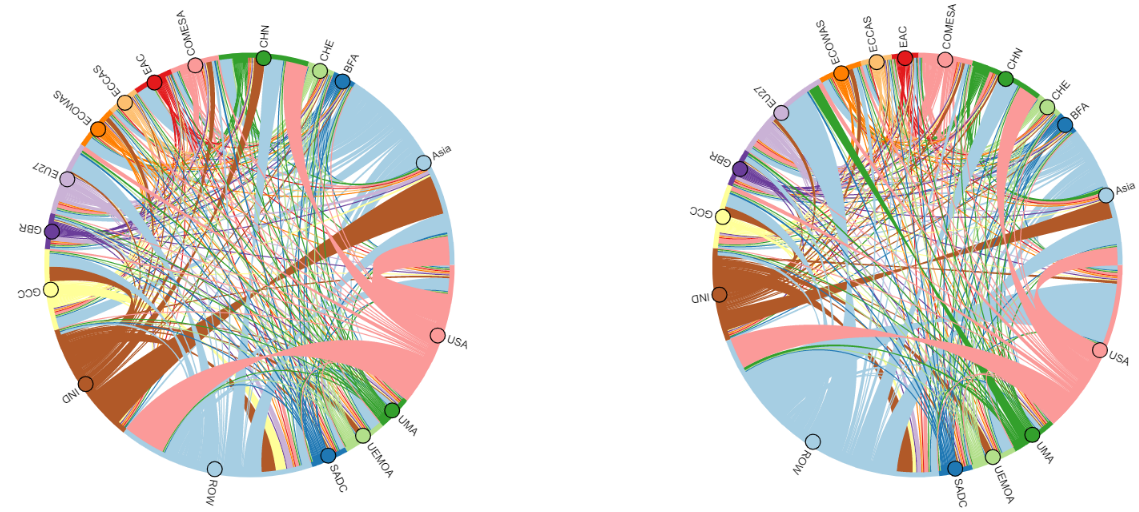


Figure 14: Scatterplot of CWASI and MAGNET data for 2014. Colors distinguish the different sectors considered.



(a) CWASI network 2014 **(b)** MAGNET network 2014

Figure 15: Blue virtual water trade networks from CWASI database (a) and MAGNET model output (b) for 2014 at the global scale. The colors distinguish the different exporting regions.

We can therefore see that MAGNET overestimates the exported blue virtual water compared to the data provided by CWASI. The axes show different magnitudes (considering that the values are given in logarithmic scale as the quantities cover different orders of magnitude). Some differences are also visible when comparing these chord diagrams in Figure 15. For example, outflows concerning the rest of the world (ROW) seem to be much more abundant in the MAGNET output. However, the two networks are similar and the differences may be due to several reasons that will be analyzed in-depth in the next steps of this analysis: (i) different calculations for virtual blue water: CWASI looks at the crop water requirement as blue water (CWASI), while MAGNET considers the withdrawal of blue water for irrigation of a specific crop (thus also including potentially "wasted" water) as shown in Supplementary Materials (Figure 18). CWASI has no data on irrigation water withdrawal to compare with MAGNET data because it calculates blue crops' water footprint in terms of crop water requirement. (ii) Different clustering of some countries in the regions considered: the analysis was aimed to include as many countries as possible covered by the CWASI database following the categorized area division in the GTAP database[7]. (iii) Different amounts of exported tonnes reported in the two different databases.

[7] https://www.gtap.agecon.purdue.edu/databases/regions.aspx?version=9.211

5. Connecting CWASI with MAGNET

5.1. Different approaches

The CWASI database considers virtual water in terms of crop water requirement, defined as the water consumed during the growing season, depends on the type of crop and the timing of the growing season. MAGNET, on the other hand, considers irrigation water in terms of its withdrawal for a specific crop. Consequently, a portion of water withdrawal could return to the surface and/or underground resources and be used again. Therefore, water withdrawal may overestimate the net consumption of water. This, of course, can be a possible explanation for the differences in volumes. We can therefore say that while CWASI looks at the water footprint of the plant as blue water (CWASI), MAGNET considers the water withdrawal of the plant (so it also includes the water that is potentially 'wasted). To explain this difference, some authors use the term requirement ratio (also known as irrigation efficiency) [5]. This term is used to indicate the ratio between the net irrigation water requirements or crop water requirements, which is the volume of water needed to compensate for the deficit between potential evapotranspiration and effective precipitation over the growing period of the crop, and the amount of water withdrawn for irrigation including the losses. At the global level, water requirement ratio values can vary from less than 20% to more than 85% [5].

An exemplary comparison is provided by the figure 16 which illustrates the blue water footprint (m3) and the tons production data for CWASI (in the left panel) and MAGNET (in the right panel) respectively. This comparison highlights that although the CWASI tons are 95% compatible with those of MAGNET, the requirement ratio between the calculated crop water requirement data (CWASI) and the water withdrawal data (MAGNET) amounts to 30%. The aim of this work is therefore to adjust the volumes of water present in MAGNET to have values that are more consistent with the calculated data and therefore to the actual crop water requirement.

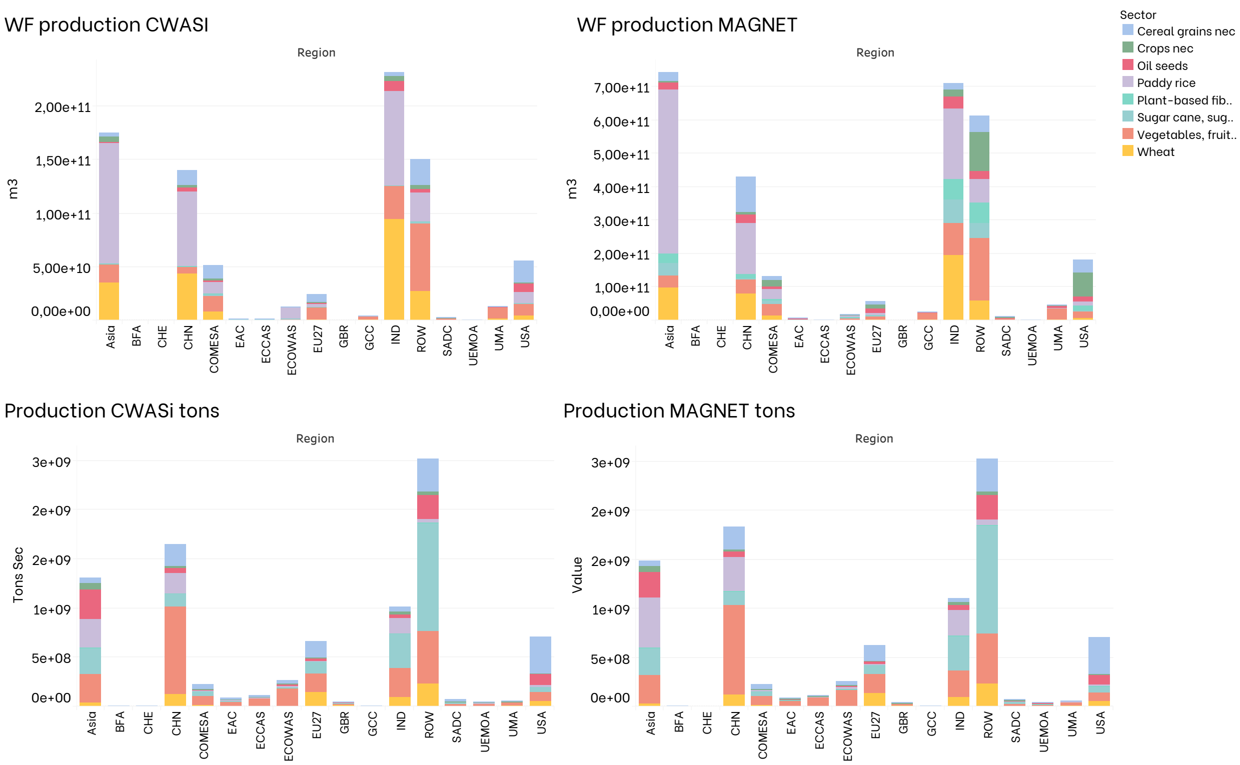


Figure 16: Comparison of the water footprint and tonnes of production in MAGNET and CWASI for 2014.

5.2. Adjustment on CWASI

To develop the base year, i.e. 2014, by connecting MAGNET with the CWASI data, we will take some steps to adjust the data that MAGNET considers as virtual blue water flows. As already mentioned, CWASI looks at the crop water requirement as blue water (CWASI) [15], while MAGNET considers the withdrawal of blue water for irrigation of a specific crop (thus also including potentially "wasted" water) as illustrated in [6].
In order to adjust the MAGNET model to the calculated data, i.e. those in the CWASI database, we proceed by calculating a unit water footprint of the exports of the various sectors considered by MAGNET, giving importance to the sector composition (i.e. the different products within each sector).
We have 8 product macro-compartments for MAGNET whereas in CWASI we have the composition of each sector. When we transform the tons into virtual water it would be good to go down to the scale of detail as within the same sector we can have very different blue uWF. An important assumption here is that the export/product volumes may change but the composition of the basket in the sector may not; we have no tools to say how the sector will be composed in 2030 as we do not have the dis-aggregated data in MAGNET.
Since MAGNET also considers the economic value of production and export (US$), we decided to calculate the weighted unit water footprint by taking the economic value of the products considered as the weight of production (or export). As a result, for both production and exports, we calculated the blue unit water footprint for each region/exporter-importer and for each sector, weighing this value on the share of dollars from production or export at the individual item level on the total value of dollars from production or export in the whole sector. Obviously, the weights change depending on whether production or export is considered, as one region can be a producer

of cassava but not export it, in which case the share of the individual item at the export level would be zero.

For production, therefore, we calculated the WF of each sector as follows:

$$uWF(\frac{m^3}{US\$})_{i,s} = \frac{\sum_{c=1}^{n} WF_{i,c}}{\sum_{c=1}^{n} US\$_{i,c}} \tag{1}$$

where i represents the producer region, s each crop sector and c every single crop. As the US$ considered in CWASI represent 84% of those considered in MAGNET, we multiplied the quantities in MAGNET by the weighted uWF ($m^3/US\$$) in order to obtain the virtual production water flows for each region and each sector considered.

Equivalently, to obtain the uWF of the export, we calculate the weighted average of the export unit water footprint (weights are the US$ exported for each crop on the total of US$ exported for the whole sector) exported from region i to region j as follows:

$$uWF(\frac{m^3}{US\$})_{i,j,s} = \frac{\sum_{c=1}^{n} VWB_{i,j,c}}{\sum_{c=1}^{n} US\$_{i,j,c}} \tag{2}$$

where subscript i refers to the exporter region, j refers to the importer one, s indicates each of the 8 sectors, while c stands for the single crop. The weight given to the average is ratio of the exported dollars of each crop to the total dollars exported by the sector.

The obtained value of the weighed uWF is then multiplied by the values in US$ in MAGNET in order to get virtual water values closer to the calculated ones. So if a region turns out to have no blue water exports/production, multiplying MAGNET US$ by the weighted blue uWF would make that value disappear, exactly in line with CWASI data.

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Supplementary Material

Primary crops CWASI list

Table 1: List of the 120 primary crops traded present in the CWASI database and subdivided for each sector according to GTAP database.

Sector	Item Name	Sector	Item Name
Cereal grains nec	Barley	Vegetables, fruit, nuts	Cashew apple
	Buckwheat		Cashew nuts, with shell
	Canary seed		Cassava
	Fonio		Cauliflowers and broccoli
	Maize		Cherries
	Millet		Chestnuts
	Mixed grain		Chick peas
	Oats		Chillies and peppers, green
	Rye		Cranberries
	Sorghum		Cucumbers and gherkins
	Triticale		Currants
Crops nec	Anise, badian, fennel, corian.		Dates
	Chillies and peppers, dry		Eggplant-baseds (aubergines)
	Cinnamon (canella)		Figs
	Cloves		Fruit Fresh Nes
	Cocoa beans		Fruit, tropical fresh nes
	Coconuts		Garlic
	Coffee, green		Gooseberries
	Ginger		Grapefruit (inc. pomelos)
	Maté		Grapes
	Natural rubber		Hops
	Nutmeg, mace and cardamoms		Kiwi fruit
	Pepper (Piper spp.)		Kolanuts
	Peppermint		Leeks, other alliaceous vegetables
	Spices, nes		Lemons and limes
	Tea		Lentils
	Tobacco, unmanufactured		Lettuce and chicory
	Vanilla		Maize, green
Oil seeds	Cottonseed		Mangoes, mangosteens, guavas
	Kapokseed in shell		Mushrooms and truffles
	Linseed		Olives
	Mustard seed		Onions (inc. shallots), green
	Oilseeds, Nes		Onions, dry
	Palm oil		Oranges
	Poppy seed		Other melons (inc.cantaloupes)
	Rapeseed		Papayas
	Sesame seed		Peaches and nectarines
	Soybeans		Pears
	Sunflower seed		Peas, dry
Paddy rice	Rice, total		Peas, green
Plant-based fibers	Cotton lint		Persimmons
	Flax fibre and tow		Pineapples
	Jute		Pistachios
	Kapok fibre		Plantains
	Manila Fibre (Abaca)		Plums and sloes
Sugar cane, sugar beet	Sugar beet		Potatoes
	Sugar crops, nes		Pumpkins, squash and gourds
Vegetables, fruit, nuts	Apples		Quinces
	Apricots		Roots and Tubers, nes
	Artichokes		Sour cherries
	Asparagus		Spinach
	Avocados		Strawberries
	Bambara beans		Sweet potatoes
	Bananas		Tangerines, mandarins, clem.
	Beans, dry		Tomatoes
	Beans, green		Vegetables fresh nes
	Blueberries		Vetches
	Broad beans, horse beans, dry		Walnuts, with shell
	Cabbages and other brassicas		Watermelons
	Carrots and turnips	Wheat	Wheat

Weighted average of WF blue for Burkina Faso (exports and imports)

Figure 17: Burkina Faso water footprint's weighted average (m^3/ton) for exports and imports. Each sector is highlighted by different colors. The weight is the percentage of blue water exported (imported) by each product compared to the total blue water exported for the whole sector.

Different methods of estimating virtual blue water

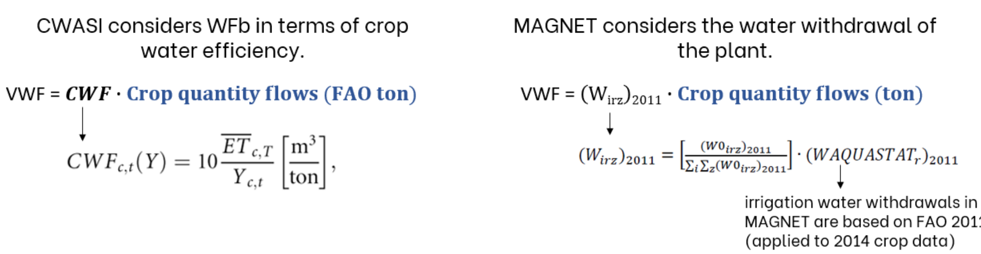

Figure 18: Different method of assessing virtual blue water between the CWASI database (on the left) and the MAGNET model (on the right).