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# Water Footprint Assessment of the Middle East

## Report

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# Water Footprint Assessment of the Middle East

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# Executive Summary

In the Middle East, water challenges are intensified by arid climates, population growth, and geopolitical tensions. Disputes arising from transboundary rivers significantly impact both food security and economic growth, highlighting the critical need for sustainable water management. Moreover, the limited availability of water for food production necessitates the importation of water-intensive food products from other regions. Commissioned by the Inter-Islamic Network on Water Resources Development and Management (INWRDAM) and funded by the Swiss Agency for Development and Cooperation (SDC) through the Blue Peace Middle East initiative (BPME), this report evaluates water use, efficiency, and allocation in the region, taking into account external water dependencies on third countries.

This report examines water use across sectors in the water-scarce Middle East, focusing on Iran, Iraq, Lebanon, Jordan, Syria, and Türkiye. It employs the water footprint and virtual water trade concepts to assess water use and water dependencies comprehensively. The water footprint quantifies freshwater use, while virtual water trade evaluates water transfers through international trade. These frameworks contribute to a holistic understanding of the region's water landscape, crucial for crafting sustainable water management strategies.

The water footprint comprises three key components: green (rainwater used in crop growth, indicating drought sensitivity), blue (surface and groundwater consumption, highlighting susceptibility to water scarcity), and grey (freshwater needed to dilute pollutants, reflecting water pollution).

An analysis of the water footprint and virtual water in Iran, Iraq, Lebanon, Jordan, Syria, and Türkiye was conducted across key sectors, including crop production, industry, energy, and domestic water supply. The study spans from 2012 to 2022, providing insights on an annual and 10-year average basis.

Production activities in the region utilize a total of 263 km3 of water, covering agriculture, energy, industry, and domestic water use. The breakdown by water source indicates that 50% is attributed to green water footprint, 33% to blue water footprint, and 17% to grey water footprint.

In the region, agriculture plays a pivotal role, consuming approximately 224 km3 of water, a volume nearly three times the annual discharge of the Euphrates and Tigris River basins. This reliance on agriculture is highly influenced by rainfall, constituting about 60% of total use, making it sensitive to changing precipitation patterns. Key food crops such as wheat, barley, maize, and sunflowers are particularly vulnerable, posing risks to the region's food security during droughts. Additionally, economy-driven crops like hazelnuts and olives heavily depend on green water. Türkiye significantly contributes to green water use, primarily linked to wheat and hazelnut production, with the former serving as a crucial food source and the latter being an essential export crop in the northern part of the country.

The region's annual blue water use, totalling around 88 km3, surpasses the combined annual discharge volume of the Euphrates and Tigris River basins. This consumption is predominantly driven by agriculture and energy needs. Agriculture, especially associated with crops like wheat, cotton, and rice, along with energy use linked to natural gas and oil production, significantly contributes to this water footprint. Iran emerges as the primary contributor to the blue water footprint in both agriculture and energy sectors.

The total water withdrawn for agriculture is nearly three times higher than the actual consumption, reaching around 200 km3. This substantial difference can be attributed to water losses through irrigation systems or inadequate water management practices.

The two countries, Iran and Türkiye, stand as pivotal centres for agricultural production in the region, collectively contributing to more than 80% of the total water use. They play a critical role in generating most of the food and feed for the area. However, their water productivity differs significantly, with Türkiye exhibiting high water productivity in agriculture due to substantial rainfall, while Iran grapples with low water productivity, heavily relying on irrigation.

Iran's notable blue water footprint is primarily influenced by crops such as wheat, rice, and pistachios. In contrast, Türkiye's blue water footprint encompasses cotton, wheat, sugar beet, and maize. Furthermore, Iran's water consumption is largely driven by domestic needs, while Türkiye emerges as the region's largest virtual water exporter, providing substantial volumes of green and blue virtual water to all other five countries, with a focus on wheat and cotton. On the other hand, Iran's major blue water consumption is attributed to the oil and natural gas industry, while Türkiye's stems predominantly from hydropower, distinguishing it from agricultural use.

The regional water demand for internal consumption and export activities, relies predominantly on local water resources, accounting for approximately 70%, with the remaining 30% met through virtual water imports. Jordan and Lebanon exhibit the highest external water dependency at 90% and 72%, respectively, while Syria has the lowest at around 18%, potentially influenced by data discrepancies. About 85% of the water demand is allocated to internal consumption, with the remaining 15% directed towards agri-food export-related activities.

The water footprint of consumption, representing citizens' water needs for goods and services, averages around 1400 litres per capita. Notably, Türkiye and Iran show higher per capita water volumes at around 1700 litres, while Jordan and Iraq have lower figures at around 1000 litres.

The water footprint of production in the region displays minimal year-to-year fluctuations despite a significant increase in population over the last decade. While production levels remain constant, the six countries in focus have notably heightened their external dependency on water resources, particularly concerning food security crops like wheat, barley, soybean, and maize.

Annually, the region imports substantial volumes of green water embedded in agricultural products, with wheat being a major contributor, alongside soybean, maize, sunflower, oil palm, cacao, rice, and barley. These imports originate from various countries, including Russia (wheat, sunflower), Brazil (maize, soybean, sugarcane), Ukraine (sunflower, wheat), India (rice, soybean, cotton), Indonesia (oil palm, rubber), Argentina (oil palm), and Malaysia (oil palm), significantly influencing the water dependencies of the region.

Cotton emerges as the dominant contributor to blue virtual water imports, holding the highest share, followed by rice, sugar cane, maize, wheat, and barley. Turkmenistan (cotton) leads among contributing countries, followed by India (rice, sugar cane, cotton), the USA (cotton, rice, almond), Uzbekistan (cotton), Russia, and Pakistan (cotton, rice).

The region's food security relies heavily on wheat imports, especially from Russia and Ukraine, with high external water dependency in countries like Jordan and Lebanon. Rice, sunflower, and maize also show significant dependence on external water resources, ranging from 35% in Iran to 100% in Lebanon and Jordan. The textile industry in Türkiye, a vital economic component, relies heavily on external water resources for cotton, with 83% sourced beyond national borders. Key partners like Russia, Ukraine, Central Asia, the USA, and India contribute significantly to the region's food security and economic growth. The increasing externalization of feed supply, particularly the surge in soybean imports from South America, highlights a growing dependence on distant water resources.

Water use for export in the region revolves around key crops, including wheat, olives, hazelnuts, cotton, and pistachios, with distinct associations to Türkiye, Syria, and Iran.

This study on the Middle East's water footprint suggests crucial areas for further investigation. Analysing shared river basins, assessing future water risks, conducting scenario analyses for optimal water use, and exploring cross-border climate risks are key recommendations. These studies aim to enhance understanding, inform decision-making, and develop proactive strategies for sustainable water management in the region.

# 1 Introduction

Water is essential for all consumption and production activities. Every product, from food to electronics, relies on water for both its production and consumption and is intricately linked to issues of water scarcity and pollution (Rockström, 2009). For instance, rainwater and irrigation are utilized in the cultivation of cotton. This cotton is subsequently processed into items such as T-shirts, effectively incorporating water use into the final product. The interconnected flow of water within the production chain ultimately and over-consumption patterns jointly impact water resources by reducing availability or contributing to water pollution. In other words, our existing production and consumption patterns exert considerable pressure on water resources, establishing what is known as our water footprint (Hoekstra, 2008).

Traditionally, we assess water use and pollution associated with the goods and services we consume by focusing on the geographic region where we reside. This approach is sensible since a significant portion of water used in production is usually sourced directly from nearby rivers or extracted from groundwater in the vicinity of the production area. Given that this use is direct, the availability, quality, and scarcity of this water, particularly under current and future climate conditions, significantly influence risk management, water-related policies, and environmental strategies at the local level. For instance, water and agriculture policies in Türkiye specifically consider the water resources within Türkiye's borders at the river basin level. This logical approach aligns with the fact that production activities in Türkiye rely on water directly obtained from its river basins. Consequently, if these water resources were to become unavailable, the impact would be immediate.

Conversely, some economic sectors depend on ingredients and products that are not domestically produced but are crucial for manufacturing, ensuring food security, agri-food production, or direct consumption by citizens. Since water is either embedded in these products or used during their production, the cross-border trade flow of these products creates a link between these sectors and the water resources in the original production regions. As a result, the food, energy, or goods consumed within a country— due to importing commodities from other countries for production and consumption—become susceptible to hydrological extremes and climate change impacts in those production regions (Ercin et al., 2021).

The Middle East faces formidable water challenges, with arid climates, population growth, and geopolitical tensions intensifying the struggle for sustainable water resources (Zekri, 2020). Severe water scarcity issues in the countries of the region are related to the non-availability of water resources, population growth, climate change, and inefficient water management practices (Wolf, 2023). Transboundary rivers often lead to disputes over shared water, impacting food security and economic growth. The balance between water availability, its efficient utilization, and equitable allocation is central to the region's future stability and development. Addressing these challenges requires innovative and cooperative strategies to ensure sustainable water management, enhance resilience to climate variability, and foster regional cooperation for lasting solutions.

The presence of extreme scarcity of water resources and transboundary water flows in this region often sparks conflicts and gives rise to crises related to food security and economic growth. Given the critical scarcity of water in this area, understanding its use, efficiency, and allocation across various sectors, including food and energy, becomes a crucial element for future planning, livelihood sustainability, and fostering peace in the region.

Furthermore, it is crucial for the livelihood of this region to understand the extent to which their food security depends on other countries or the availability of water resources beyond their borders. This understanding can shed light on the interdependencies that exist, providing valuable insights into the region's vulnerability to external factors and other countries. It can enable more informed decision-making in devising strategies for sustainable agricultural practices, ensuring adequate food production, and fostering resilience in the face of potential fluctuations or disruptions in transboundary water resources.

The report leverages the concepts and frameworks of water footprint and virtual water trade to comprehensively understand water use in the region across various sectors and cross-border water dependencies. The water footprint is a quantitative measure of the total volume of freshwater used directly or indirectly to produce goods and services consumed by individuals, communities, or nations. The concept of virtual water trade refers to the transfer of water resources embedded in goods and services across national borders through international trade. These concepts enable the evaluation of the actual water consumption associated with the production and trade of commodities, revealing the water-related implications of agri-food trade. By integrating these frameworks, the study aims to quantify and evaluate the region's water use dependencies and offer comprehensive insights into sustainable water management strategies.

This report is an outcome of a project commissioned by the Inter-Islamic Network on Water Resources Development and Management (INWRDAM), made possible through funding from the Swiss Agency for Development and Cooperation (SDC) via the Blue Peace Middle East initiative (BPME).

The structure of the report is as follows: Chapter 2 introduces key concepts and their interpretations. In Chapter 3, the analysis results are presented, specifically the water footprint of production, consumption, and virtual water trade for the entire region, treating the six countries as a single entity. Chapter 4 outlines key insights derived from the analysis. Chapter 5 offers suggestions for future analytics that could benefit the region. The appendices contain additional detailed information, including country-level results, a concise summary of water resources, water scarcity maps and the methodology employed in this analysis.

# 2 Understanding Key Concepts

## 2.1 Water footprint

The concept of 'water footprint assessment' serves as the framework to assess the freshwater consumption and pollution associated with producing goods and services in this study. Examining the lifecycle of a basic cotton t-shirt elucidates this concept, as each phase, from the cultivation of cotton to the manufacturing processes transforming it into a wearable garment, collectively contributes to the overall water footprint of this product. For example, a water footprint of 1000 litres for a T-shirt implies that this amount of water is either consumed or polluted during its production along its supply chain. This information is valuable because it raises awareness about the unseen water consumption and pollution behind the goods and services consumed in daily activities.

The water footprint can be characterized from the standpoint of a product, producer, or consumer. It can be further defined for an individual, business, region, or a country. **A product water footprint** represents the total water consumed across all stages of a product, as illustrated in the example of a cotton T-shirt. In this project, on a product level, the focus was explicitly on calculating the water footprint of crops, encompassing the volume of water consumed and polluted during the growth phase of crops like maize and sugar. The water footprint of derived products for traded goods, such as ketchup from tomatoes, and juices from fruits, was also calculated based on their primary ingredient’s footprint.

**The water footprint of a country/region** denotes the total volume of water used for all the products that the respective country or region produces. For instance, Türkiye's water footprint of production encompasses the total amount of water consumed in agriculture, industry, energy production and domestic water use in Türkiye.

**The water footprint of consumption** refers to the total amount of water used throughout the entire lifecycle of the goods and services consumed by individuals, communities, or nations. It considers not only the direct water use involved in the production and processing of products but also the indirect water use associated with their supply chains. For instance, when someone purchases a product, the water footprint of consumption includes the water used to grow or manufacture the raw materials, as well as the water used in various stages of production, transportation, and distribution.

## 2.2 Components of water footprint

The water footprint consists of three integral components, each shedding light on different aspects of water use. The green water footprint, encompassing rainwater consumption during crop or vegetation growth, becomes crucial in assessing drought sensitivity. If the green water footprint of a particular crop is substantial, it signifies a heavy reliance on rainwater, making the crop highly vulnerable to drought conditions. In such instances, prolonged periods of drought can adversely affect the yield and overall production of the crop. Understanding the interplay between the green water footprint and drought susceptibility is pivotal for evaluating the resilience and sustainability of agricultural practices in the face of changing climate conditions.

The blue water footprint, accounting for surface and groundwater consumption in various processes, is crucial in assessing susceptibility to water scarcity, water stress, and hydrological drought. A significant blue water footprint indicates a substantial reliance on these water sources, potentially exacerbating water-related challenges. High blue water consumption can contribute to water stress in regions as well where water resources are already strained, leading to increased competition for limited supplies.

Lastly, the grey water footprint reflects the freshwater required to dilute pollutants given into the water systems and meet water quality standards, indicating the environmental pressure of water pollution. A large grey water footprint indicates problems of water pollution.

## 2.3 Virtual water trade

The virtual water trade associated with a region or country has two components: import and export. The virtual water import of a region represents the total amount of water used to produce the commodities imported by the region from outside its borders. Similarly, the virtual water export of a region refers to the water used locally in the region to produce commodities for export. A schematic representation of the virtual water trade framework is given in Figure 1

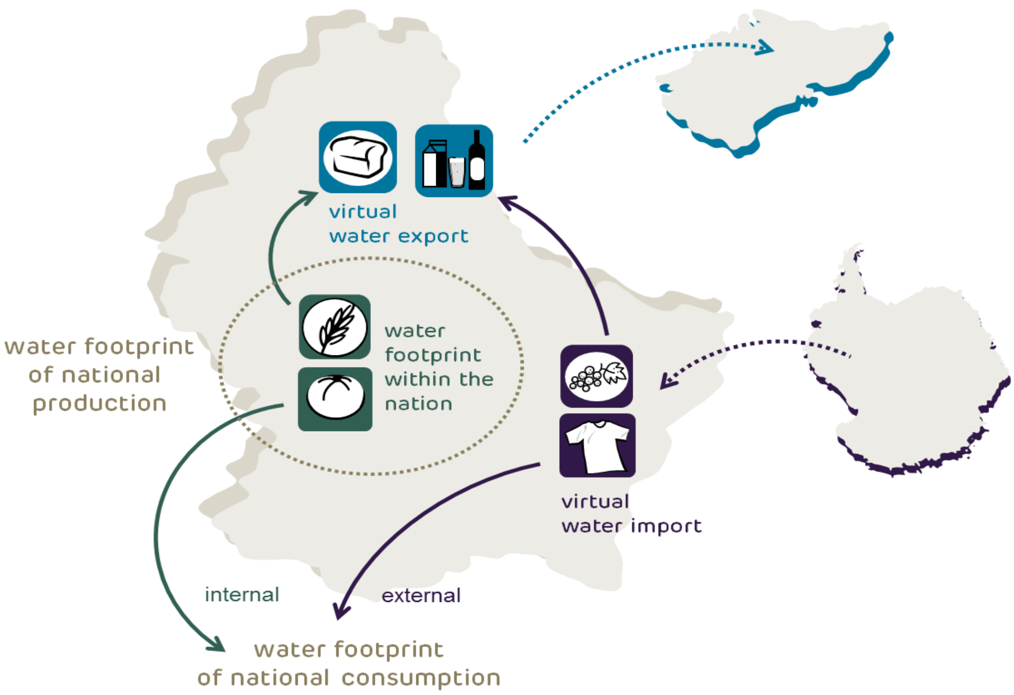


*Figure 1: Virtual water trade analysis framework (from Ercin, 2022)*

In virtual water trade analysis, an additional aspect to consider is the origin of the water utilized in manufacturing traded goods. The 'green' virtual water import/export signifies the quantity of rainfall utilized in the production of traded agricultural items, playing a crucial role in evaluating the vulnerability of these imported/exported commodities to drought. Meanwhile, the 'blue' virtual water import/export pertains to the volume of surface and/or groundwater employed in the production of traded goods. This aspect can reveal either the susceptibility of the traded products to water stress and hydrological drought or shed light on contributing factors to water-related issues, such as the decline of groundwater levels in production areas. The third aspect, the 'grey' virtual water import/export, serves as an indicator of water pollution. Grey virtual water imports indicate a region's impact on water pollution beyond its borders due to the production of imported goods.

Similarly, grey virtual water exports depict the impact in terms of water pollution resulting from the production of goods for export in the country of origin (Ercin, 2022) (Table 1).

*Table 1. Interpretation of virtual water trade analysis (from Ercin, 2022).*

| | Virtual water import | Virtual water export |
|---|---|---|
| **What does it refer to?** | Water used to make products imported, like Russia's water for Iran's wheat. | Water used domestically for exported goods, like water use in Türkiye for a cotton t-shirt sold in Europe. |
| **What does it tell us?** | Dependency on external water resources of various economic sectors.<br><br>Remote impacts of agri-food consumption on water resources outside a region's borders. | Impact of exports on local water resources in terms of quantity and quality.<br><br>Economic value of water use associated with exports. |
| **Why does it matter?** | Highlights susceptibility to water challenges beyond borders (e.g., drought severity, water scarcity). For example, it unveils the impact of water scarcity or pollution beyond Iran's borders on Iran's economy. | Answers critical questions like: Will there be enough water in the medium term for a region's export industry? What is the export sector's impact on society's water access, agriculture, and environmental sustainability? |
| **Key Insights** | Green virtual water import/export: drought sensitivity.<br><br>Blue virtual water import/export: water stress sensitivity or pressure on water resources<br><br>Grey virtual water import/export: contribution to water pollution | |

# 3 Water footprint of the Middle East

## 3.1 The water footprint of production

The water footprint of production in Iran, Iraq, Lebanon, Jordan, Syria, and Türkiye was assessed across crop production, industry sector, energy sector, and domestic water supply. The water footprint of each sector was calculated in terms of green, blue, and grey water footprints, except for the grey component of energy production, due to a lack of data. The assessment covers the period from 2012 to 2021 on an annual and 10-year average basis.

The water footprint of production has two components: total and per product (i.e. crops). The first, measured in million (or billion) $m^3$, signifies the total water consumed by sectors within a year. For instance, water footprint of crop production refers to all water used for agriculture within the region. If a country like Iran utilizes water from a river for agriculture, the annual blue water footprint reflects the cumulative volume of water consumed from that river, impacting available water for other essential purposes such as household use and environmental preservation. Expressed in $m^3$ per tonne of product, the latter aims to assess the water efficiency of major crops produced in the region across six countries. This assessment reveals differences in water use for the same crop across countries. For instance, wheat in Iran may require more irrigation water (blue water), making it vulnerable to reduced river flows. In contrast, wheat in Türkiye relies more on rainfall (green water), indicating sensitivity to drought. However, the low blue water footprint of wheat in Türkiye may suggest efficient use of limited water resources.

### 3.1.1 The total water footprint of production

The total water footprint of production in the region is approximately 263 billion $m^3$ per year. Within this total, 50% is attributed to the green water footprint and 33% to blue. The remaining 17% is related to the grey water footprint, representing the volume of water that is polluted (Figure 2). Breaking down the total water footprint by sectors, crop production has the largest share at 85%, followed by the energy sector at 6%, domestic water use at 6%, and the industry sector contributing 3%.

The green water footprint in the region is approximately 132 billion $m^3$ per year entirely associated with crop production. The blue water footprint of the region is 88 billion $m^3$ per year with approximately 82% linked to crop production and 17% related to the energy sector. The remainder, around 1%, is associated with industrial and domestic water supply. The total grey water footprint of production is 44 billion $m^3$, with 47% linked to crop production, 36% to domestic water supply, and 17% to the industry (Figure 2). It is important to note that the exclusion of the grey water footprint of energy production largely underestimates the total greywater footprint of production in the region.

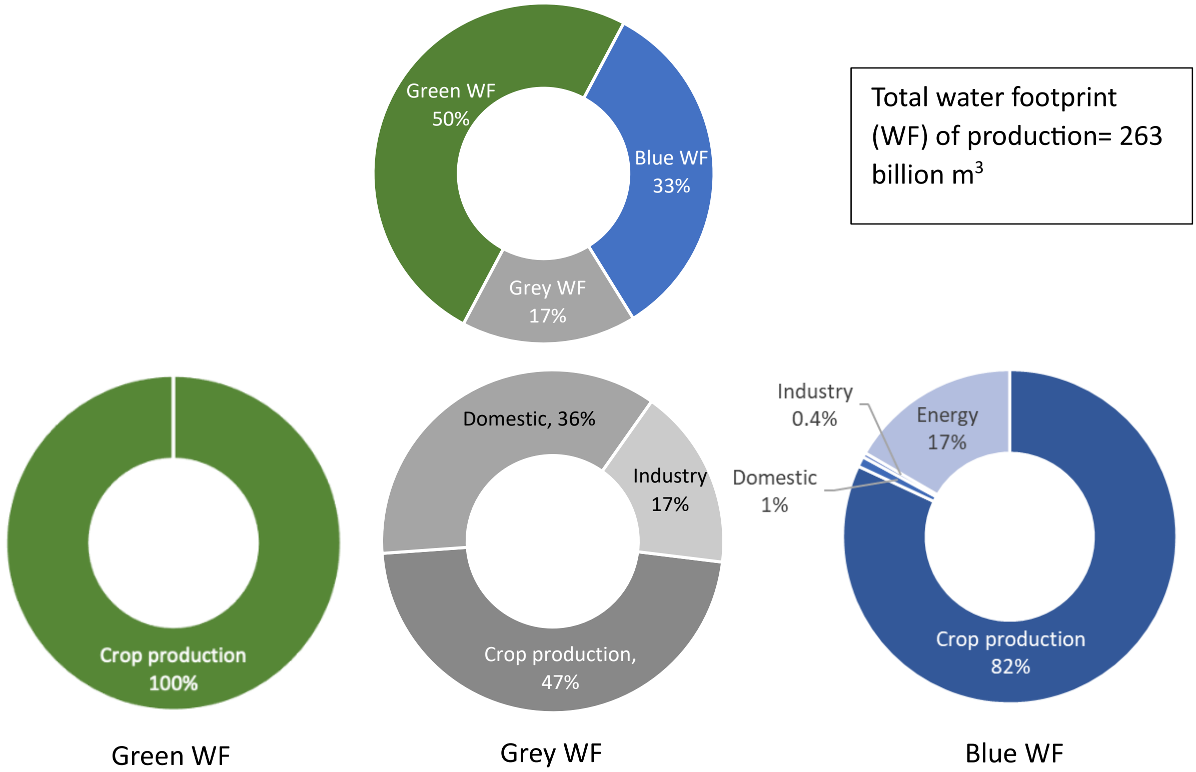


*Figure 2: Allocation of the water footprint (WF) components is illustrated in the upper figure, while the lower figures depict sectoral breakdowns (green WF on the left, grey WF in the middle, and blue WF on the right), all represented as a percentage of the total in the Middle East Region, encompassing Iran, Iraq, Lebanon, Jordan, Syria, and Türkiye (for the average of 2012-2021).*

On an annual basis, the water footprint of production in the region has shown minimal fluctuation between 2012 and 2021. The lowest estimation occurred in 2018 at 247 billion $m^3$, while the largest estimated value was in 2019, reaching 284 billion $m^3$. The fluctuation can be attributed to the water footprint of crop production and related to changes in volumes of crop production and crop yield changes (Figure 3).

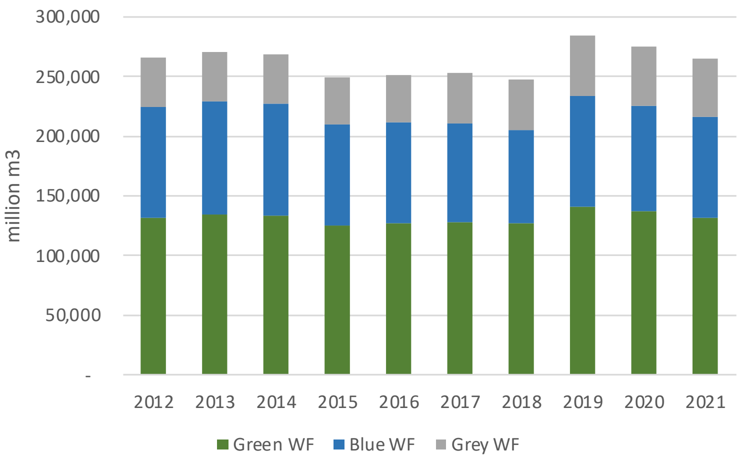


*Figure 3: The water footprint of production in the Middle East region per year between 2012 and 2021, per green, blue and grey components.*

Among the six countries, Iran holds the largest share of the total water footprint of production, constituting 41% of the total, followed closely by Türkiye at 39% and Iraq at 10%. Syria contributes 8%, while Jordan and Lebanon represent 1% and 0.6% of the total water footprint of production, respectively. Turning to the green component, Türkiye takes the lead with 52% of the total, followed by Iran at 33%, Syria at 9%, Iraq at 5%, and Jordan and Lebanon at 0.6% and 0.4%, respectively. Regarding the blue water footprint of production, Iran dominates with 57% of the total blue water footprint of production, followed by Türkiye at 22%, Iraq at 12%, and Syria 7%. Jordan and Lebanon contribute 1.2%, and 0.7% to the total blue, respectively. Examining the total grey water footprint of production, Iran, and Türkiye each hold a significant share of around 35% of the total, followed by Iraq at 18%, Syria at 8%, Jordan at 3%, and Lebanon at 1% (Figure 4).

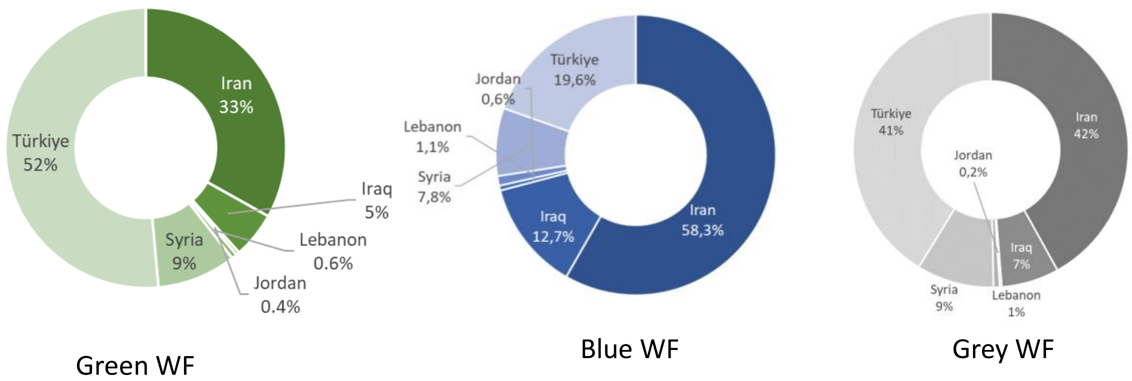


*Figure 4: Allocation of the water footprint (WF) components per country (green WF on the left, blue WF in the middle, and grey WF on the right), all represented as a percentage of the total water footprint of production in the Middle East Region (average of 2012-2021).*

### 3.1.2 The water footprint of crop production

The green water footprint of crop production is 132 billion $m^3$ annually.
Figure 5, the upper diagram, illustrates the distribution of green water footprints across various crops, emphasizing the proportional contributions each crop makes to the overall green water footprint. Wheat leads the way, constituting 53% of the total green water footprint. Next, barley contributes 14%, while olives make up 5%, and hazelnuts contribute 3%. Maize, tea, grapes, chickpeas, and sunflower each have lower shares, ranging from 2% to 1%.

Türkiye and Iran stand out as the primary contributors to the green water footprint within the context of wheat cultivation among the six countries, representing 47% and 48%, respectively, of the total associated with wheat production. Türkiye holds the predominant share of barley production, contributing approximately 50% to the overall green water footprint of barley, followed by Iran and Syria, each accounting for 20% of the total. Additionally, Türkiye dominates the green water footprint in olives, with a share of 55%, while Syria follows at 36%. Almost all of hazelnut production's green water footprint is concentrated in Türkiye. The spatial distribution map of the green water footprint of crop production in the region is given in Figure 6.

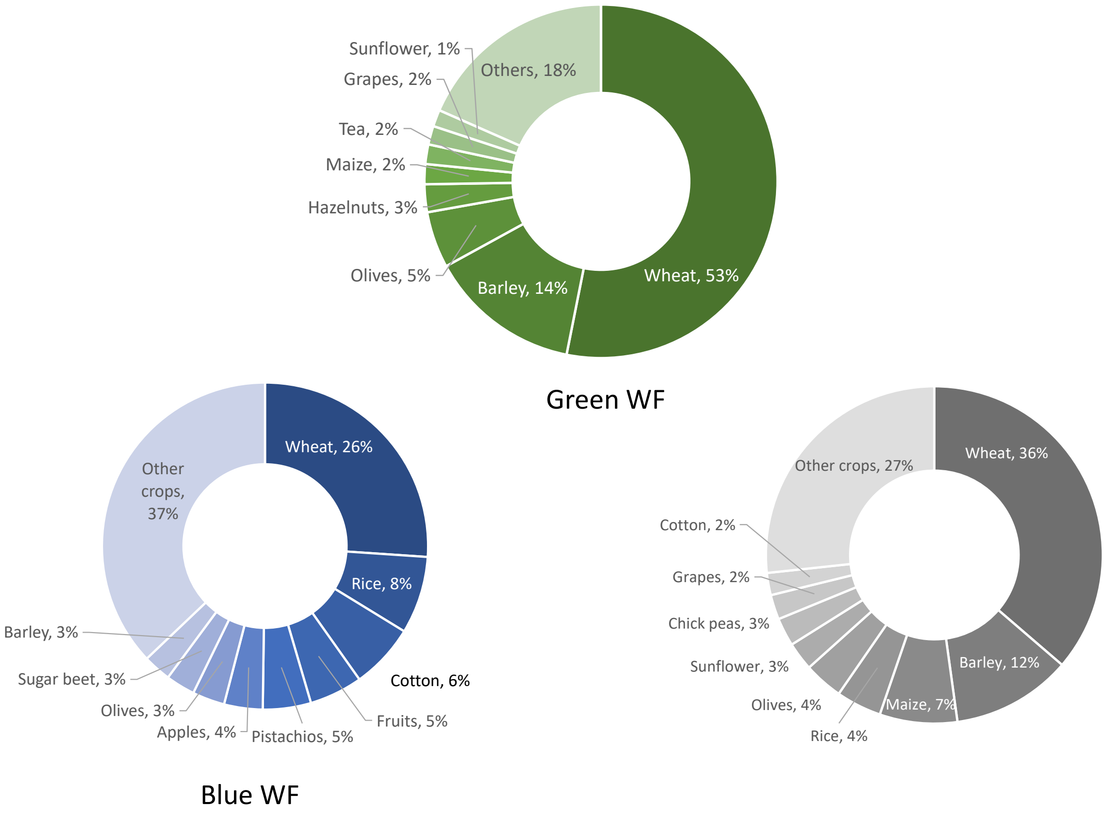


*Figure 5: Allocation of the water footprint (WF) components per crop: green WF at the top, blue WF in the bottom-left, and grey WF in the bottom right. All percentages are relative to the total water footprint of crop production in the Middle East Region for the average of 2012-2021 and the total for Iran, Iraq, Lebanon, Jordan, Syria, and Türkiye.*

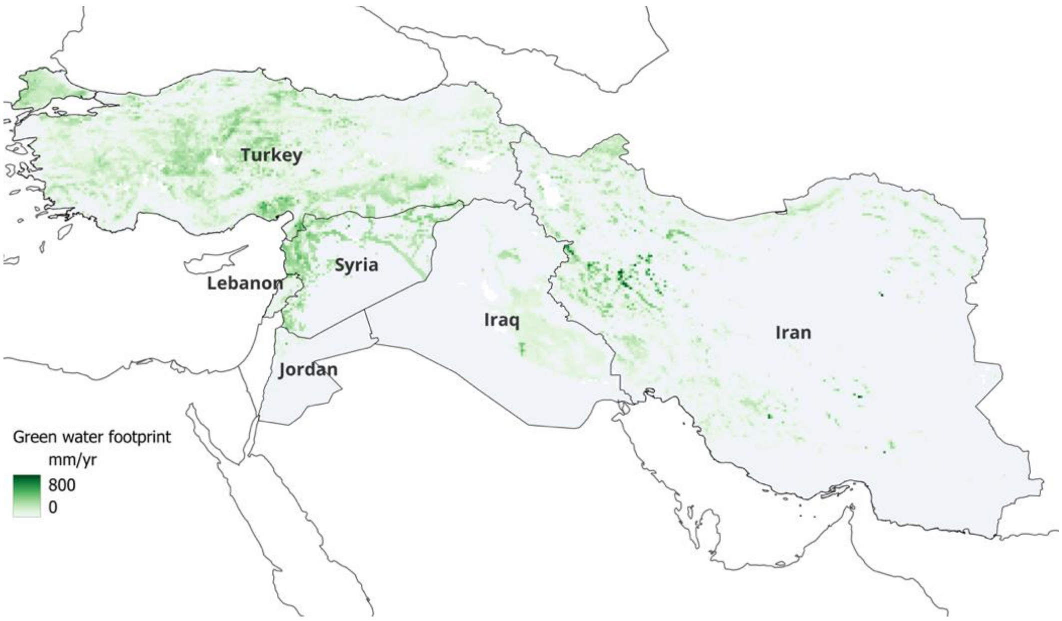


*Figure 6: The green water footprint of crop production map in the Middle East region (in mm/year).*

In the context of the blue water footprint of crop production, wheat emerges as the predominant contributor with a 26% share, trailed by rice at 8%, cotton at 6%, and fresh fruits, holding a 5% share. Other contributions come from pistachios (5%), apples (4%), sugar beet, olives, and barley (3% each). Iran has the largest share of blue water footprint of crop production, accounting for 50% of the region's total, followed by Türkiye at 20%, Iraq at 13%, and Syria at 8%. The spatial distribution map of the blue water footprint of crop production is provided in Figure 7.

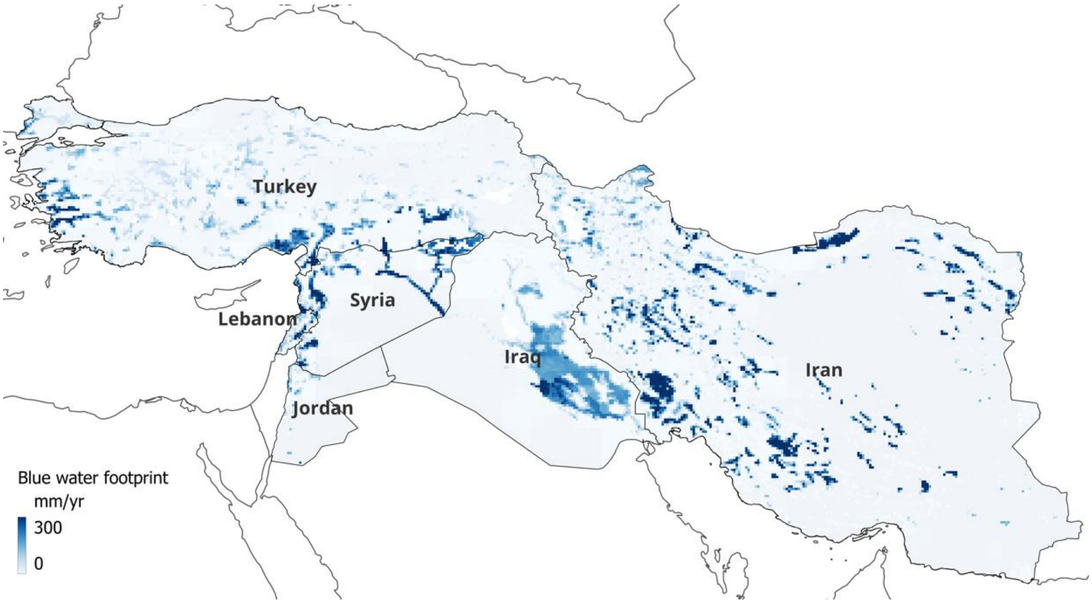


*Figure 7: The blue water footprint of crop production map in the Middle East region (in mm/year)*

Wheat cultivation in Iran is predominantly irrigated, resulting in 60% of the blue water footprint related to wheat production in the region. Likewise, most of the blue water footprint related to pistachios (92%) and rice (71%) is concentrated in Iran. Türkiye accounts for nearly 78% of the blue water footprint associated with cotton production. The primary crops contributing to Iran's significant blue water footprint include wheat, rice, and pistachios. In Türkiye, prominent contributors encompass cotton, wheat, sugar beet, and maize. Iraq's blue water footprint is determined by wheat, barley, and rice, while Lebanon's is related to olives, potatoes, and apples, Syria's is from olive and wheat and Jordan's blue water footprint is from olives, tomatoes, and peaches.

Shifting to the grey water footprint of crop production, wheat takes the lead with a substantial 36% share, succeeded by barley at 12%, maize at 7%, and rice at 4% (Figure 5). Other crops contributing largely to the grey water footprint are sunflowers, chickpeas, and grapes. Iran and Türkiye emerge as the primary contributors to the grey water footprint of crop production, jointly accounting for 83% of the total, with Iran at 42% and Türkiye at 41%. By comparison, Syria follows with 9%, Iraq with a 7% share, while Lebanon and Jordan each contribute approximately 1%. The grey water footprint map of production (including domestic supply and industry) is given in Figure 8.

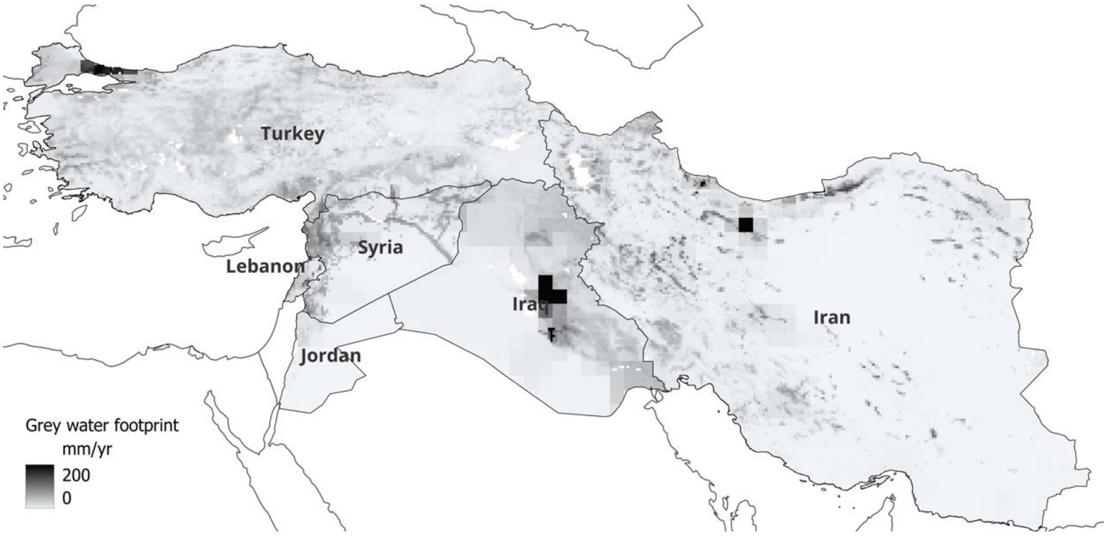


*Figure 8: The grey water footprint of production map in the Middle East region (in mm/year).*

### 3.1.3 The water footprint of key crops (per unit production)

The key crops cultivated in the Middle East region include wheat, barley, cotton, pistachio, olive, rice, maize, apple, and sunflower in terms of contribution to the total water footprints both from green and blue perspectives. These crops are commonly grown in six countries, contributing significantly to both water consumption and playing crucial roles in ensuring food security and bolstering the economy. Additionally, other noteworthy crops in the region encompass hazelnuts, sugar beet, and tea in Türkiye; dates in Iraq; potatoes and oranges in Lebanon; and tomatoes, and peaches in Jordan. Sugarcane and dates are other crops in Iran, while lentils and grapes in Syria. Figure 9 illustrates the water footprints per tonne of the key crops produced in the region. Overall, Iran stands out among the six countries, consistently demonstrating the highest water footprint per tonne for most crops. Iranian crops also exhibit significant blue water footprint components. For instance, the water footprint of wheat in Iran is nearly twice that of Türkiye, with 28% of it being irrigated. This trend is mirrored in pistachio and olive cultivation.

Iraq is another country where the water footprint per tonne of key crops surpasses that of its counterparts. The prevalence of a high blue water footprint component in Iraq underscores the reliance on irrigation for crop cultivation, a characteristic shared with Iran. In the face of water shortages, both Iran and Iraq are susceptible to production losses in vital crops like wheat, posing a significant threat to food security.

On the contrary, both Türkiye and Lebanon stand out for their relatively low water footprint per tonne when compared to the other five countries in the region. Most key crops in these nations heavily depend on rainfall for their cultivation. Noteworthy crops such as wheat, barley, olive, and maize are predominantly grown in Türkiye, and their production is significantly influenced by natural precipitation patterns. Despite the advantage of a low water footprint per crop, the strong reliance on rainfall also exposes these regions to vulnerability in the face of drought conditions.


*Figure 9: The water footprint per tonne of key crops produced in the Middle East region (in m³/tonne).*

### 3.1.4 Comparison of crop water footprints to global benchmarks

The global water footprint benchmark for wheat is 1069 $m^3$/tonne (Mekonnen & Hoekstra, 2014). When compared to this benchmark, all countries exhibit higher water footprints for wheat. Iran has the highest water footprint at around 3800 $m^3$/tonne, trailed by Jordan at around 3400 $m^3$/tonne and Syria at around 2900 $m^3$/tonne.

The global water footprint benchmark for barley is 546 $m^3$/tonne (Mekonnen & Hoekstra, 2014). In comparison to this benchmark, all countries have higher water footprints for barley. Syria has the highest water footprint at around 6000 $m^3$/tonne, followed by Iraq at around 3400 $m^3$/tonne and Jordan at around 2900 $m^3$/tonne.

The global water footprint benchmark for cotton is 1898 $m^3$/tonne (Mekonnen & Hoekstra, 2014). When compared to this benchmark, all countries exhibit larger water footprints for cotton. Iraq has the largest water footprint at around 7400 $m^3$/tonne, trailed by Iran and Syria each at around 4100 $m^3$/tonne.

The global water footprint benchmark for rice is 952 $m^3$/tonne (Mekonnen & Hoekstra, 2014). In comparison to this benchmark, Türkiye matches this figure with around 1000 $m^3$/tonne. At the same time, Iraq (around 3900 $m^3$/tonne) and Iran (around 2200 $m^3$/tonne) exhibit much higher water footprints for rice production.

It is noteworthy that for wheat, barley, cotton and rice, Türkiye consistently ranks as one of the countries with the lowest water footprints per $m^3$ of crop produced. The production of these crops in Türkiye is hence, from a water perspective, relatively efficient. For the majority of crops, the water footprints of production in the least efficient countries are 3-10 times greater than the global benchmark.

### 3.1.5 The water footprint of other sectors: industry, domestic water use and energy

In the industrial sector, the blue water footprint was calculated as 0.4 billion $m^3$. The domestic water use sector, encompassing household and public water supply, exhibits a blue water footprint of 0.9 billion $m^3$. The energy sector has a significant blue water footprint of 14.6 billion $m^3$.

Iraq has the largest blue water footprint for industry and Iran and Türkiye has the largest shares in blue water footprint of domestic water use. Iran has the largest share in blue water footprint of energy amongst these six countries (Figure 10). The grey water footprints of the industry and domestic water use stand at 7.5 and 15.7 billion $m^3$, respectively, with each country's shares aligning with their respective blue water footprint shares.

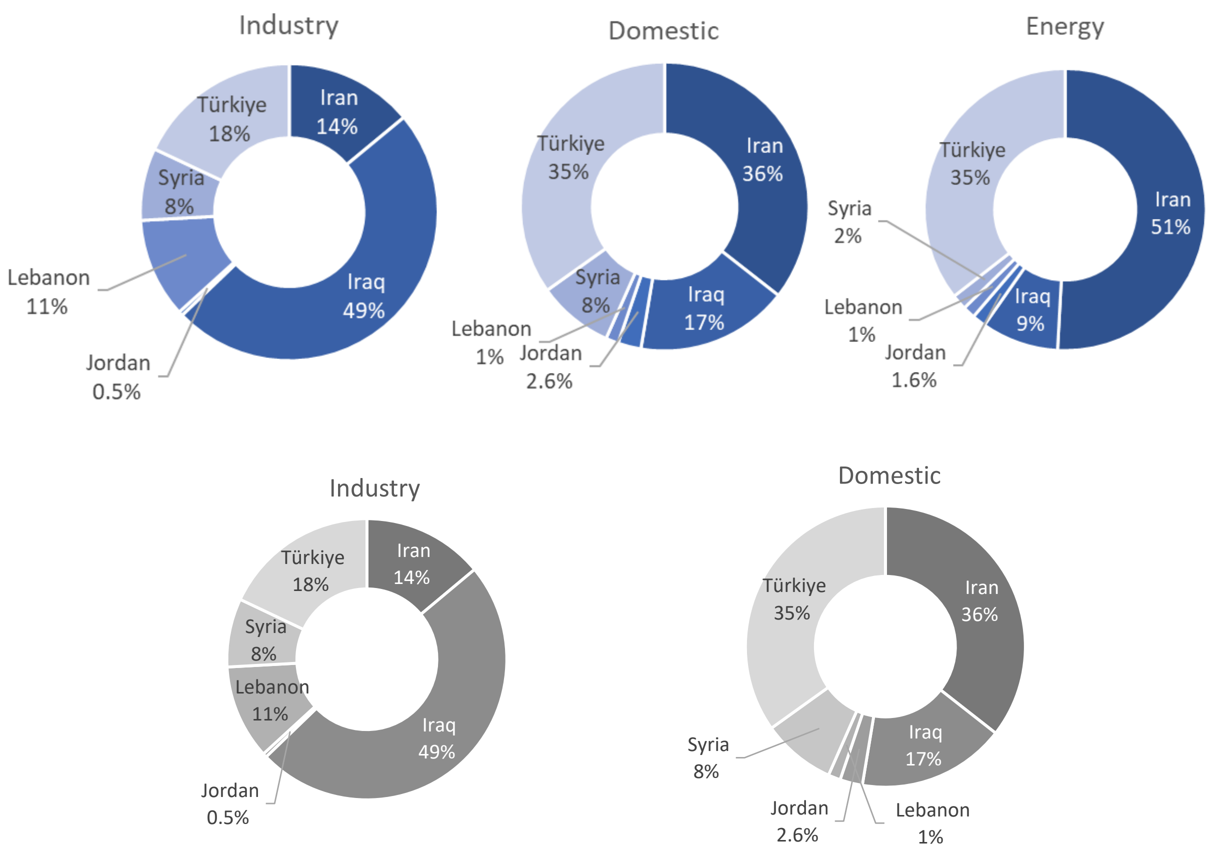


*Figure 10: The blue (top three figures) and grey (bottom two figures) water footprint of industry, domestic water supply, and energy production per country share within each sector.*

The percentages in  Figure 11  represent the distribution of various energy types within the blue water footprint of the energy sector in the region. Natural gas stands out with the highest contribution, accounting for 46% of the total blue water footprint. Oil follows closely behind at 33%, while coal contributes 13%. Hydro and, wind, solar., make up 8% and 0.4%, respectively, while nuclear has a minimal 0.3% share. For natural gas and oil, Iran has the largest blue water footprint, while for hydropower, Türkiye takes the lead.

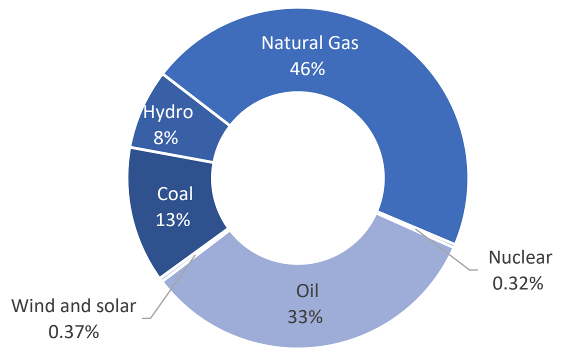


*Figure 11: The blue water footprint of energy, shares of energy production type.*

## 3.2 Virtual water trade

The virtual water trade of the six countries was evaluated from two perspectives: first, considering the six countries as a single region and assessing trade between this region and the rest of the world (excluding virtual water trade between these counties); second, solely examining the virtual water trade occurring among the six countries.

### 3.2.1 Virtual water trade with countries outside the region

The region annually imports 91 billion m$^3$ of green water and 12 billion m$^3$ of blue water in relation of import of agricultural products. Wheat claims the largest portion of green virtual water imports at 18%, trailed by soybean (15%), maize (9%), sunflower (9%), oil palm(6%), cacao (6%), rice (5%), and barley (5%) (Figure 12, top left). Green virtual water imports originate from several countries, with Russia taking the lead at 19% (wheat, sunflower), followed by Brazil at 14% (maize, soybean, sugarcane), Ukraine at 8% (sunflower, wheat), India (rice, soybean, cotton) and Indonesia (oil palm, rubber) at 7% each, and Argentina and Malaysia (oil palm) contributing 6% and 5%, respectively (Figure 12, top right).

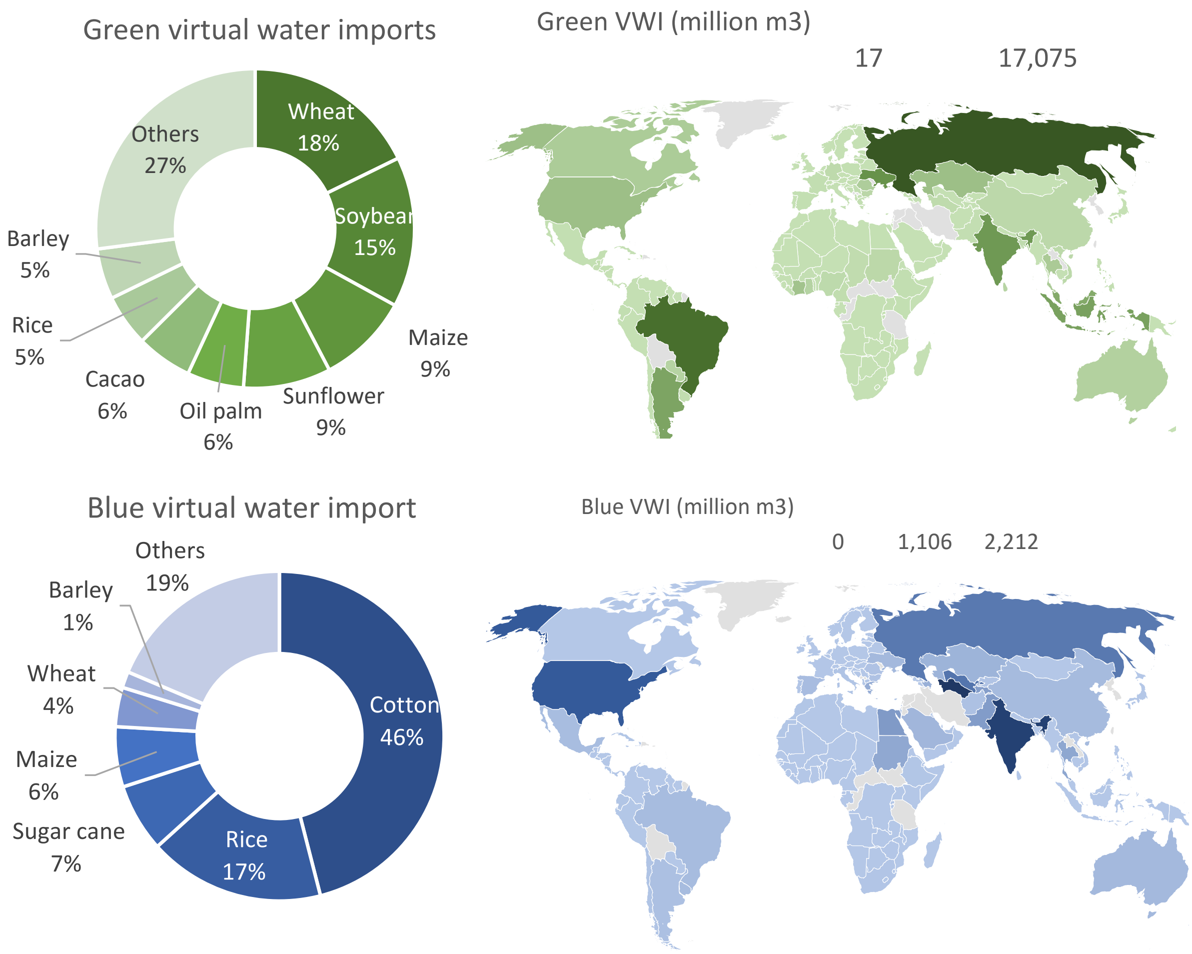


*Figure 12. Percentage breakdown of virtual water import (VWI) for each crop and per origin of country in relation to the total green and blue virtual water imports (upper figure green, bottom figure for blue) .*

The breakdown of crops for blue virtual water imports is as follows: cotton accounts for the highest share at 46%, followed by rice at 17%, sugar cane at 7%, maize at 6%, wheat at 4%, and barley at 2%. In terms of country shares, Turkmenistan (cotton) leads with 20%, trailed by India (rice, sugar cane, cotton) at 17%, the USA (cotton, rice, almond) at 10%, Uzbekistan (cotton) and Russia at 7% each, and Pakistan (cotton, rice) at 4% (Figure 12, bottom left and right).

The region annually exports a combined total of 10 billion m$^3$ of green water and 5 billion m$^3$ of blue water embedded in its exported goods to destinations outside the region. The breakdown of green virtual water exports shares for various crops is as follows: wheat dominates with the largest portion at 32%, trailed by hazelnuts at 19%, olives at 11%, grapes at 6%, dates at 5%, pistachios at 4%, while sunflower and cotton each contribute 2%. The destinations are as follows: Italy takes the lead with 9% (hazelnuts, pistachios, olives), succeeded by Germany (hazelnuts, grapes) at 6%, the United Arab Emirates (dates, olives) at 5%, and the USA (olives, maize), Saudi Arabia (olives, wheat), and India (dates) (Figure 13, top figures).

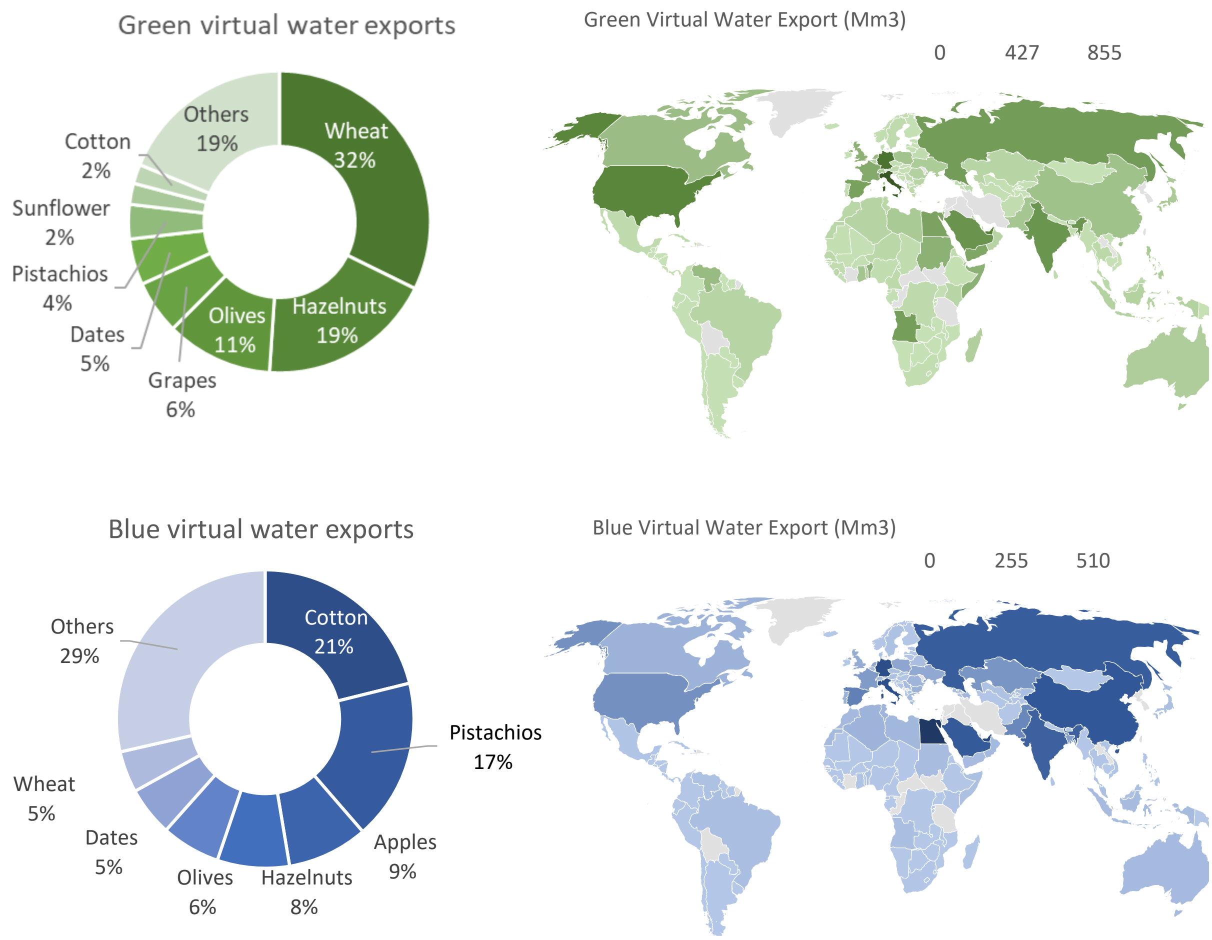


*Figure 13. Percentage breakdown of virtual water export for each crop and per country in relation to the total green and blue virtual water exports. (upper figure green, bottom figure for blue)*

The distribution of blue virtual water exports per crop highlights distinct contributions, with cotton commanding the highest share at 21%, followed by pistachios at 17%, apples at 9%, hazelnuts at 8%, olives at 6%, dates at 5%, and wheat also at 5%. The destinations are: Egypt (apple, cotton) in the lead at 11%, followed by the United Arab Emirates at 8% (pistachios), Germany (cotton, pistachios) at 7%, and Italy (cotton, hazelnut), the Russian Federation (pistachios, tangerines), Saudi Arabia (olives, pistachios), China (pistachios, cotton), and India (pistachios, dates), (Figure 13, bottom figures).

### 3.2.2 Virtual water trade among the countries in the region

The virtual water trade among the six countries is presented in Table 2. The columns indicate virtual water exports for each country, while the rows display the volume of virtual water imports. For instance, Türkiye's virtual water import (green) from Iran is 86 million $m^3$, and Türkiye's green virtual water export to Iran is 87 million $m^3$.

*Table 2. Virtual water imports and exports between six countries. The numbers show virtual water import by the reporting country and virtual water export by the partner country (in million $m^3$).*

| Reporting country | Partner country | | | | | |
|---|---|---|---|---|---|---|
| | Iran | Iraq | Jordan | Lebanon | Syria | Türkiye |
| **Green virtual water trade** | | | | | | |
| Iran | - | 0.4 | 2 | 0.6 | 5 | 87 |
| Iraq | 422 | - | 9 | 9 | 9 | 2,502 |
| Jordan | 5 | 3 | - | 4 | 25 | 28 |
| Lebanon | 11 | 4 | 1 | - | 49 | 80 |
| Syria | 17 | 5 | 7 | 7 | - | 643 |
| Türkiye | 86 | 3 | 0.6 | 0.8 | 356 | - |
| **Blue virtual water trade** | | | | | | |
| Iran | - | 0.1 | 0.2 | 0.6 | 4 | 33 |
| Iraq | 591 | - | 15 | 13 | 6 | 337 |
| Jordan | 13 | 0.2 | - | 8 | 38 | 8 |
| Lebanon | 35 | 3 | 0.5 | - | 42 | 14 |
| Syria | 18 | 0.2 | 5 | 13 | - | 121 |
| Türkiye | 155 | 1.4 | 0.2 | 0.3 | 362 | - |

**Iran:**

Iran emerges as importer of green virtual water, primarily relying on Türkiye for a volume of 87 million $m^3$, predominantly associated with the trade of olives and tobacco. This is followed by imports from Syria (5 million $m^3$), Jordan (2 million $m^3$), Iraq (0.4 million $m^3$), and Lebanon (0.6 million $m^3$). Olives constitute a major product linked to Iran's green virtual water imports from other countries in the region as well.

In the domain of blue virtual water imports, Türkiye stands out as the main contributor with a volume of 33 million $m^3$. Syria, Lebanon, Jordan, and Iraq play small roles in blue virtual water imports to Iran. Most of these imports are associated with cotton from Türkiye, olives from Syria and Jordan, and potatoes from Lebanon.

**Iraq:**

Iraq's green virtual water import relies on Türkiye for a volume of 2.5 billion $m^3$. This import is closely tied to essential crops such as wheat, maize, and barley. Other notable contributors to Iraq's green virtual water import include Iran (422 million $m^3$) with a focus on wheat and apples, Syria (9 million $m^3$) involving olives and wheat, Jordan (9 million $m^3$) with contributions from peaches, tobacco, and tangerines, and Lebanon (9 million $m^3$) featuring olives, oranges, and peaches.

In the domain of blue virtual water, Iraq exhibits a reliance on both Iran and Türkiye, importing volumes of 591 and 337 million $m^3$, respectively. Major crops associated with these imports include apples, pistachios, and wheat from Iran, and wheat, sunflower, and rice from Türkiye. Additionally, other contributors to Iraq's blue virtual water imports include Jordan (15 million $m^3$) involving peaches and tangerines, Lebanon (13 million $m^3$) featuring peaches and oranges, and Syria (6 million $m^3$) with contributions from olives and cotton.

**Jordan:**
Jordan's green virtual water trade prominently hinges on Türkiye, relying on a volume of 28 million $m^3$ import. This import is closely linked to essential crops such as wheat, chickpeas, and hazelnuts. Other contributors to Jordan's green virtual water import include Syria (25 million $m^3$) with a focus on barley and apples, Iran (5 million $m^3$) involving pistachios and grapes, Iraq (3 million $m^3$) with contributions from dates, and Lebanon (4 million $m^3$) featuring wheat.

In the blue virtual water trade, Jordan relies on Syria by importing large volumes of 38 million $m^3$ of blue water. Major crops associated with these imports include apples and anise seeds. Additionally, other contributors to Jordan's blue virtual water imports encompass Iran (13 million $m^3$) involving pistachios, Türkiye (8 million $m^3$) featuring cotton, and Lebanon (8 million $m^3$) related to potatoes and bananas.

**Lebanon:**
Türkiye stands out as a major contributor to the green virtual water import with 80 million $m^3$, with key products including wheat, sunflower, and hazelnut. Another partner is Syria, providing 49 million $m^3$ of green virtual water, with a focus on olives. Iran contributes 11 million $m^3$, primarily through the import of products such as pistachios. Jordan (3.5 million $m^3$ ) and Iraq (1. million $m^3$ ) also play roles in Lebanon's green virtual water import, with their contributions centred around crops like dates.

Turning to blue virtual water trade, Lebanon imports 42 million $m^3$ from Syria, primarily associated with olives, fruits, spices, and anise seed. From Iran and Türkiye, Lebanon imports 35 and 14 million $m^3$ of blue virtual water, respectively, with products such as pistachios from Iran and cotton, sunflower, and wheat from Türkiye. Additionally, Lebanon imports 3 million $m^3$ of blue virtual water from Iraq and 0.5 million $m^3$ from Jordan, featuring contributions related to fruits (Iraq) and tomatoes (Jordan).

**Syria:**
In terms of green virtual water import, Türkiye emerges as a significant contributor, providing Syria with 643 million $m^3$ of green water. This import is associated with various crops, including wheat, sunflower, barley, and chickpeas. Additionally, Syria imports green virtual water from Iran (17 million $m^3$ ) with a focus on pistachios and wheat, Jordan (7 million $m^3$) involving barley and apples, Iraq (5 million $m^3$ ) with contributions related to wheat, and Jordan and Lebanon (round 7 million $m^3$, each) featuring wheat and bananas.

Turning to the blue virtual water import, Türkiye is a major contributor as well, providing Syria with 121 million $m^3$ of blue water import related to rice, maize, sunflower, and cotton. This is followed by Iran, with million $m^3$ related to pistachios, wheat, and dates. Additionally, Syria imports blue virtual water from Lebanon (13 million $m^3$ ), featuring contributions related to bananas and potatoes, and from Jordan (5.4 million $m^3$ ), with notable crops including wheat and tomatoes.

**Türkiye:**

Regarding green virtual water trade, Türkiye plays a dual role as both an importer and an exporter. Türkiye imports green virtual water from Syria (356 million $m^3$ ) – olives; Iran (86 million $m^3$ ) – wheat, pistachios, dates; Iraq (3 million $m^3$ ) -dates; and Jordan (0.6 million $m^3$ ) - wheat.

Turning to the blue virtual water trade, Türkiye imports 362 million $m^3$ from Syria, primarily associated with cotton and olives. From Iran, Türkiye imports 155 million $m^3$ of blue virtual water, with products such as pistachios, dates, and apples. Additionally, Türkiye imports 1.4 million $m^3$ of blue virtual water from Iraq and 0.3 million $m^3$ from Lebanon, featuring contributions related to wheat (Iraq) and potatoes.

## 3.3 Water footprint of consumption

Figure 14 provides a per capita perspective on the water footprint of crop consumption, outlining the volumes of green water, blue water, and grey water footprint related to its citizen's yearly food consumption for countries in the region, measured in litres. Türkiye exhibits the largest water footprint of crop consumption per capita in the region, amounting to 1542 litres. Most of this footprint, 78%, is attributed to green water, while 14% is from blue water sources. Iran follows with the second-largest water footprint per capita at 1527 litres, with 56% derived from green water and 35% from blue water. Syria, Lebanon, and Iraq's water footprints of consumption per capita are at 1010, 950, and 880 litres, respectively. In Syria and Lebanon, green water dominates, while in Iraq, blue water holds a larger share. Jordan's water footprint of consumption is 745 litres, primarily associated with green water.

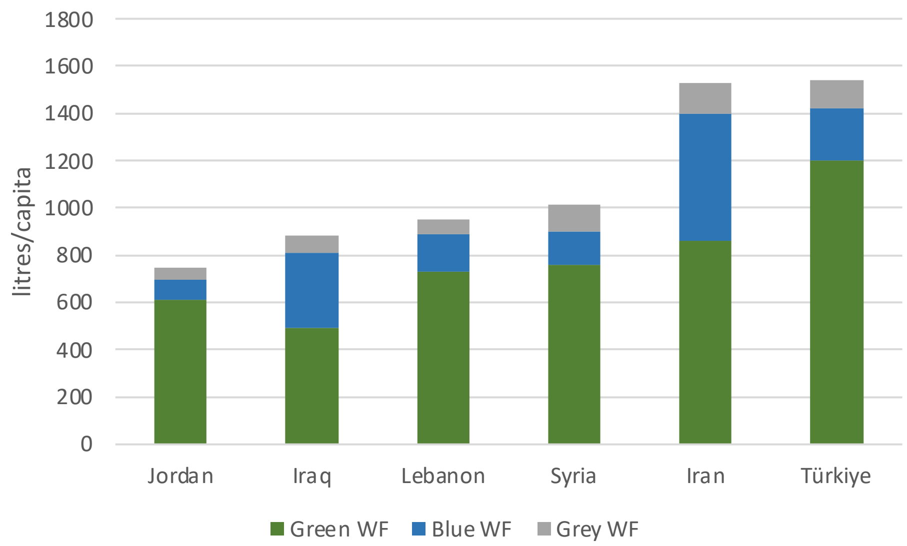


*Figure 14. The water footprint of consumption per capita, in litres, related to crop products.*

## 3.4 Water dependencies to other countries

The following data highlights the diverse landscape of water resource dependencies in the Middle East, shedding light on the percentage of domestically supplied water footprint of consumption for various countries. Iran demonstrates a significant level of self-sufficiency, with 74% of its consumption-related water footprint being produced domestically. Iraq follows closely, with almost half (49%) of its water footprint sourced within its borders. Jordan, on the other hand, is heavily reliant on external sources, with only 13% of its consumption-related water footprint being supplied domestically. Lebanon's water dependency is also notable, as 69% of its consumption-related water footprint comes from abroad. In stark contrast, Syria exhibits a high level of self-sufficiency, with 95% of its water footprint of consumption being domestically supplied. Türkiye relies on external sources for 28% of its consumption-related water footprint, while domestically supplying 72%.

### 3.4.1 Crop water dependencies

Table 3 offers a detailed perspective on water dependency ratios for essential crops across selected Middle Eastern nations. Jordan stands out with all crops, including wheat (94%), barley (87%), and cotton (100%), displaying complete reliance on external water sources, emphasizing potential challenges in sustaining agricultural production. Iraq demonstrates diverse dependencies, with cotton (97%) and sunflower (99%) heavily dependent on external water, while wheat (35%) and barley (3%) maintain a more balanced mix. Lebanon's agricultural sector exhibits a significant reliance on external water, particularly for crops like cotton (100%) and rice (100%). Iran generally maintains lower water dependency ratios across crops, indicating a more self-sufficient approach to agricultural water management. Syria displays mixed dependencies, while Türkiye showcases varying degrees of reliance, with cotton (83%) and sunflower (71%) relying more on external water sources compared to other crops.

*Table 3.External water dependency ratios to other countries, per crop – key crops, in % of the total water demand of the crop addressed (green and blue).*

| | Wheat | Barley | Cotton | Rice | Sunflower | Maize |
|---|---|---|---|---|---|---|
| Iran | 8 | 40 | 82 | 38 | 83 | 86 |
| Iraq | 35 | 3 | 97 | 72 | 99 | 45 |
| Jordan | 94 | 87 | 100 | 100 | 100 | 100 |
| Lebanon | 84 | 69 | 100 | 100 | 100 | 99 |
| Syria | 14 | 3 | 27 | 100 | 95 | 45 |
| Türkiye | 21 | 9 | 83 | 49 | 71 | 40 |

## 3.5 Water use in crops for export purposes

Table 4 provides insights into the percentage of water use dedicated to the cultivation of specific crops for export purposes in several Middle Eastern countries. In Iran, water for export in cotton and pistachios account for 16% and 37%, respectively. Iraq directs 32% of its water resources to cotton production for export. Jordan allocates 8% of its water use to olives, Lebanon designates 22% to olives, and Syria utilizes 27% and 34% for olives and cotton, respectively, intended for export. In Türkiye, hazelnuts dominate water use for export at 55%, with cotton and pistachios requiring 29% and 20%, respectively.

*Table 4. Percentage of domestic water use (green and blue) that is used for export purposes per crop per country (for selected crops)*

| | Olives | Cotton | Hazelnut | Pistachios |
|---|---|---|---|---|
| Iran | 0 | 16 | 0 | 37 |
| Iraq | 32 | 0 | - | |
| Jordan | 8 | - | - | - |
| Lebanon | 22 | - | - | - |
| Syria | 27 | 34 | - | - |
| Türkiye | 20 | 29 | 55 | 20 |

# 4 Key insights

This comprehensive study delves into the intricate water dynamics of six Middle Eastern countries: Iran, Iraq, Lebanon, Jordan, Syria, and Türkiye. Focusing on green and blue water use, key crops, virtual water trade, and external dependencies, the study provides valuable insights into the region's water sustainability, food security, and economic resilience. The following insights can be considered key outcomes of this study:

***Agriculture and Energy Dominate Regional Water Use***

- Agriculture in the region consumes approximately 224 $km^3$, which is equivalent to around three times the annual discharge volume of the Euphrates and Tigris River basins.
- Agriculture relies heavily on rainfall, constituting approximately 60% of the total use and demonstrating sensitivity to shifts in rainfall patterns. This is particularly true for vital food crops in the region, such as wheat, barley, maize, and sunflowers. Consequently, the area's food security is vulnerable to drought risks. Economy-driven crops, including hazelnuts and olives, also extensively depend on green water.
- The green water use in the region is predominantly driven by Türkiye, holding the largest share, mainly associated with wheat and hazelnut production. The first is the source of food, the latter is an export crop and an important income in the north part of the country.
- The significant reliance on green water use for production activities highlights vulnerability to drought conditions. Regional droughts have the potential to considerably impact the region's economy. Therefore, conducting a comprehensive assessment of drought severity in the region, considering both extreme cases and the influence of climate change, would be beneficial for future planning and resilience strategies.
- Annual blue water use in the region totals around 88 $km^3$, exceeding the combined annual discharge volume of the Euphrates and Tigris River basins. This consumption is primarily driven by agriculture and energy needs. Agriculture, particularly linked to crops like wheat, cotton, and rice, as well as energy use associated with natural gas and oil production, significantly contribute to this water footprint. Iran emerges as the leading contributor to the blue water footprint in both agriculture and energy sectors.
- Crops with a large water footprint in the region are wheat, barley, cotton, pistachio, olive, rice, maize, apple, and sunflower.

***Significant Water Losses: Challenges in Irrigation Systems and Management***

- The total blue water use for agriculture is 72 km3, yet the total water withdrawn for agriculture is nearly three times higher than the actual consumption, reaching approximately 200 $km^3$. This substantial difference could be attributed to water losses through irrigation systems or inadequate water management practices.

***Iran and Türkiye: Dominant Factors in Regional Water Use and The Source of Food Supply***

- These two countries are the primary hubs for agricultural production, collectively accounting for over 80% of the total water use in the region. They play a crucial role in producing the majority of the food and feed for the area.
- Water productivity contrast: Türkiye shows high water productivity in agriculture driven by rainfall, whereas Iran faces challenges with low water productivity, heavily relying on irrigation.
- Iran's significant blue water footprint is driven by wheat, rice, and pistachios, while Türkiye's includes cotton, wheat, sugar beet, and maize.
- While Iran's water use is domestic consumption driven, Türkiye is the largest virtual water exporter in the region, providing significant volumes of green and blue virtual water to all other five countries. These exports are primarily related to wheat and cotton.
- Iran's major blue water consumption is attributed to the oil and natural gas industry, while in Türkiye, it predominantly arises from hydropower, distinct from agricultural use.

***Iraq and Syria: Significant Local Blue Water Use Yet Reliant on External Water Resources***

- Iraq stands as the third-largest water user in the region, with Syria following closely behind. The Euphrates and Tigris rivers, shared with Türkiye, serve as the primary sources of blue water for Iraq and the Euphrates for Syria.
- Iraq's water consumption is predominantly driven by blue water use, while Syria relies heavily on rainfed sources.
- In Syria, green water use is associated with crops like wheat, barley, and olives, while blue water is linked to these products and cotton. Contrarily, in Iraq, the majority of blue water use is attributed to wheat cultivation, a crop primarily reliant on rainfed practices in Syria.
- Iraq exhibits a dependency of around 46% on external water resources, while Syria's dependency is comparatively lower at around 22%. Iraq relies significantly on external water sources for crops like wheat, cotton, sunflower, and maize. Similarly, Syria demonstrates high dependency on the latter two crops as well.
- Iraq's virtual water imports are primarily associated with wheat (sourced from Türkiye and Russia) and rice. This underscores Iraq's high dependence on other countries for its staple food supply.

***Lebanon and Jordan: Low Water Availability, High External Dependency***

- Both Lebanon and Jordan exhibit significant external dependency on water resources, with approximately 72% in Lebanon and 89% in Jordan.
- This external dependency extends to all food supply crops in the region, including wheat, barley, sunflower, maize, and others.
- Jordan and Lebanon are majorly reliant on green water imports, particularly related to wheat, barley, maize, and rice, while their blue water imports are associated with these cereal crops as well. This signifies a significant dependence on external sources for water-intensive agricultural products.

***Regional Water Demand Outstrips Local Supply, Significantly Externalized***

- Regional water demand stands at approximately 382 $km^3$, covering both internal consumption and export activities. The majority, about 70%, is sourced from local water resources, with the remaining 30% fulfilled through virtual water imports.
- Jordan and Lebanon exhibit the highest external dependency for their water demand, reaching 90% and 72%, respectively. In contrast, Syria has the lowest external dependency at around 18%. However, it's important to note that this discrepancy in Syria's data could potentially be attributed to issues with the availability of production and trade data during the analysis period.
- Approximately 85% of this water demand is allocated for internal consumption, while the remaining 15% is directed towards agri-food export-related activities.
- The water footprint of consumption, representing the water needed for citizens' consumption of goods and services such as food, energy, and water supply, is approximately 1400 liters per capita. In Türkiye and Iran, this per capita water volume is higher, around 1600 liters, while in Jordan and Iraq, it is lower, around 1000 liters.

***Food security and economy is highly dependent on external water resources.***

- The water footprint of production exhibits minimal year-to-year fluctuations, even as the population in the region has significantly increased over the last decade. While production levels remain constant, these six countries have substantially heightened their external dependency on water resources. This is particularly notable in relation to food security crops such as wheat, barley, and feed products like soybean and maize.
- The region's food security is reliant on wheat imports, primarily sourced from Russia and Ukraine. In Jordan, this external water dependency is as high as 97%, while in Lebanon, it stands at 84%, and in other countries, it is less than 20%.
- Another food staple, rice, exhibits even greater dependence on external water resources. The lowest dependency is in Iran, around 35%, while in Türkiye, it is 50%, and as high as 100% in Lebanon and Jordan.
- This holds true for sunflower and maize as well, with external water dependency to third countries in the total demand ranging from higher than 70% (i.e. Türkiye) in each country, up to 100% (Iraq, Jordan, Lebanon) in sunflower and maize, falling between 40-100%. It's important to note that these two crops are crucial feed supplies, contributing significantly to protein intake in the region.
- The textile industry is a vital component of Türkiye's economy and industrial landscape. However, a key consideration is its heavy reliance on external water resources for its primary raw material, cotton. Approximately 83% of Türkiye's total demand for cotton is sourced from water beyond its national borders.
- Russia, Ukraine, Central Asia, the USA, and India play pivotal roles as key partners for this region in terms of food security and economic growth. Any climatic shock, such as a severe drought, has the potential to jeopardize the region's livelihood and stability.
- Feed supply is becoming more externalized, exemplified by the recent surge in soybean imports. This trend underscores a growing dependence on external water resources, particularly those situated in South America.

***Water use for Export Industry***

- Water use for export is primarily associated with crops like wheat, olives, hazelnuts, cotton, and pistachios. Specifically, wheat, hazelnuts, and cotton are linked to Türkiye, olives to both Türkiye and Syria, and pistachios to Iran.

***Incomplete Water and Trade Data in Iran, Iraq, and Syria***

- The availability and accuracy of water and trade data are crucial for understanding and managing water resources effectively. However, it is noted that the data for both water use and trade is incomplete in the regions of Iran, Iraq, and Syria. This data gap poses challenges in comprehensively assessing the water footprint, trade dependencies, and their implications for these countries. A more thorough and accurate collection of water and trade data is essential for informed decision-making, sustainable resource management, and addressing potential challenges related to water scarcity and trade dependencies in these regions.

# 5 A way forward

This study represents a comprehensive and up-to-date analysis of the water footprint in the Middle East region, providing insights into water use and dependencies. To complement this work, a few follow-up studies are recommended:

**Water Footprint per Shared River Basin:**
Conduct analyses focused on water footprints within shared river basins such as the Euphrates and Tigris. This approach would yield valuable information regarding transboundary water issues and the productivity of water resources for various countries within the same basin. Additionally, it could establish a scientific foundation for discussions and negotiations concerning water allocation among these critical rivers.

**Future Water Risk and Impact Assessment:**
Explore changes in drought patterns and identify water risks associated with future conditions, including climate change, fluctuations in food supply, and population growth. Understanding the impacts of droughts, extreme heat events, and water scarcity under climate change scenarios can serve as crucial indicators of potential challenges in the region. Such analyses could further catalyse discussions on effective strategies for allocating scarce water resources among different sectors and crops, fostering proactive measures to address emerging water-related issues.

Furthermore, it is recommended that future studies include impact assessments of water use and pollution on the environment and biodiversity. This would contribute valuable insights to our understanding of the broader ecological consequences associated with water-related activities.

**Scenario Analysis for Optimal Water Footprint:**
Conduct a scenario analysis to determine which adaptation strategies lead to the lowest water footprint of production. This should include an exploration of water productivity enhancements, technological advancements, self-sufficiency measures, and the impact of trade liberalization. Evaluating various scenarios will provide valuable insights into the most effective strategies for minimizing water footprints in agricultural production, contributing to sustainable water management in the region.

**Cross-Border Climate Risk Assessment:**
Investigate the cross-border climate risks in the region, considering its high dependence on external resources. Even countries like Türkiye are increasingly relying on water resources beyond their borders. Assess and quantify the risks associated with drought, climate change, and water extraction at the cross-border level. Understanding these interdependencies will provide crucial insights for developing strategies to mitigate climate-related risks and enhance regional resilience in the face of changing environmental conditions.

# 6 Key recommendations

As highlighted by key insights into regional water use patterns, agriculture and energy consumption emerge as dominant players, demanding urgent attention for sustainable water management strategies in the region. In response to these challenges, we present a set of comprehensive policy and in-house implementation recommendations aimed at fostering resilient, efficient, and responsible water use in the Middle East.

1. Comprehensive Drought Assessment and Early Warning Systems: Conduct a thorough and ongoing assessment of drought severity in the region, considering both extreme cases and the influence of climate change. This assessment should inform future planning and resilience strategies, especially for the vulnerable agriculture sector. Considering the importance of early warning systems for drought mitigation, we recommend implementing a robust and integrated Early Warning Drought System (EWDS) tailored to the specific needs and conditions of the region.

2. Irrigation System Efficiency Policies: Implement policies to enhance the efficiency of irrigation systems, addressing significant water losses in agriculture. Promote the use of modern and water-efficient irrigation technologies to minimize water waste.

3. Diversification of Agriculture: Encourage the diversification of crops, promoting those with higher water productivity under local conditions. Consider introducing incentives for crops that are less water-intensive and more resilient to climate variations.

4. Capacity Building for Farmers: Develop and implement training programs to strengthen the capacity of farmers, focusing on efficient water management practices and climate change adaptation. This should include education on improved irrigation techniques and sustainable farming practices.

5. Blue Water Footprint Reduction Targets: Set reduction targets for the blue water footprint in both agriculture and energy sectors. Establish regulations and incentives to encourage industries to adopt technologies and practices that minimize their impact on blue water resources.

6. Virtual Water Management: Develop policies to manage virtual water imports and exports efficiently. This includes understanding the dependencies on external water resources for specific crops and industries, and strategizing to minimize risks associated with such dependencies.

7. Enhanced Water Data Collection: Invest in improving the accuracy and completeness of water and trade data, especially in regions with data gaps like Iran, Iraq, and Syria. Strengthen data collection mechanisms to facilitate informed decision-making and sustainable resource management.

8. Water Pricing Mechanisms: Implement water pricing mechanisms that reflect the true value of water, encouraging more responsible use in both agriculture and energy production. This can help in reducing excessive water consumption and promoting water-efficient practices.

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# Appendix I: Method, data, and assumptions

## A1.1. Water footprint of production

### A1.1.1. Water footprint of crops

The water footprint analysis adheres to the methodology outlined by Hoekstra et al. (2011). Initial water footprint calculations for crops used the WaterPub database (WFN, 2023), covering the reference period from 1996 to 2005. To create an up-to-date database for the water footprint of crops from 2012 to 2021, a ratio-based approach was employed, accounting for changes in crop yield relative to the reference period. This methodology, detailed by Ercin et al. (2019), facilitated the establishment of the most recent water footprint volumes. Crop yields and production data were sourced from the Food and Agricultural Organization of the United Nations (FAOSTAT, 2023). The water footprints of 146 primary crops were calculated individually, considering green, blue, and total water footprints per country and year globally. The water footprint of crop production was calculated by multiplying the unit water footprint of crops by the annual production amounts per country.

### A1.1.2. Water footprint of industry and domestic water supply

Data on water use in industry and domestic water consumption were collected from AQUASTAT (FAO's Global Information System on Water and Agriculture) (AQUASTAT, 2023) to maintain consistency in data sources across all six countries. The most recent data for each country were selected as the reference year. For domestic water supply, the blue water footprint was 10% of the total water withdrawal, with the grey water footprint accounting for the remaining 90%. In the industrial sector, the blue-to-grey water footprint ratio was 5% to 95% of the total water withdrawal.

### A1.1.3. Water footprint of energy production

The total water footprint of energy production per year was calculated using data on total energy production per country obtained from the International Energy Agency (International Energy Agency, 2020). This data was then combined with information on the water footprint per unit of energy produced for each energy source.

Mekonnen et al. (2015) provided ranges of total water footprints per unit of energy production for various energy sources, with an upper and lower end. The average of these end values was selected as the water footprint per unit of energy produced for coal, natural gas, nuclear, oil, and 'wind, solar and others'. The water footprint of the 'wind, solar and others' energy source was taken as the average of 'photovoltaics' and 'wind.'

For hydro-energy, Hogeboom et al. (2018) estimated the water footprint per unit of energy produced in Türkiye and Iran. These values were used to estimate the water footprint of both countries. No data is provided for Iraq, Jordan, Lebanon, and Syria. Hence, it was assumed that the water footprint per unit of production of hydro-energy in those countries equals the average of the values provided for Türkiye and Iran.

Furthermore, the assumption was made that the total water footprint of energy production equals the blue water footprint. The exception is 'biofuels and waste,' for which the total water footprint per unit of energy produced was assumed to be zero. This is because biofuel in the region is primarily produced from manure and agricultural waste products, resulting in no significant water footprint directly attributable to biofuel production.

## A1.2. Virtual water trade

For the virtual water trade analysis, the conceptual methodological framework established by Hoekstra et al., 2011, and further refined by Ercin in 2019 was followed. Trade data for the period spanning from 2012 to 2022 was taken from UNComtrade (2023). This trade database was chosen due to its extensive coverage of agri-food trade, encompassing over 1500 crop-derived products. Additionally, it provides comprehensive datasets for all six countries involved in the project, offering material flow data in physical quantities and monetary terms, spanning from 1980 to 2022.

As reporting countries, the trade statistics for Iran, Iraq, and Syria were incomplete. To address this data gap, export data from partner countries was incorporated. While this approach enhances the completeness of datasets for the respective years and crops in these nations, the intra-trade among these three countries remained incomplete.

Moreover, the exports declared by reporting countries did not align with the declarations of partner countries. This discrepancy led to an imbalance in the calculated virtual water imports and exports when viewed from the perspectives of reporting countries and partner countries. In this analysis, only the reporting country perspective was considered.

Trade statistics served as input for a network model designed to estimate second-degree import and export locations. For instance, consider Iraq's wheat imports sourced from Türkiye, a nation that imports wheat from countries such as Russia, Mexico, and Germany. This designates Türkiye as an intermediary in the wheat trade between Iraq and these nations, prompting a more intricate, second-tier analysis. Additionally, Türkiye domestically produces its wheat. Consequently, when Iraq imports wheat from Türkiye, a segment originates from Türkiye's domestic production, while the remainder is sourced from countries Türkiye imports from. The allocation of Iraq's wheat imports between Türkiye's domestic production and its imports from other countries is determined by the proportion of Türkiye's domestic production to its total imports. As a result, the water footprint of Iraq's wheat imports is distributed among Türkiye, Russia, Mexico, and Germany according to this ratio.

# Appendix II: Country level analysis

Here, water availability overviews and WFA results are presented, structured according to the different countries.

## A2.1. Iran

### A2.1.1. Water availability overview

Iran has access to approximately 137 billion $m^3$ of renewable water resources per year. This translates into an amount of 1,632 $m^3$ per capita per year. Of this amount, the largest part is provided by surface water, as Iran has access to 105.8 billion $m^3$ of renewable surface water per year. Additionally, Iran has access to 49.3 billion $m^3$ of renewable groundwater per year (FAO, 2020). This means that out of the total renewable water resources, around 77% is provided by surface water, and 23% is provided by groundwater.

Iran has several large rivers, with the Karun River being the only navigable one due to the steep and irregular nature of the others. The Karun River, with an extensive length of 890 kilometres, flows through the southwestern region of the country, ultimately converging with the Shatt al-Arab. This watercourse is created by the confluence of the Euphrates and Tigris rivers in Iraq. The limited amount of streams that flow into the Central Plateau disperse into the saline marshes (FAO, 2008).

The yearly extraction of groundwater amounts to 63.8 billion $m^3$ (billion $m^3$), surpassing the total infiltration of 58 billion $m^3$. This leads to a national groundwater overexploitation of 5.6 billion $m^3$. Notably, a significant portion of this overexploitation is concentrated in the central basins, where surface water resources are comparatively scarce (Zekri, 2020).

Over the last half-century, Iran has experienced prolonged and severe droughts, posing a significant threat to water availability across various sectors. Iran's susceptibility to these climate-related challenges is influenced by increased water demands from a growing population and the agricultural sector. It is anticipated that climate change will further heighten the risk of droughts in certain regions of the country while causing floods in others. Furthermore, Iran has witnessed significant floods in recent history (Fanack Water, 2021).

### A2.1.2. The water footprint of production in Iran

The total water footprint of production in Iran, averaged between 2012 and 2021, is approximately 109 billion $m^3$ per year. Within this total, 40% is attributed to the green water footprint, which signifies rainwater utilization. The blue water footprint constitutes 46% of the total water footprint, indicating the use of ground and surface water resources in the region. The remaining 14% is related to the grey water footprint, representing the volume of water that is polluted (Figure A 1).

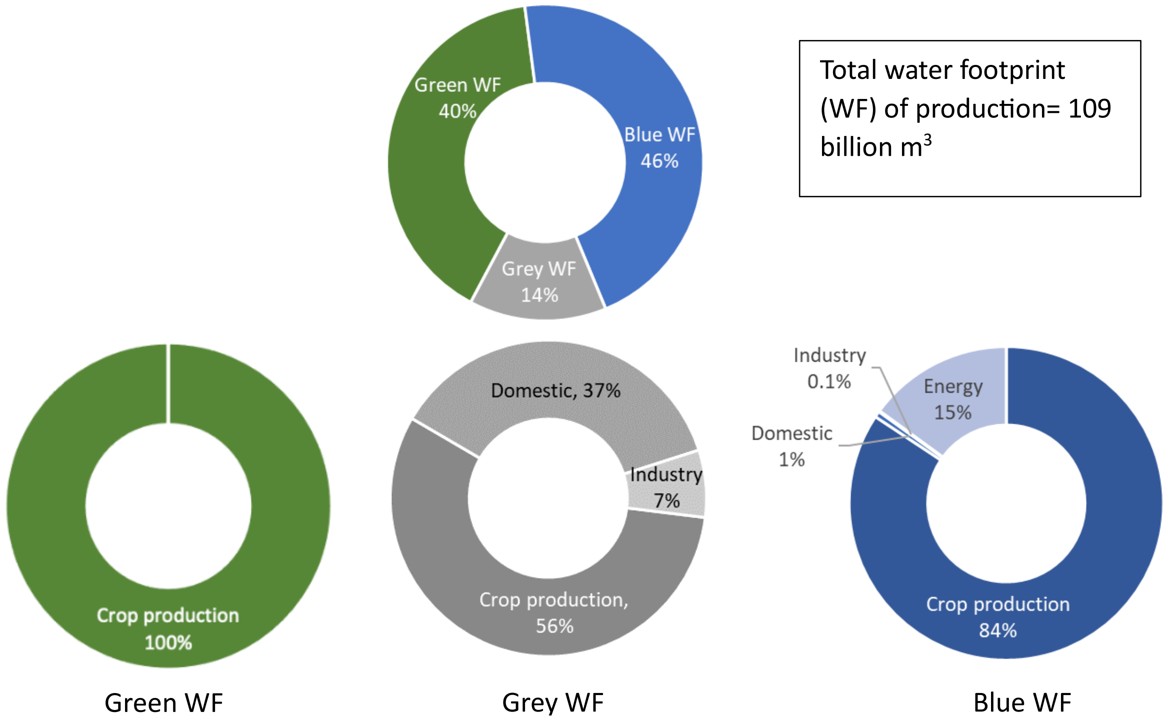


*Figure A 1: : Allocation of the water footprint (WF) components is illustrated in the upper figure, while the lower figures depict sectoral breakdowns (green WF on the left, grey WF in the middle, and blue WF on the right), all represented as a percentage of the total water footprint in Iran (for the average of 2012-2021).*

On an annual basis, the estimated water footprint of production in Iran has shown a decreasing trend between 2012 and 2022, with one particular spike in 2019. This is related to changes in production and crop yields.

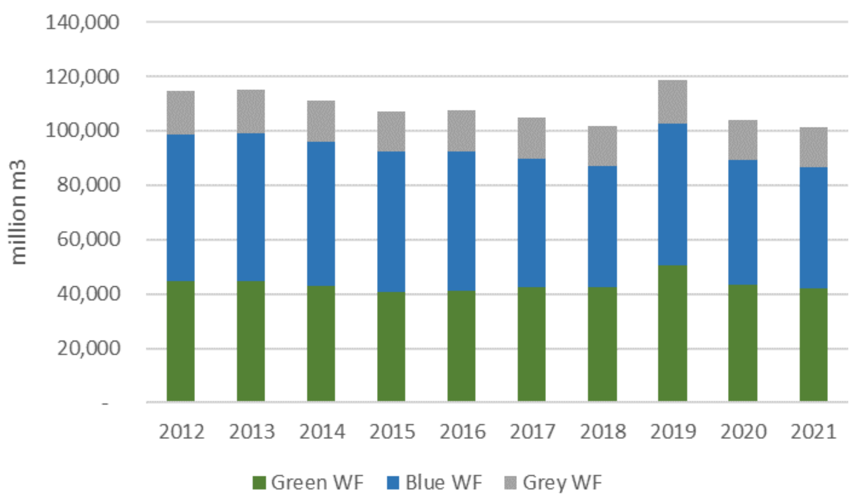


*Figure A 2: The water footprint (WF) of production in Iran per year between 2012 and 2021, per green, blue and grey components.*

## The water footprint of crop production in Iran

The water footprint of crop production is 44 billion m$^3$ annually (10-year average). Figure A 3 illustrates the yearly distribution of green, blue and grey water footprints across various crops, emphasizing the proportional contributions each crop makes to the overall footprint. Wheat has the largest share of the green, blue and grey water footprint, followed by Barley and Rice.

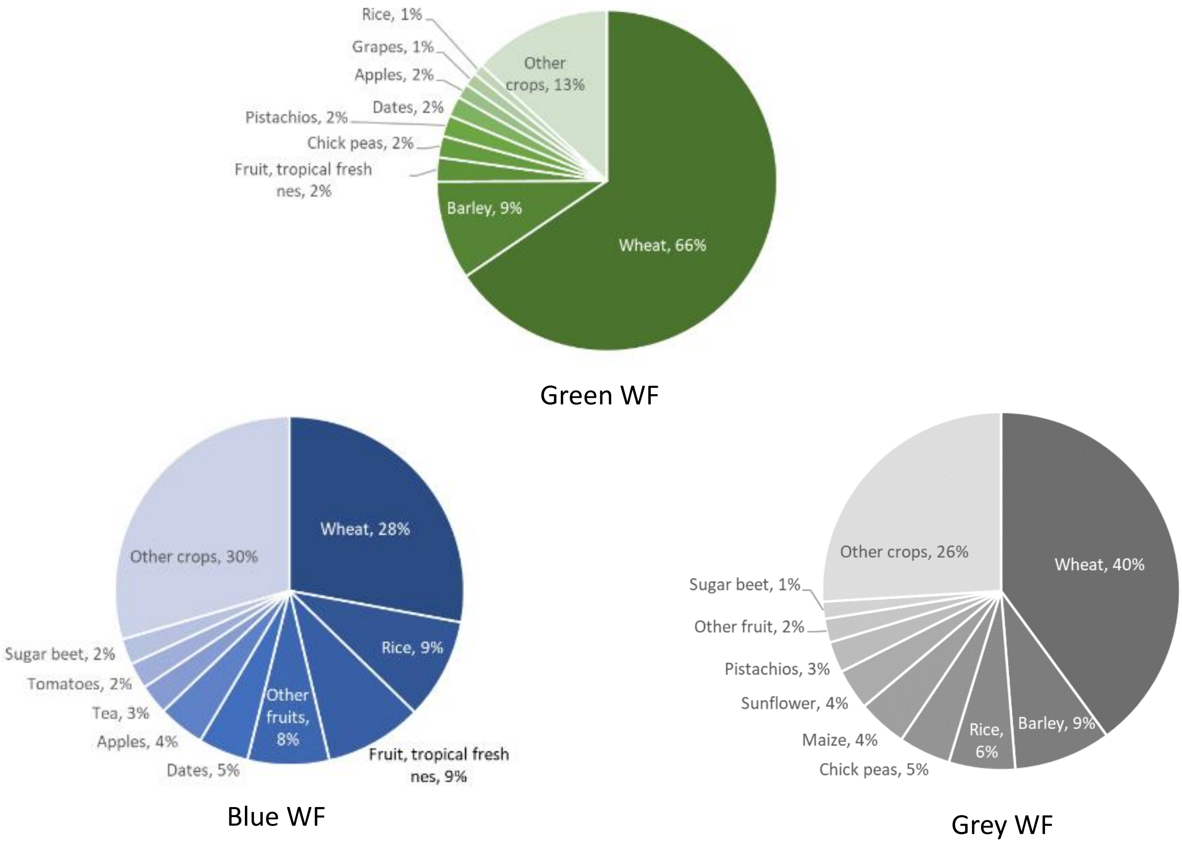


*Figure A 3: : Allocation of the water footprint (WF) components per crop (green WF on the top, blue WF on the bottom left, and grey WF on the bottom right), all represented as a percentage of the total of crop production in Iran (for the average of 2012-2021).*

## The water footprint of other sectors: industry, domestic water use and energy in Iran

In the industrial sector, the blue water footprint was calculated as 0.06 billion m³. The domestic water use sector, encompassing household and public water supply, exhibits a blue water footprint of 0.3 billion m³. The energy sector has a significant blue water footprint of 7.4 billion m³. The grey water footprints of the industry and domestic water use stand at 1 and 5.6 billion m³, respectively.

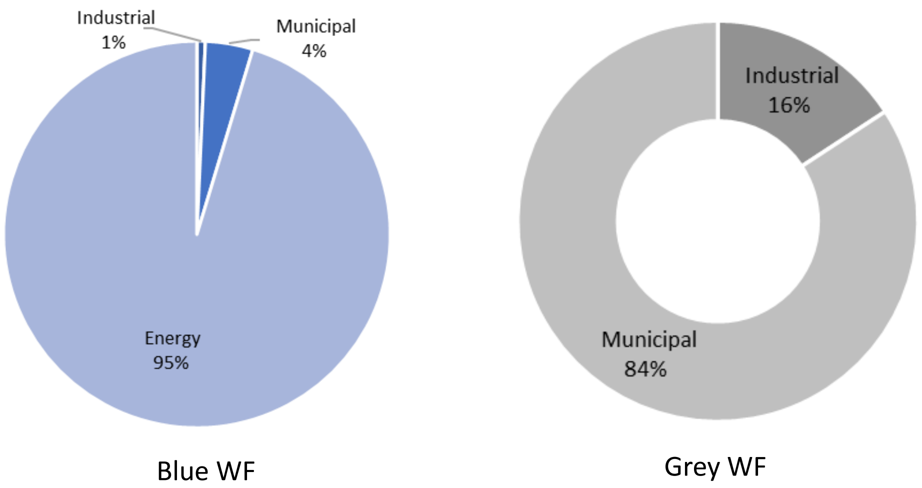


*Figure A 4: : Blue (on the left) and grey (on the right) water footprint allocation, represented as a percentage of total water footprint for industrial use, municipal use and energy production in Iran (for the average of 2012-2021).*

The percentages in Figure A 5 represent the distribution of various energy types within the blue water footprint of the energy sector. It can be seen that Natural Gas has the highest share in the total water footprint, with 69%, followed by Oil at 30% and Hydropower at 1%.

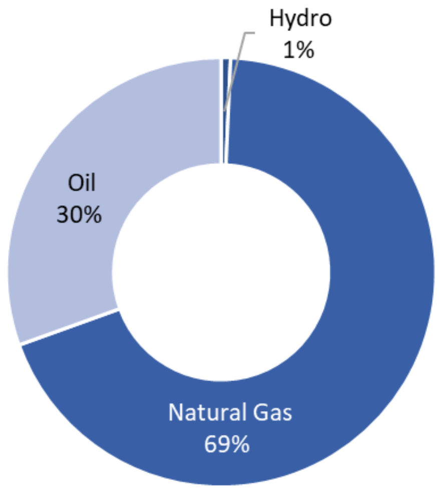


*Figure A 5: The blue water footprint of energy, shares of energy production type in Iran, in %.*

### A2.1.3. Virtual water trade of Iran

Iran annually imports 28.3 billion $m^3$ of green water and 2.2 billion $m^3$ of blue water in relation to import of agricultural products. Soybean claims the largest portion of green virtual water imports at 23%, trailed by maize (20%), wheat (10%), barley (10%), rice (7%), oil palm (6%), other nuts (6%), and sunflower (4%). Green virtual water imports are distributed among several countries, with Brazil taking the lead at 27%, followed by India at 12%, Russia at 9%, Kazakhstan at 9%, Indonesia at 8%, Argentina at 7%, Malaysia at 6% and Ukraine at 5% (Figure A 6, top left and right).

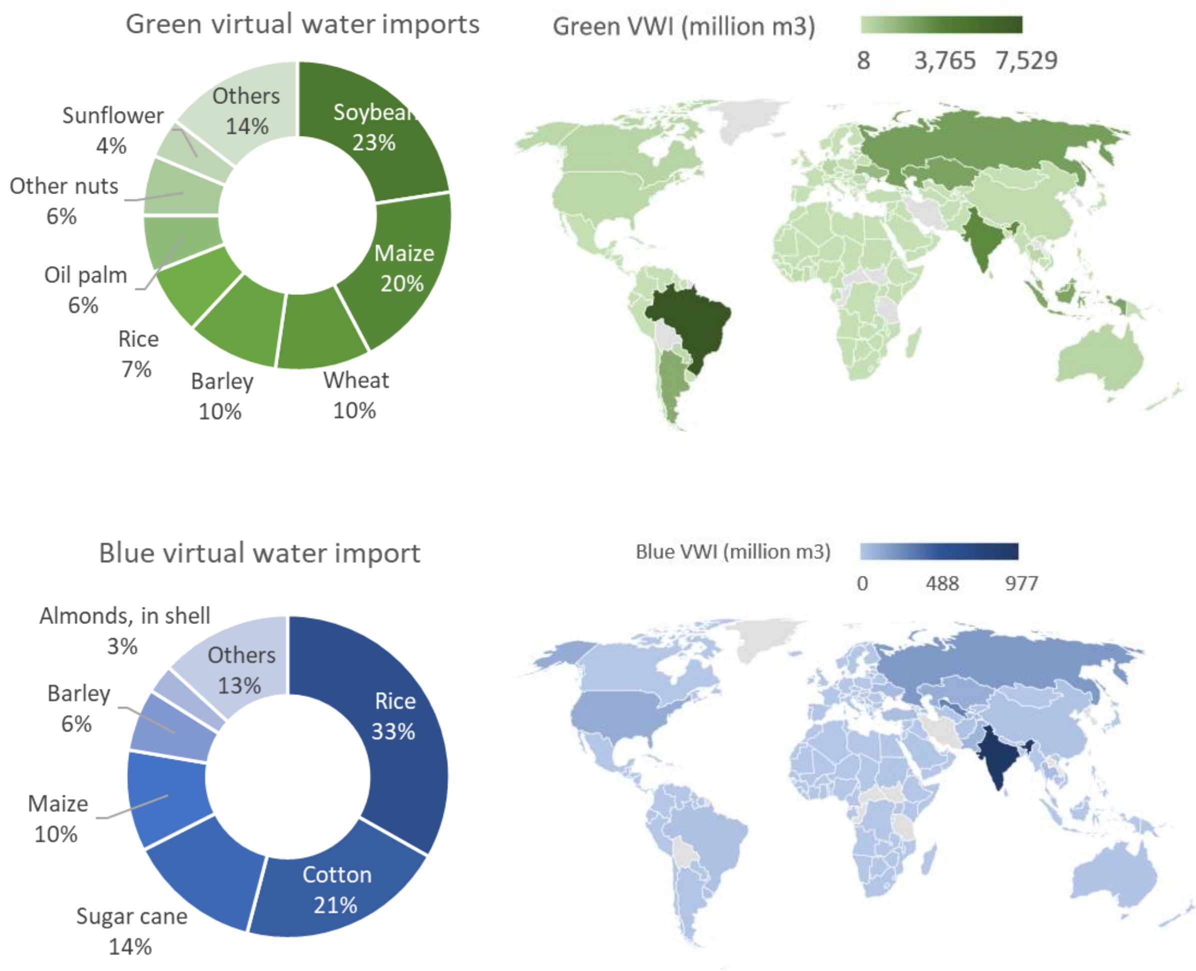


*Figure A 6: : Percentage breakdown of virtual water import (VWI) for each crop for Iran in relation to the total green and blue virtual water imports.*

The breakdown of crops for blue virtual water imports is as follows: rice accounts for the highest share at 33%, followed by cotton at 21%, sugar cane at 13%, maize at 10%, barley at 6%, and almonds at 3%.In terms of country shares, India leads with 45%, trailed by Uzbekistan at 13%, Russia at 9%, the USA and Kazakhstan at 5% each, and Tajikistan at 4% (Figure A 6, bottom left and right).

Iran annually exports a total of 0.9 billion $m^3$ of green water and 2 billion $m^3$ of blue water embedded in its exported goods. The breakdown of green virtual water export shares for various crops is as follows: Pistachios dominates with the largest portion at 36%, trailed by dates at 15%, grapes at 12%, wheat at 10%, chick peas at 6%, apples at 4%, watermelons at 3% and tea leaves at 1%. The destination of green virtual water exports is as follows: the United Arab Emirates take the lead with 13%, followed by Türkiye at 10%, Pakistan at 8%, India at 7%, China, Russia and Hong Kong at 6% each, Kazakhstan at 5%, and Oman and Germany at 4% each (Figure A 7, top figures).

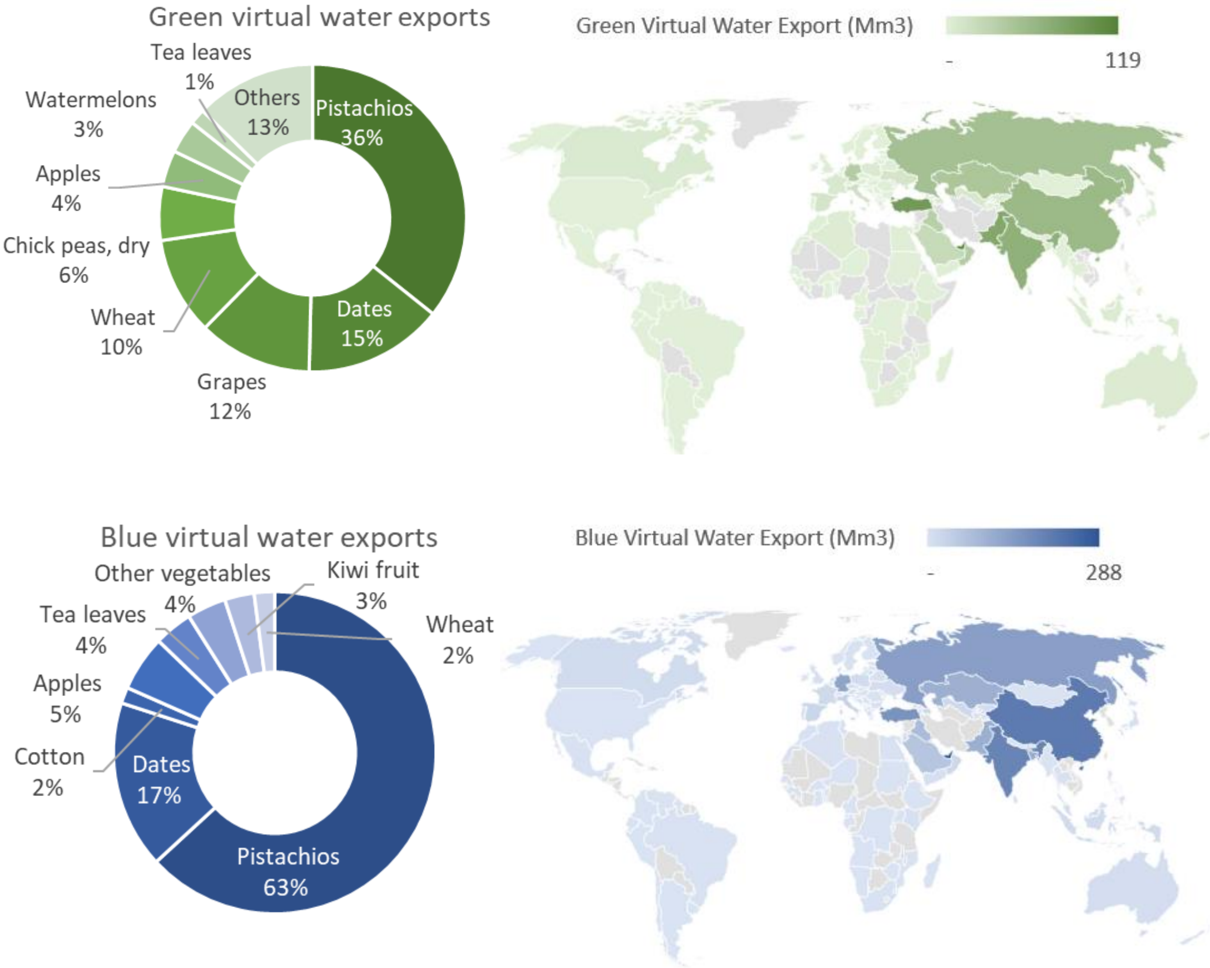


*Figure A 7: : Percentage breakdown of virtual water export for each crop for Iran in relation to the total green and blue virtual water exports.*

The distribution of blue virtual water exports per crop highlights distinct contributions, with Pistachios commanding the highest share at 63%, followed by dates at 17%, apples at 5%, tea leaves and other vegetables at 4% each, Kiwi fruit at 3% and wheat as well as cotton at 2%. Complementing this crop-specific breakdown, the corresponding country shares in blue virtual water exports depict the United Arab Emirates in the lead at 15%, followed by China and Hong Kong SAR at 11%, India at 10%, Türkiye at 8%, Russia at 7%, Germany and Bangladesh at 6%, Pakistan and Kazakhstan at 5% and Saudi Arabia at 3% (Figure A 7, bottom figures).

## A2.2. Iraq

### A2.2.1. Water availability overview

The most recent numbers indicate that Iraq has access to approximately 89.9 billion $m^3$ per year of renewable water resources, which equals to 2,286 $m^3$ per capita per year. By far the most important source is surface water, contributing a total of 88.6 billion $m^3$ per year (FAO, 2020). 96.5% of the renewable water resources is provided by surface water, and around 3.5% by groundwater (FAO, 2022).

The Tigris and Euphrates are the dominant rivers in Iraq, with their watersheds and tributaries accounting for 100% of the country's surface water. Both the Tigris and Euphrates main stems are transboundary rivers, originating in Türkiye. Prior to converging into the Shatt al-Arab, the Euphrates flows for approximately 1,000 kilometres, and the Tigris covers around 1,300 kilometres, within Iraq's borders.

The long-term annual flow of the Euphrates watershed was historically estimated to be 30 billion $m^3$ per year (billion $m^3$/yr), while the Tigris watershed, including its tributaries, was estimated to be 21.2 billion $m^3$/yr (Al-Ansari, 2021). As of 2021, the discharge at Baghdad of the Tigris River and its tributaries is estimated to be about 16 billion $m^3$ while it is about 4.4 billion $m^3$ in the Euphrates (Al-Ansari, 2021).

In terms of water quality, salinity and pollution from municipal, industrial, and agricultural activities are the two major challenges that Iraq currently faces. The expansion of agriculture has led to a progressive increase in the salinity levels of local rivers. Additionally, economic development and population growth contribute to higher loads of various contaminants (Khaleefa & Kamel, 2021). The deterioration in water quality is further exacerbated by droughts.

### A2.2.2. The water footprint of production in Iraq

The total water footprint of production in Iraq, averaged between 2012 and 2021, is approximately 25 billion $m^3$ per year. Within this total, 28% is attributed to the green water footprint, which signifies rainwater utilization. The blue water footprint constitutes 42% of the total water footprint, indicating the use of ground and surface water resources in the region. The remaining 30% is related to the grey water footprint, representing the volume of water that is polluted (Figure A 8)

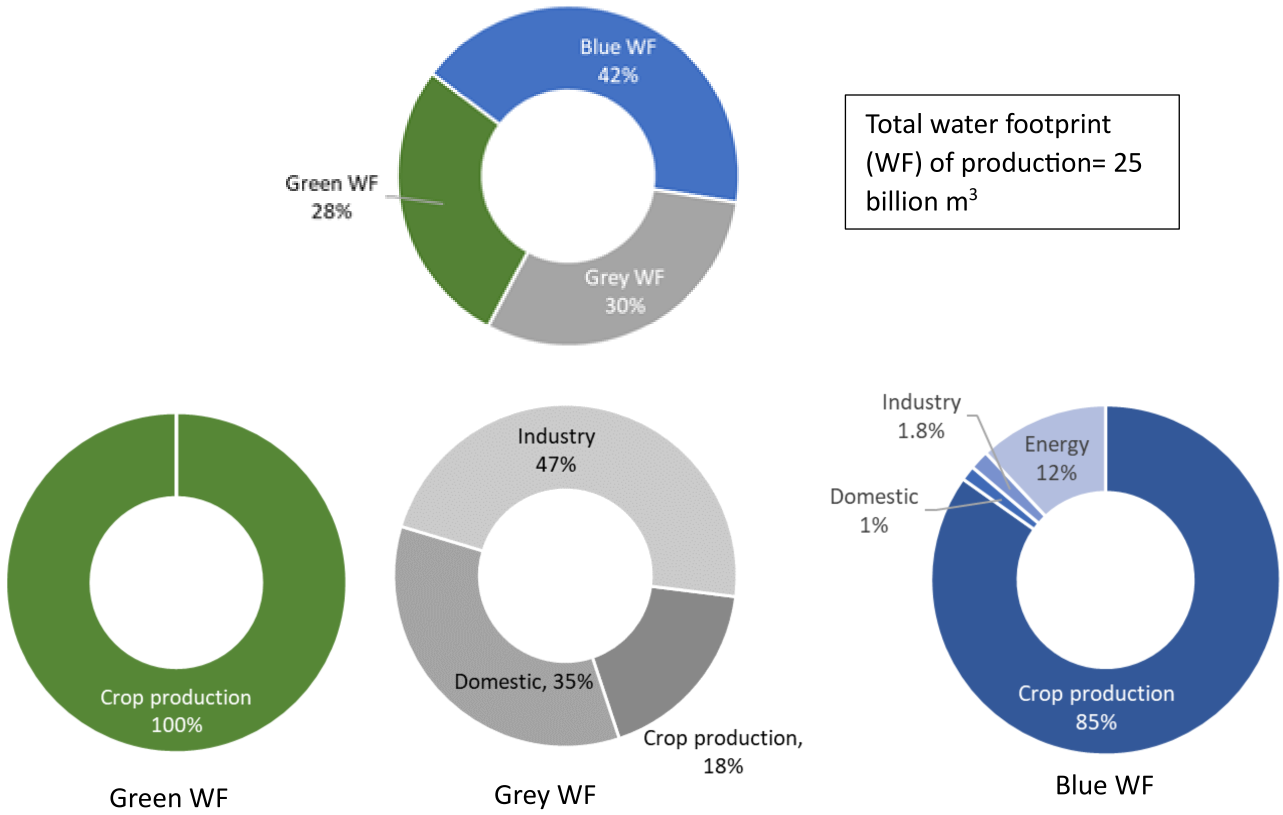


*Figure A 8: Allocation of the water footprint (WF) components is illustrated in the upper figure, while the lower figures depict sectoral breakdowns (green WF on the left, grey WF in the middle, and blue WF on the right), all represented as a percentage of the total water footprint in Iraq (for the average of 2012-2021).*

On an annual basis, the estimated water footprint of production in Iraq has shown significant fluctuation between 2012 and 2022. This reduction in Iraq's water footprint of production might be caused by reported droughts in the country during that period (Albarakat et al., 2022).

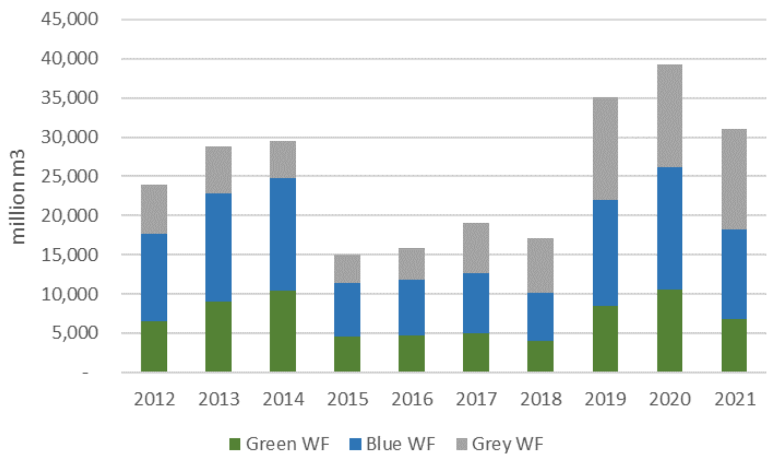


*Figure A 9: The water footprint (WF) of production in Iraq per year between 2012 and 2021, per green, blue and grey components.*

## The water footprint of crop production in Iraq

The total water footprint of crop production is 7 billion $m^3$ annually (10-year average). Figure A 10 illustrates the yearly distribution of green, blue and grey water footprints across various crops, emphasizing the proportional contributions each crop makes to the overall footprint. Wheat, barley and dates have the largest shares in the green water footprint, with 58%, 18% and 12% respectively. The largest share of blue water footprint is taken by wheat, barley, rice, maize and apples with 40%, 17%, 11%, 4% and 3% respectively. The largest share of grey water footprint is taken equally by wheat and maize at 20%, rice at 16%, dates at 14% and barley at 5%.

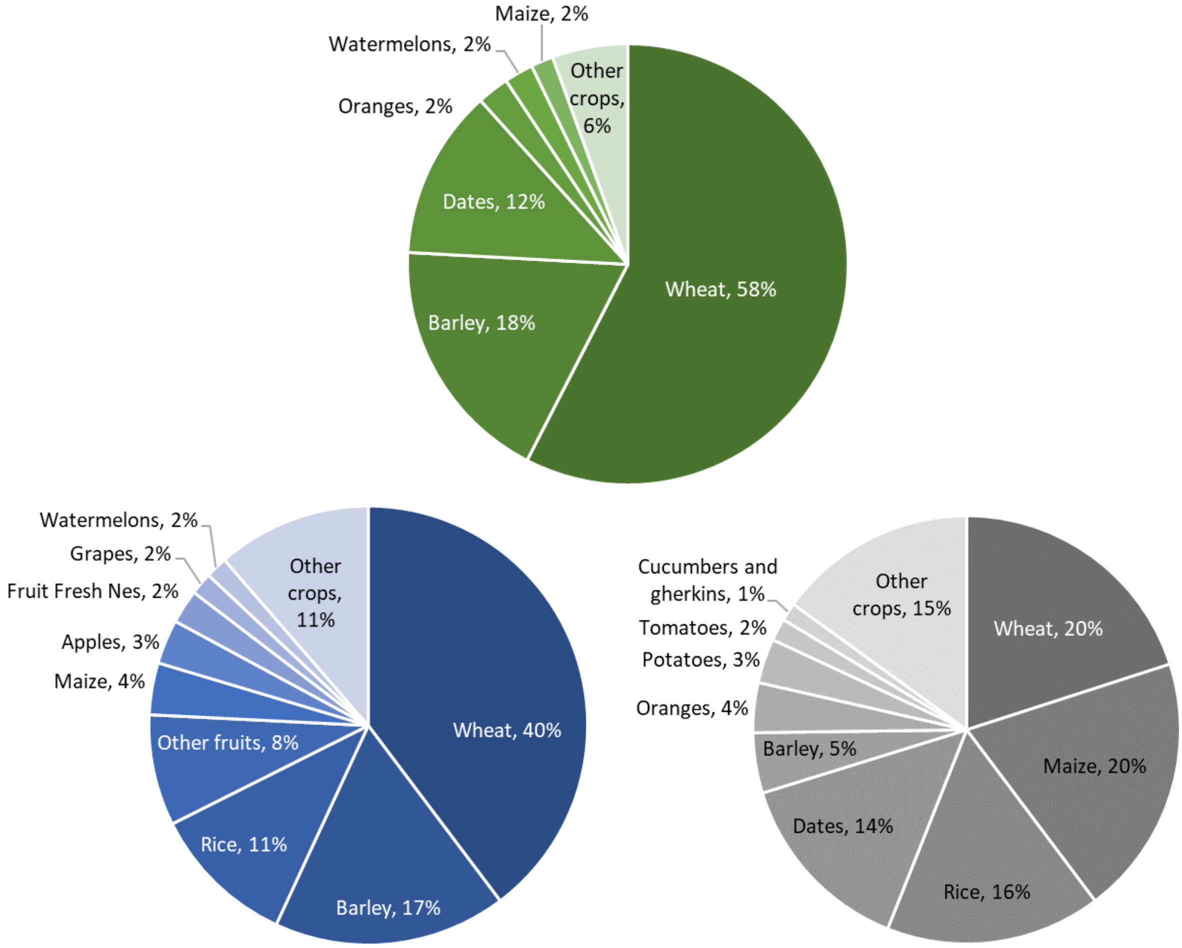


*Figure A 10: Allocation of the water footprint (WF) components per crop (green WF on the top, blue WF on the bottom left, and grey WF on the bottom right), all represented as a percentage of the total of crop production in Iran (for the average of 2012-2021).*

## The water footprint of other sectors: industry, domestic water use and energy in Iraq

In the industrial sector, the blue water footprint was calculated as 0.2 billion $m^3$. The domestic water use sector, encompassing household and public water supply, exhibits a blue water footprint of 0.1 billion $m^3$. The energy sector has a more significant blue water footprint of 1.3 billion $m^3$. The grey water footprints of the industry and domestic water use stand at 3.7 and 2.7 billion $m^3$.

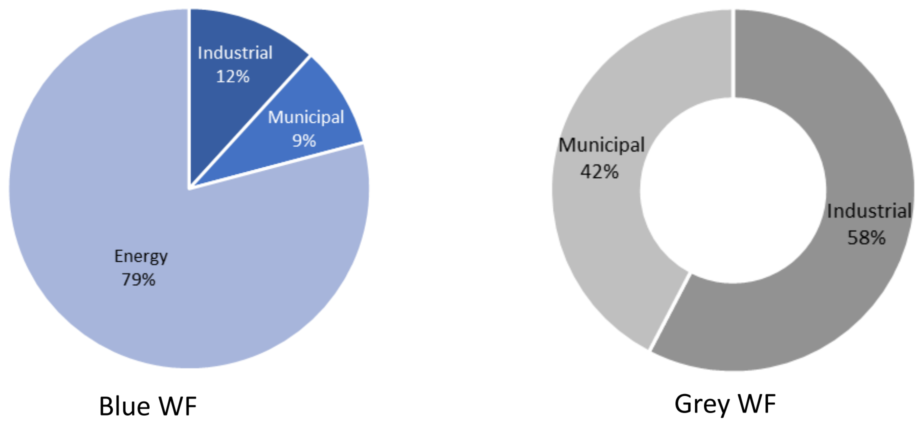


*Figure A 11: Blue (on the left) and grey (on the right) water footprint allocation, represented as a percentage of total water footprint for industrial use, municipal use and energy production in Iraq (for the average of 2012-2021).*

The percentages in Figure A 12 represent the distribution of various energy types within the blue water footprint of the energy sector. It can be seen that Oil has the largest share in the total water footprint, with 66%, followed by Natural Gas at 31% and Hydropower at 3%.

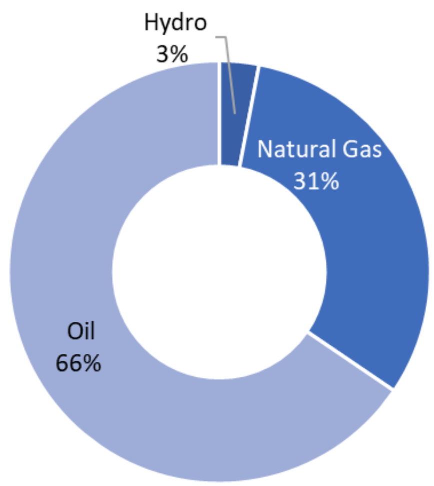


*Figure A 12: The blue water footprint of energy, shares of energy production type in Iraq.*

### A2.2.3. Virtual water trade of Iraq

Iraq annually imports 13.1 billion $m^3$ of green water and 2.2 billion $m^3$ of blue water in relation to import of agricultural products. Wheat claims the largest portion of green virtual water imports at 29%, trailed by rice (14%), sunflower (12%), sugar cane and cacao (each 7%), soy bean (6%), tea leaves (3%), and maize (3%). Green virtual water imports are distributed among several countries, with Türkiye taking the lead at 19%, followed by Russia at 9%, India and Brazil at 8%, Ukraine at 7%, Thailand and Australia at 6%, Argentina at 5% and Malaysia at 4% (Figure A 13, top left and right).

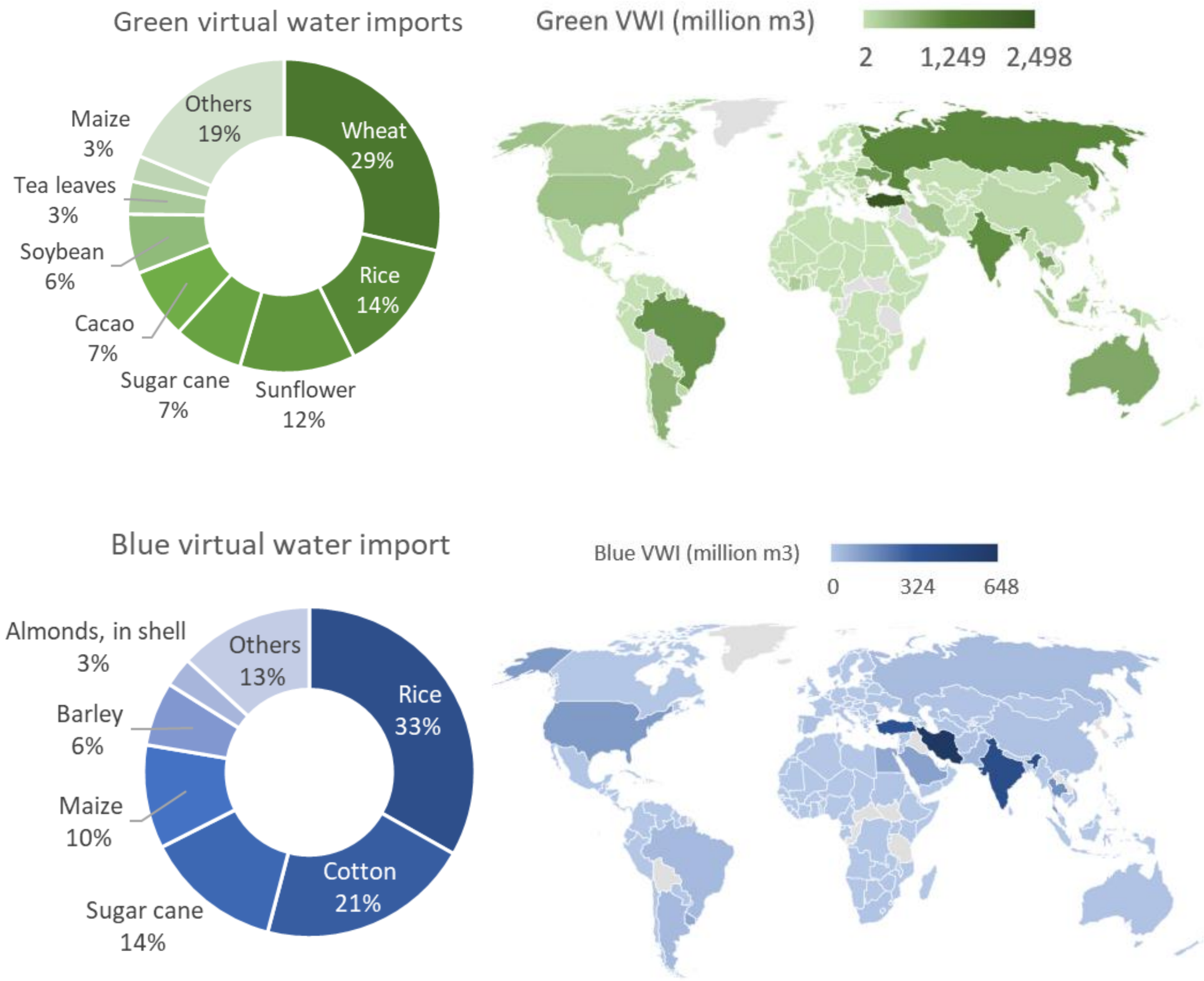


*Figure A 13: : Percentage breakdown of virtual water import (VWI) for each crop for Iraq in relation to the total green and blue virtual water imports.*

The breakdown of crops for blue virtual water imports is as follows: Rice accounts for the highest share at 33%, followed by cotton at 21%, sugar cane at 14%, maize at 10%, barley at 6%, and almonds in shell at 3%.In terms of country shares, Iran leads with 27%, trailed by India at 17%, Türkiye at 14%, Thailand at 7%, the USA at 5%, and Saudi Arabia, Uruguay and Egypt at 4% (Figure A 13, bottom left and right).

Iraq annually exports a total of 0.7 billion $m^3$ of green water and 0.4 billion $m^3$ of blue water embedded in its exported goods. The breakdown of green virtual water export shares for various crops is as follows: Dates dominate with the largest portion at 57%, trailed by barley at 32%, wheat at 10%, olives at 1% and maize at 0.6%. The destination of green virtual water exports is as follows: the United Arab Emirates take the lead with 13%, followed by Türkiye at 10%, Pakistan at 8%, India at 7%, China, China Hong Kong SAR and Russia at 6% each, Kazakhstan at 5% and Germany as well as Oman at 4% (Figure A 14, top figures).

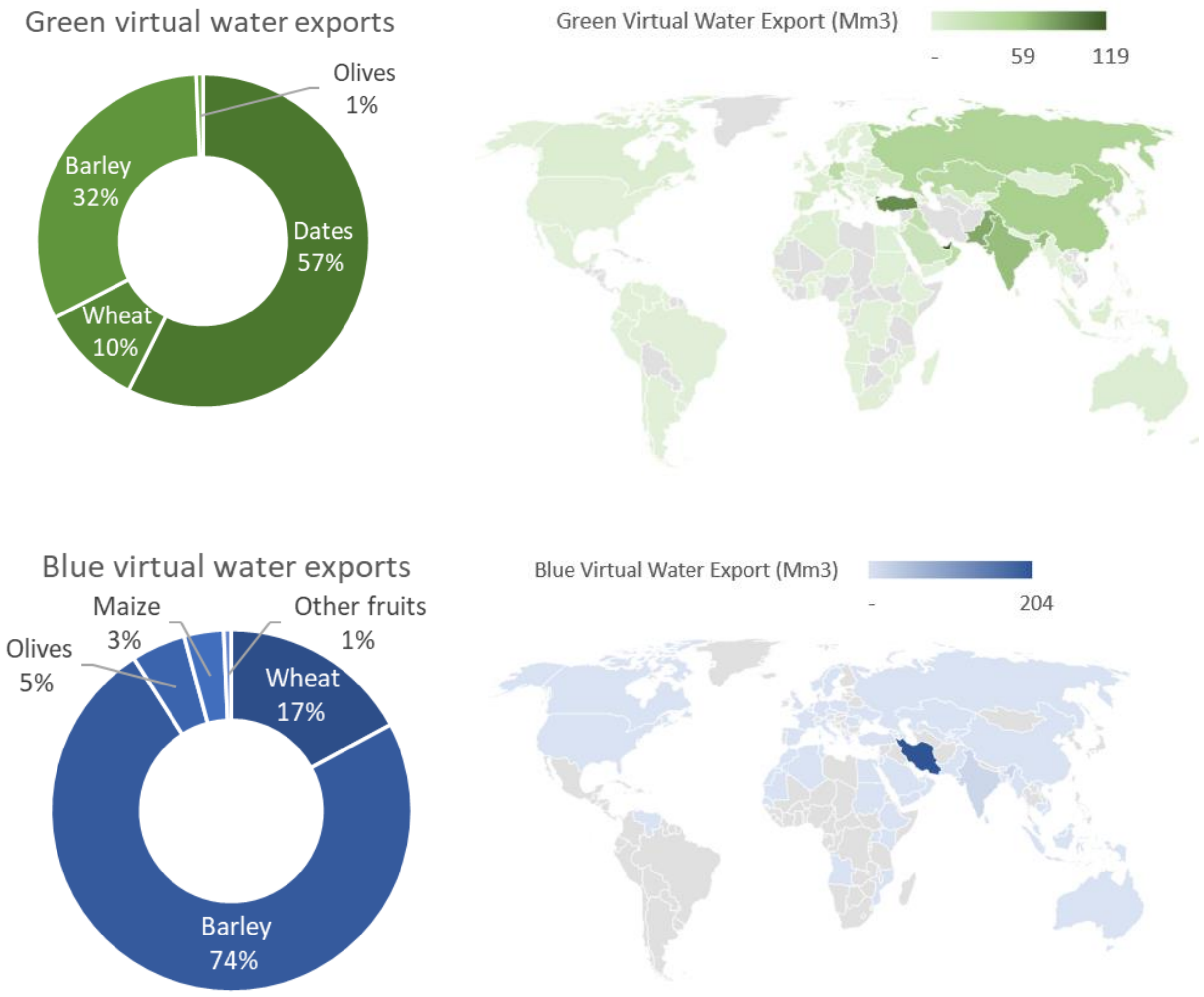


*Figure A 14: Percentage breakdown of virtual water export for each crop for Iraq in relation to the total green and blue virtual water exports.*

The distribution of blue virtual water exports per crop highlights distinct contributions, with barley commanding the highest share at 74%, followed by wheat at 17%, olives at 5%, maize at 3% and other fruits at 1%. Complementing this crop-specific breakdown, the corresponding country shares in blue virtual water exports depict Iran in the lead at 90%, followed by India at 7% and Lebanon as well as Türkiye at each 1% (Figure A 14, bottom figures).

## A2.3. Lebanon

### A2.3.1. Water availability overview

Lebanon has access to approximately 4.5 billion $m^3$ of renewable water resources per year. This translates into an amount of 703.25 $m^3$ per capita per year. Of this amount, surface water provides access to 3.8 billion $m^3$ renewable surface water per year. Additionally, Lebanon has access to 3.2 billion $m^3$ of renewable groundwater per year (FAO, 2020). This means that out of the total renewable water resources, around 54% is provided by surface water, and 46% is provided by groundwater.

Lebanon has 40 rivers, of which 16 are considered perennial. Furthermore, Lebanon has two primary groundwater aquifers, the Jurassic and Cretaceous. These aquifers are primarily comprised of karstic limestone and cover an exposed area of approximately 5,600 square kilometres within the country (UNDP, 2014). These two aquifers are often referred to as Lebanon's "water towers" due to their significant role in supplying water resources.

In total, Lebanon has identified 51 groundwater basins. Among these, six are considered unproductive aquifers, primarily due to their geological formations, while the remaining 45 are productive aquifers. Notably, 28 of these productive aquifers are located in the Mediterranean province, and the remaining 17 are situated in the interior province (UNDP, 2014).

Lebanon is faced with a range of water-challenges. It's water management infrastructure is in need of investments, water utilities are managed ineffectively (e.g. a high rate of non-revenue water among other issues), there is limited water storage, and current irrigation practices are largely inefficient. Furthermore, available ground and surface water resources are under mounting pressure because of overuse and pollution (USAID, 2017).

### A2.3.2. The water footprint of production in Lebanon

The total water footprint of production in Lebanon, averaged between 2012 and 2021, is approximately 3 billion $m^3$ per year. Within this total, 26% is attributed to the green water footprint, which signifies rainwater utilization. The blue water footprint constitutes 35% of the total water footprint, indicating the use of ground and surface water resources in the region. The remaining 39% is related to the grey water footprint, representing the volume of water that is polluted (Figure A 15).

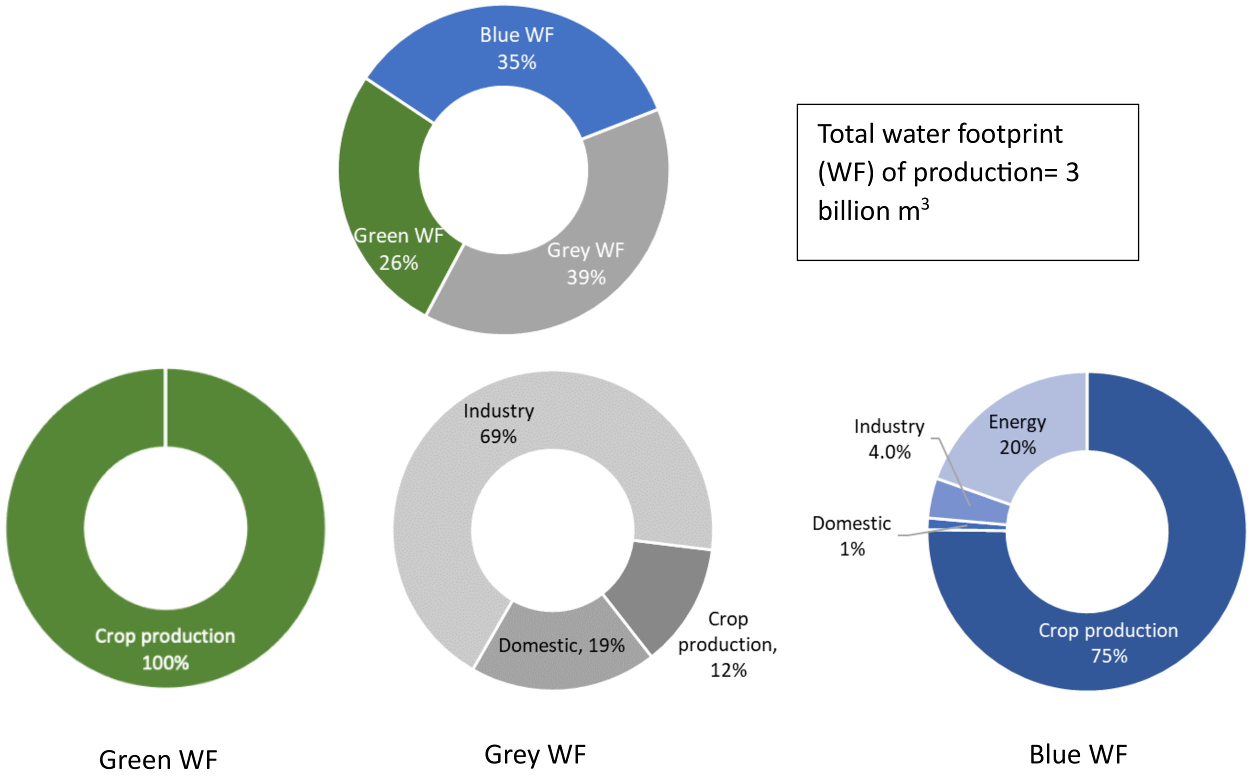


*Figure A 15: Allocation of the water footprint (WF) components is illustrated in the upper figure, while the lower figures depict sectoral breakdowns (green WF on the left, grey WF in the middle, and blue WF on the right), all represented as a percentage of the total water footprint in Lebanon (for the average of 2012-2021).*

On an annual basis, the estimated water footprint of production in Lebanon has shown a slight increasing trend between 2012 and 2022.

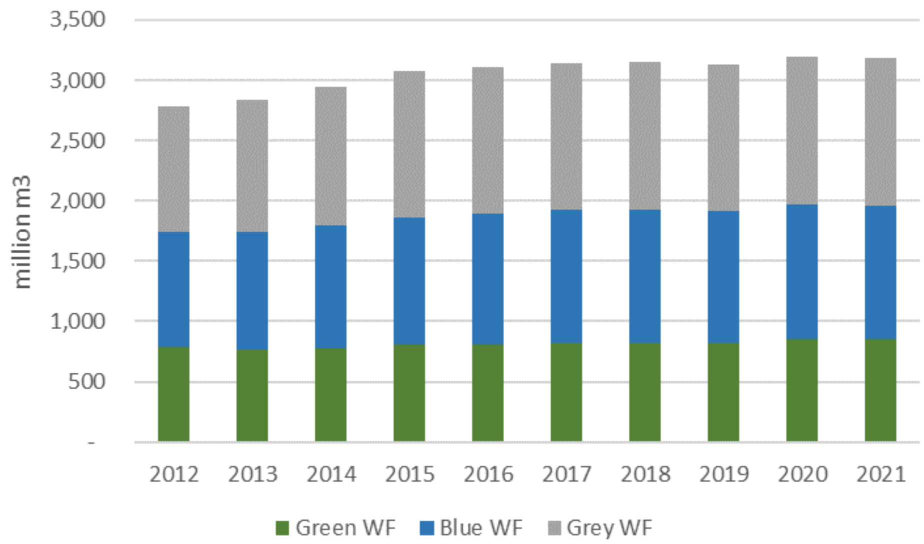


*Figure A 16: The water footprint (WF) of production in Lebanon per year between 2012 and 2021, per green, blue and grey components.*

## The water footprint of crop production in Lebanon

The total water footprint of crop production is 0.8 billion $m^3$ annually (10-year average). Figure A 17, illustrates the yearly distribution of green, blue and grey water footprints across various crops, emphasizing the proportional contributions each crop makes to the overall footprint. The largest share of the green water footprint is taken by Olives at 29%, Wheat at 20%, Apples at 7% and Barley at 5%. For the blue water footprint, the largest share are taken by Olives at 19%, Potatoes at 17% and Apples at 14%. For the grey water footprint, the largest share is taken by Tomatoes at 22%, Cucumber at 13%, Fresh vegetables at 10% and dry onions at 10%.

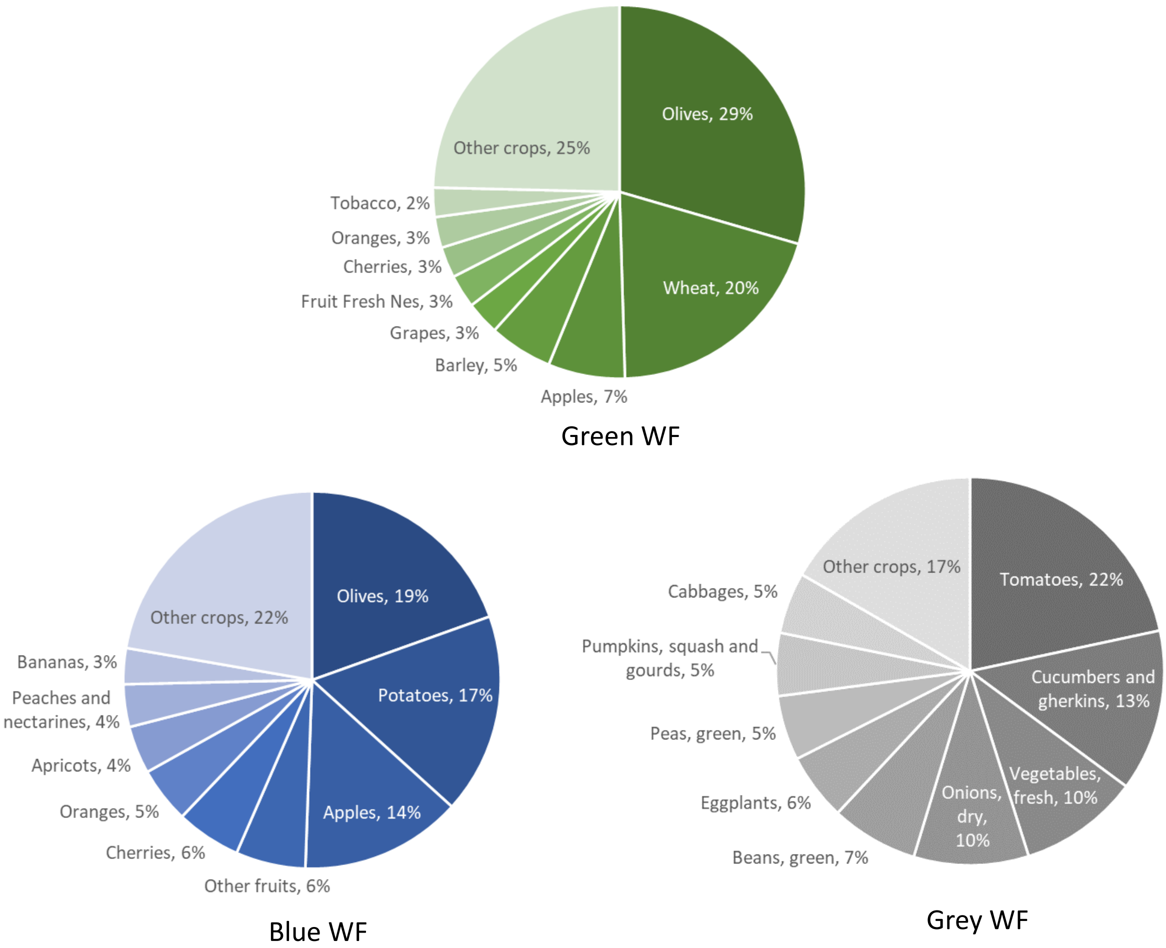


*Figure A 17: Allocation of the water footprint (WF) components per crop (green WF on the top, blue WF on the bottom left, and grey WF on the bottom right), all represented as a percentage of the total of crop production in Lebanon (for the average of 2012-2021).*

## The water footprint of other sectors: industry, domestic water use and energy in Lebanon

In the industrial sector, the blue water footprint was calculated as 0.04 billion $m^3$. The domestic water use sector, encompassing household and public water supply, exhibits a blue water footprint of 0.01 billion $m^3$. The energy sector has a more significant blue water footprint of 0.2 billion $m^3$. The grey water footprints of the industry and domestic water use stand at 0.8 and 0.2 billion $m^3$.

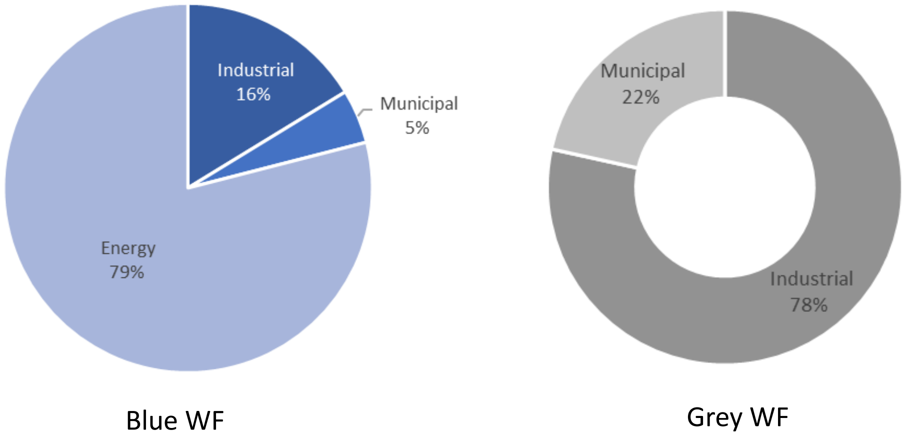


*Figure A 18: Blue (on the left) and grey (on the right) water footprint allocation, represented as a percentage of total water footprint for industrial use, municipal use and energy production in Lebanon (for the average of 2012-2021).*

The percentages in Figure A 19 represent the distribution of various energy types within the blue water footprint of the energy sector. It is easily seen that the largest share of the blue water footprint of energy is related to Oil, with a 93% share, followed by Hydropower at 4% and Coal at 3%.

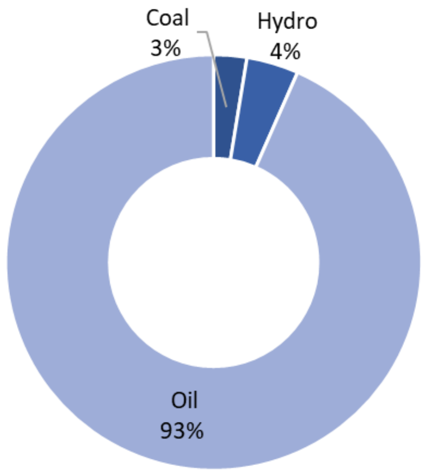


*Figure A 19: The blue water footprint of energy, shares of energy production type in Lebanon.*

### A2.3.3. Virtual water trade of Lebanon

Lebanon annually imports 3.6 billion $m^3$ of green water and 0.4 billion $m^3$ of blue water in relation to import of agricultural products. Wheat claims the largest portion of green virtual water imports at 24%, trailed by maize and soybean (each 10%), sunflower (8%), coffee (8%), sugar cane (7%) and cacao and sesame seed (each 6%). Green virtual water imports are distributed among several countries, with Ukraine taking the lead at 17%, followed by Russia at 14%, Brazil at 10%, Argentina at 7%, Sudan at 5%, Malaysia at 4%, and Indonesia, India, the USA and Romania at each 3% (Figure A 20, top left and right).

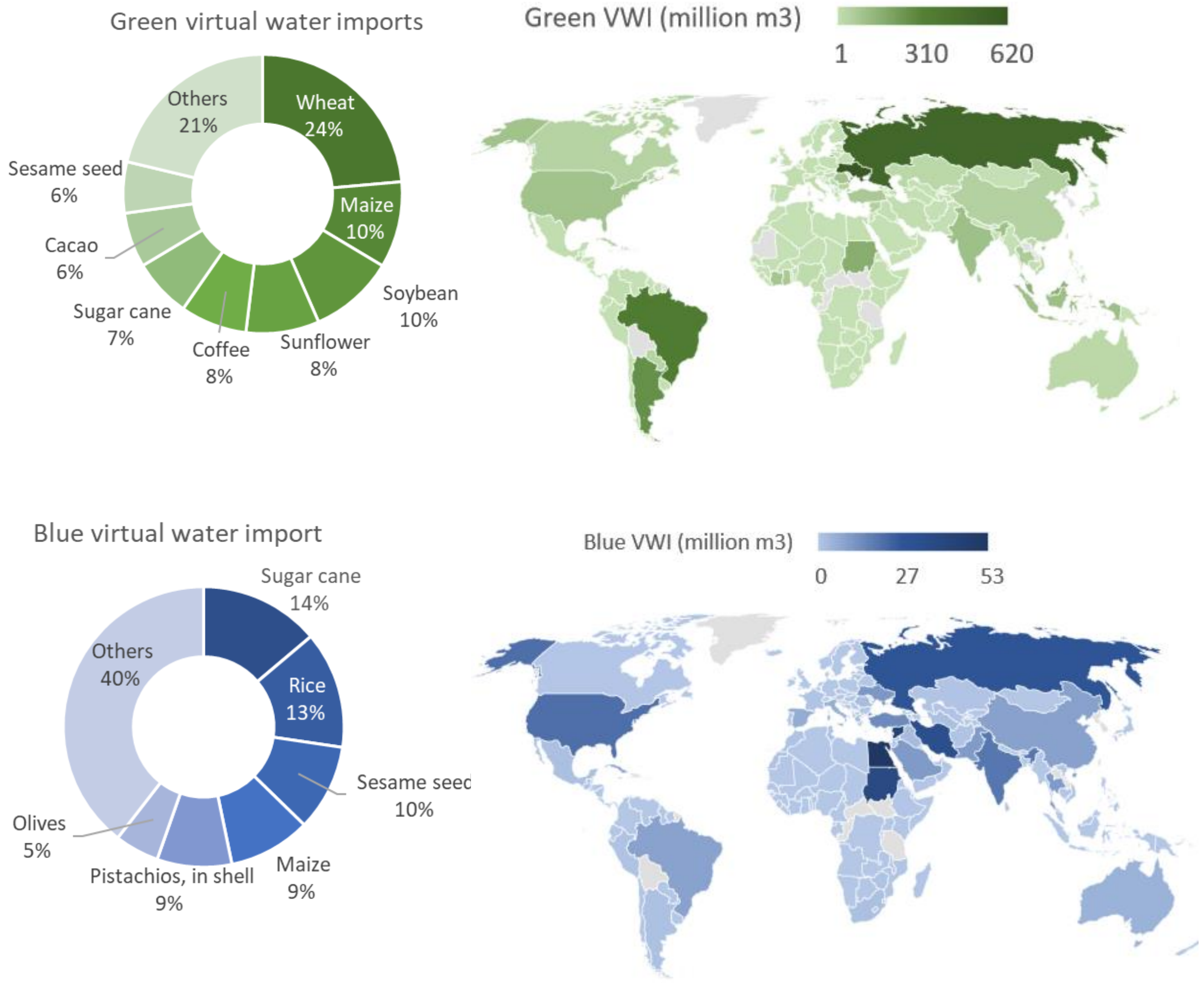


*Figure A 20: Percentage breakdown of virtual water import for each crop for Lebanon in relation to the total green and blue virtual water imports.*

The breakdown of crops for blue virtual water imports is as follows: Sugar cane accounts for the highest share at 14%, followed by rice at 13%, sesame seed at 10%, maize and pistachios in shell at each 9% and olives at 5%. In terms of country shares, Egypt leads with 15%, tailed by Syria at 12%, Sudan at 10%, Iran at 9%, Russia at 7%, the USA at 6%, India at 5%, Türkiye at 4% and Ukraine, Saudia Arabia, Thailand, Pakistan and Cuba at each 3% (Figure A 20, bottom left and right).

Lebanon annually exports a total of 0.1 billion m$^3$ of green water and 0.2 billion m$^3$ of blue water embedded in its exported goods. The breakdown of green virtual water export shares for various crops is as follows: olives dominate with the largest portion at 42%, trailed by apples at 12%, grapes at 8%, tobacco and other fruits at 5% each, wheat and oranges at each 4%, and bananas at 3%. The destination of green virtual water exports is as follows: Saudi Arabia takes the lead with 16%, followed by Egypt at 14%, Kuwait at 11%, the USA at 9%, the United Arab Emirates at 8%, Iraq at 5% and Syria, Qatar, Canada as well as Jordan at each 4% (Figure A 21, top figures).

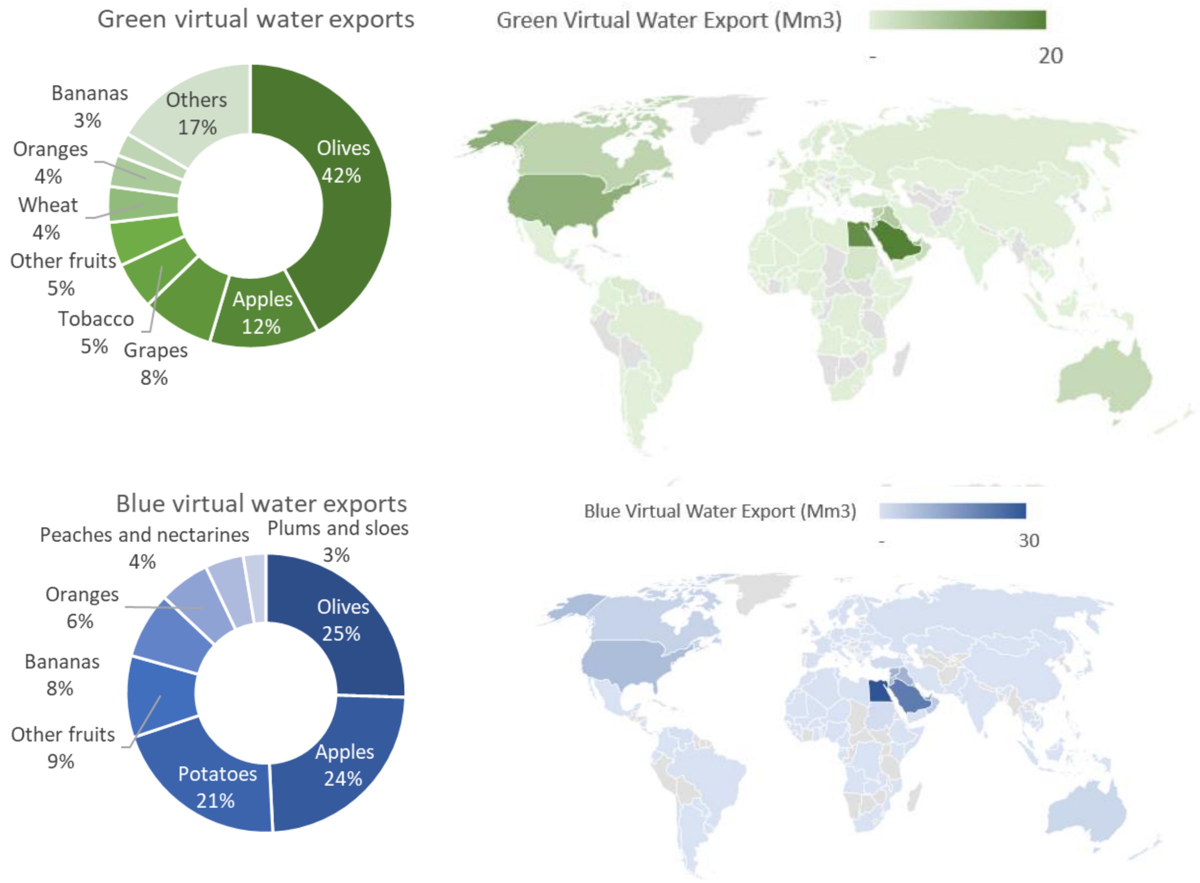


*Figure A 21: Percentage breakdown of virtual water export for each crop for Lebanon in relation to the total green and blue virtual water exports.*

The distribution of blue virtual water exports per crop highlights distinct contributions, with olives commanding the highest share at 25%, followed by apples at 24%, potatoes at 21%, other fruit at 9%, bananas at 8%, oranges at 6%, peaches and nectarines at 4%, and plums and sloes at 3%. Complementing this crop-specific breakdown, the corresponding country shares in blue virtual water exports depict Egypt in the lead at 20%, followed by Saudi Arabia at 14%, Kuwait at 13% the United Arab Emirates at 10%,Syria and Iraq at each 7%, Jordan at 6%, the USA at 5% and Qatar at 4% (Figure A 21, bottom figures).

## A2.4. Jordan

### A2.4.1. Water availability overview

Jordan has access to approximately 0.94 billion $m^3$ of renewable water resources per year. This translates into an amount of 92.76 $m^3$ per capita per year. Of this amount, surface water provides access to 0.65 billion $m^3$ renewable surface water per year. Furthermore, Jordan has access to 0.54 billion $m^3$ of renewable groundwater per year (FAO, 2020). This means that out of the total renewable water resources, around 57% is provided by surface water, and 43% is provided by groundwater.

The three primary rivers in the country are the Jordan, Yarmouk, and Zarqa. They constitute a significant component of the nation's surface water system. Water supply by these three rivers has become increasingly unreliable. This decrease in reliability can be attributed to activities such as upstream diversion and extraction in Syria (particularly concerning the Yarmouk River) and Israel (particularly concerning the Jordan River) (Zeitoun, 2019).

Jordan is one of the countries with the lowest volume of renewable water resources per capita in the world. Groundwater resources have experienced prolonged overexploitation, with the country's groundwater estimated to be depleted at twice the rate it can naturally recharge. Jordan faces acute water supply shortages, primarily driven by the rapid growth in demand and a significant rise in inefficient water use in recent years. Jordan is actively addressing its water stress situation by attempting to enhance water supply through desalination and dam construction while simultaneously reducing water consumption through the reinforcement of public water distribution networks. However, despite these measures, water stress continues to persist at an unprecedented level (Al-Addous, 2023).

### A2.4.2. The water footprint of production in Jordan

The total water footprint of production in Jordan, averaged between 2012 and 2021, is approximately 1.6 billion $m^3$ per year (10-year average). Within this total, 30% is attributed to the green water footprint, which signifies rainwater utilization. The blue water footprint constitutes 40% of the total water footprint, indicating the use of ground and surface water resources in the region. The remaining 30% is related to the grey water footprint, representing the volume of water that is polluted (Figure A 22).

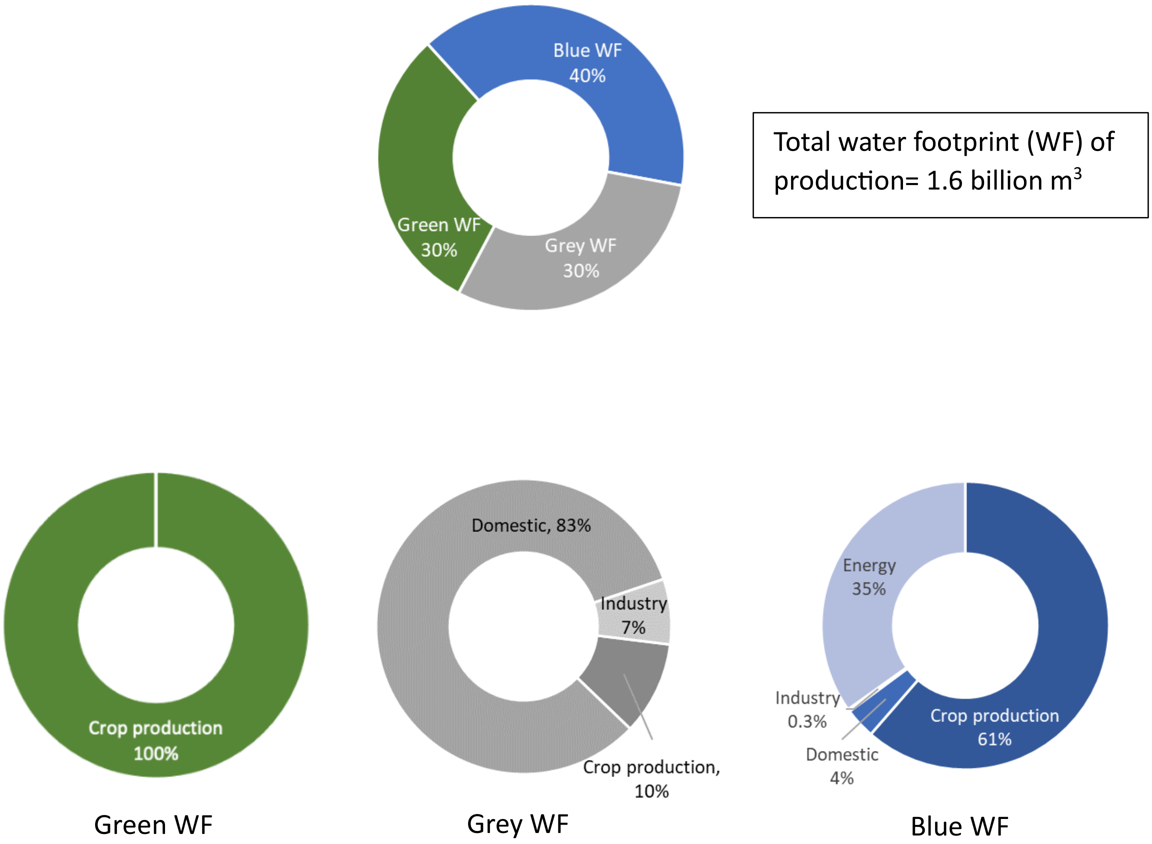


*Figure A 22: : Allocation of the water footprint (WF) components is illustrated in the upper figure, while the lower figures depict sectoral breakdowns (green WF on the left, grey WF in the middle, and blue WF on the right), all represented as a percentage of the total water footprint in Jordan (for the average of 2012-2021).*

On an annual basis, the estimated water footprint of production in Jordan has shown slight fluctuation between 2012 and 2022, with recurring increasing and decreasing trends every 2-3 years (Figure A 23).

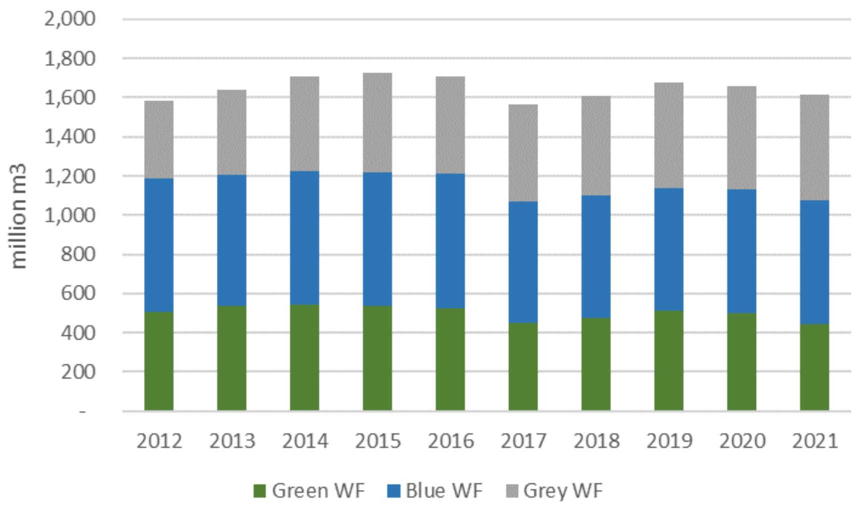


*Figure A 23: The water footprint (WF) of production in Jordan per year between 2012 and 2021, per green, blue and grey components.*

***The water footprint of crop production in Jordan***

The total water footprint of crop production is 0.5 billion $m^3$ annually (10-year average). Figure A 24 illustrates the yearly distribution of green, blue and grey water footprints across various crops, emphasizing the proportional contributions each crop makes to the overall footprint. The largest share of green water footprint is relate to Olive production, at 36%, followed by Barley at 23% and wheat at 10%. For the blue water footprint, the largest shares are related to Olives at 28%, Tomatoes at 11% and Peaches at 7%. The grey water footprint is primarily caused by cultivation of Olives, with a staggering 68% of the total, followed by Wheat at 9% and Potatoes at 5%.

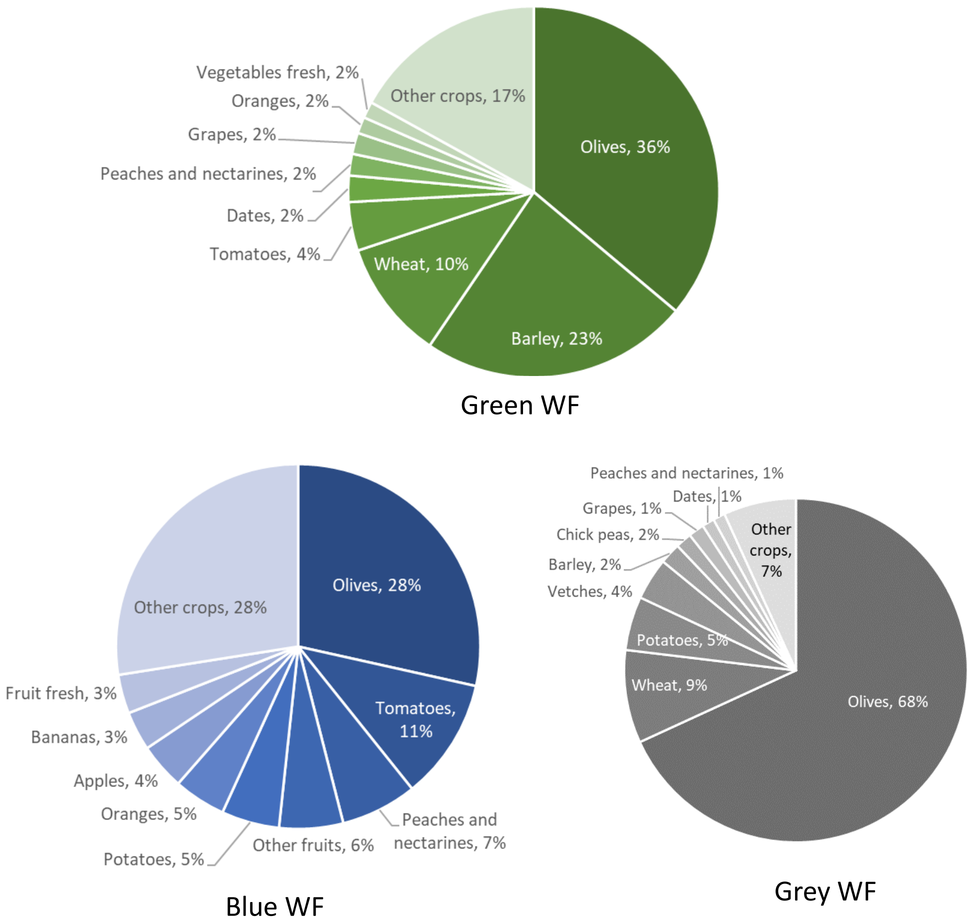


*Figure A 24: Allocation of the water footprint (WF) components per crop (green WF on the top, blue WF on the bottom left, and grey WF on the bottom right), all represented as a percentage of the total of crop production in Jordan (for the average of 2012-2021).*

## The water footprint of other sectors: industry, domestic water use and energy in Jordan

In the industrial sector, the blue water footprint was calculated as 0.002 billion $m^3$. The domestic water use sector, encompassing household and public water supply, exhibits a blue water footprint of 0.023 billion $m^3$. The energy sector has a more significant blue water footprint of 0.2 billion $m^3$. The grey water footprints of the industry and domestic water use stand at 0.035 and 0.4 billion $m^3$.

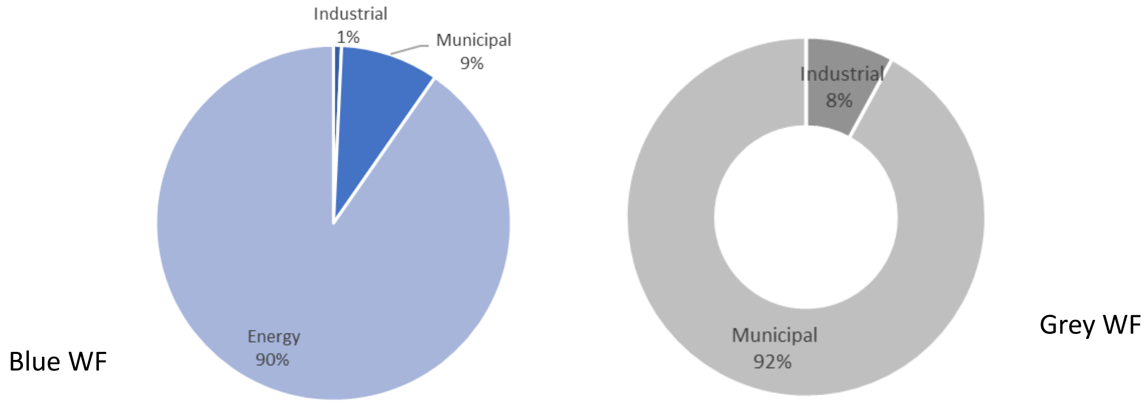


*Figure A 25: Blue (on the left) and grey (on the right) water footprint allocation, represented as a percentage of total water footprint for industrial use, municipal use and energy production in Jordan (for the average of 2012-2021).*

The percentages in Figure A 26 represent the distribution of various energy types within the blue water footprint of the energy sector. The largest share in the total water footprint of energy is taken by Oil at 56% , followed by Natural Gas at 39%, Coal at 4% and Wind & Solar at 0.87%.

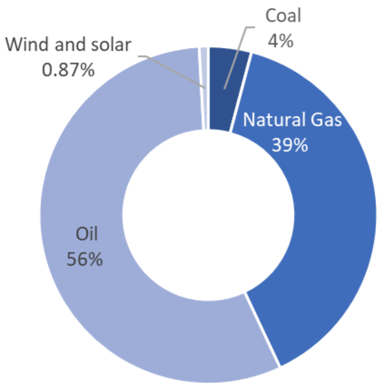


*Figure A 26: The blue water footprint of energy, shares of energy production type in Jordan.*

### A2.4.3. Virtual water trade of Jordan

Jordan annually imports 5.2 billion $m^3$ of green water and 0.5 billion $m^3$ of blue water in relation to import of agricultural products. Wheat claims the largest portion of green virtual water imports at 20%, trailed by barley (16%), maize (12%), soybean (11%), coffee (7%), sugar cane (5%), cacao (4%), and rice (4%). Green virtual water imports are distributed among several countries, with Argentina taking the lead at 18%, followed by Russia at 13%, Romania at 12%, Brazil at 8%, India and Ukraine at 7%, and the USA, Malaysia, Indonesia as well as Sudan at 3% (Figure A 27, top left and right).

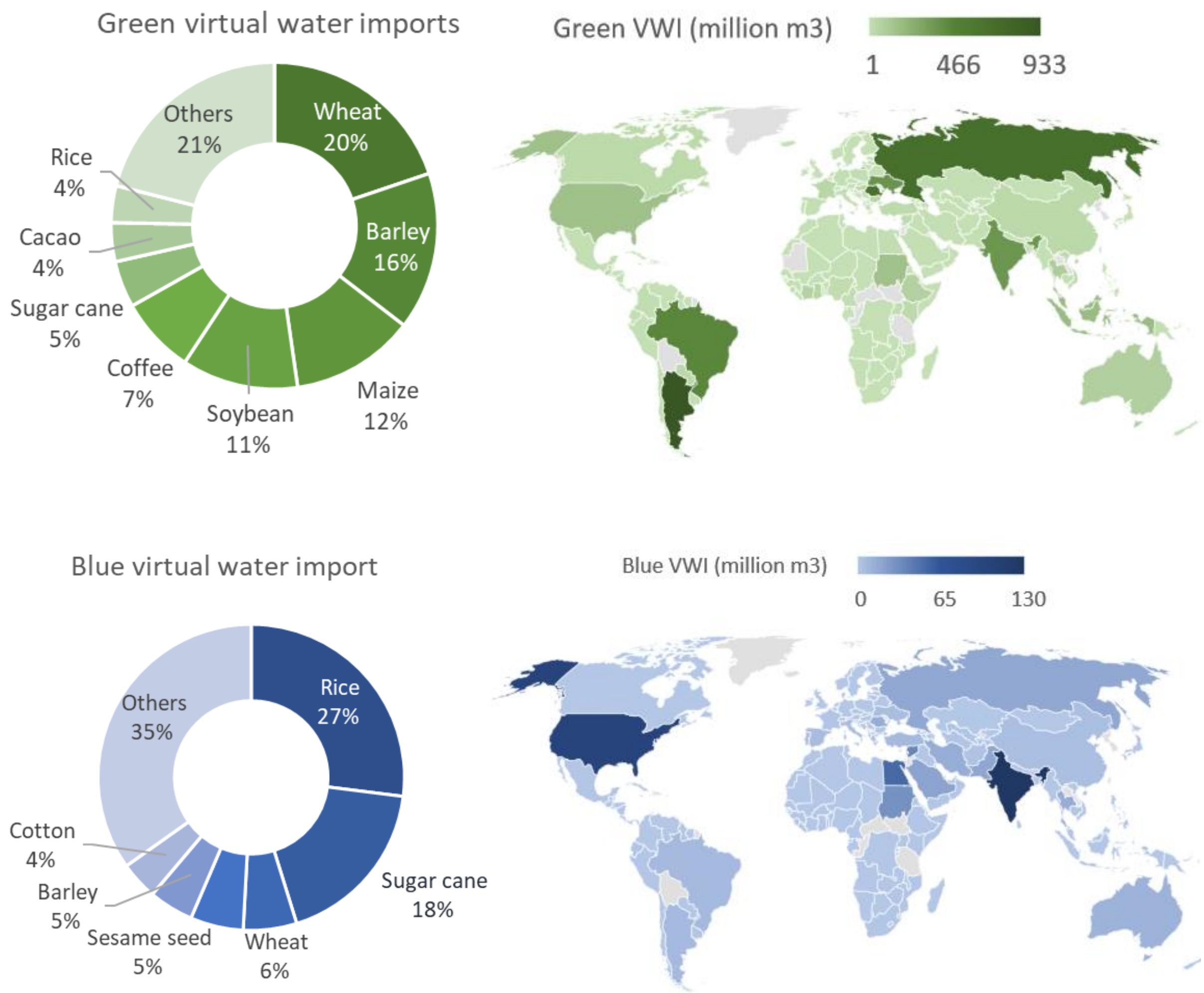


*Figure A 27: Percentage breakdown of virtual water import for each crop for Jordan in relation to the total green and blue virtual water imports.*

The breakdown of crops for blue virtual water imports is as follows: Rice accounts for the highest share at 27%, followed by sugar cane at 18%, wheat at 6%, sesame seed and barley at 5% each, and cotton at 4%. In terms of country shares, India leads with 24%, trailed by the USA at 18%, Egypt at 10%, Syria at 7%, Sudan at 6%, Saudi Arabia at 4%, and Thailand, Pakistan, Russia, Iran as well as Romania at 3% (Figure A 27, bottom left and right.).

Jordan annually exports a total of 0.05 billion $m^3$ of green water and 0.07 billion $m^3$ of blue water embedded in its exported goods. The breakdown of green virtual water export shares for various crops is as follows: olives dominate with the largest portion at 27%, trailed by tomatoes at 17%, peaches and nectarines as well as wheat at each 15%, dates at 5%, apricots at 3%, and barley, as well as tangerines, mandarins and clementines at each 2%. The destination of green virtual water exports is as follows: Saudi Arabia takes the lead with 22%, followed by Iraq, Syria and the United Arab Emirates at 13% each, Kuwait at 12%, Israel at 7%, and Qatar as well as Bahrain at 4% (Figure A 28, top figures).

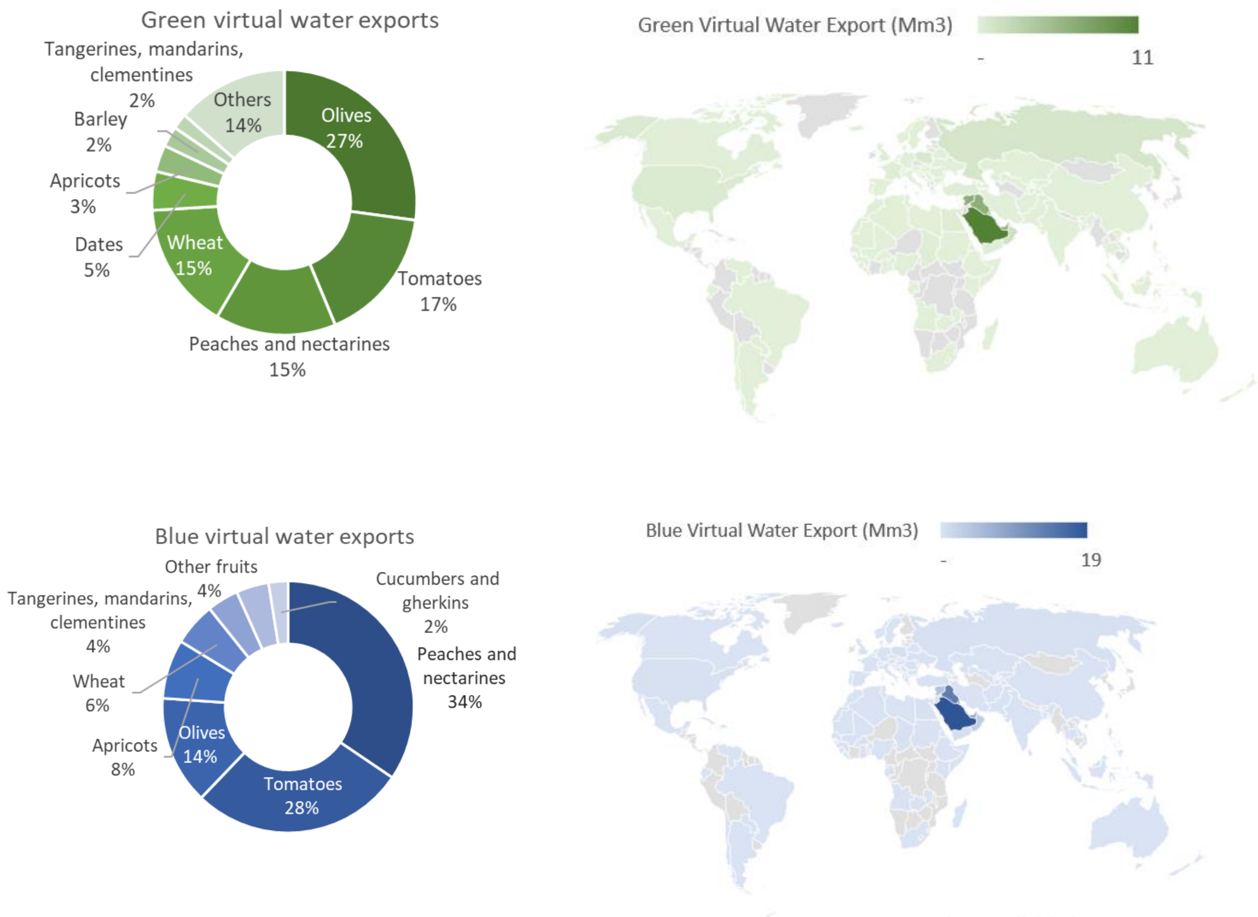


*Figure A 28: Percentage breakdown of virtual water export for each crop for Jordan in relation to the total green and blue virtual water exports.*

The distribution of blue virtual water exports per crop highlights distinct contributions, with peaches and nectarines commanding the highest share at 34%, followed by tomatoes at 28%, olives at 14%, apricots at 8%, wheat at 6%, tangerines, mandarins and clementines as well as other fruits at 4%. Complementing this crop-specific breakdown, the corresponding country shares in blue virtual water exports depict Saudi Arabia in the lead at 27%, followed by Iraq at 20%, Kuwait at 10%, the United Arab Emirates at 11%, Syria at 6%, Bahrain at 5% and Qatar, Oman and Israel at each 4%.

## A2.5. Syria

### A2.5.1. Water availability overview

Syria has access to around 16.8 billion $m^3$ of renewable water resources per year. This translates into an amount of 960 $m^3$ per capita per year. Of this amount, surface water provides access to 12.63 billion $m^3$ renewable surface water per year. Additionally, Syria has access to 6.17 billion m3 of renewable groundwater per year (FAO, 2020). This means that out of the total renewable water resources, around 67% is provided by surface water, and 33% is provided by groundwater.

Syria's primary source of freshwater is the Euphrates, alongside the Tigris. The Euphrates river originates in Türkiye, traverses Syria and Iraq, and eventually flows into the Persian Gulf. Over the past decades, as described before for Iraq, the water level of the Euphrates has experienced a substantial decline. This reduction has directly affected the quantity of water accessible for crucial sectors within Syria, including drinking water, agriculture, and hydroelectric power generation (USAID, 2021).

Groundwater is accessible in various geological formations throughout the country. Certain main aquifers are categorized as non-renewable or fossil water. Both historical and contemporary data reveal that the withdrawal of groundwater significantly surpasses the natural replenishment rate in nearly all regions (Baba, 2021).

Previously rare, severe, multiyear droughts have become two to three times more likely to occur due to climate change. This will likely further Syria's reliance on groundwater and rainwater as water sources  (USAID, 2021). The rapid growth in population and swift urbanization are compounding these challenges, resulting in an ongoing degradation of water resources.

### A2.5.2. The water footprint of production in Syria

The total water footprint of production in Syria, averaged between 2012 and 2021, is approximately 22 billion $m^3$ per year (10-year average). Within this total, 55% is attributed to the green water footprint, which signifies rainwater utilization. The blue water footprint constitutes 28% of the total water footprint, indicating the use of ground and surface water resources in the region. The remaining 17% is related to the grey water footprint, representing the volume of water that is polluted (Figure A 29).

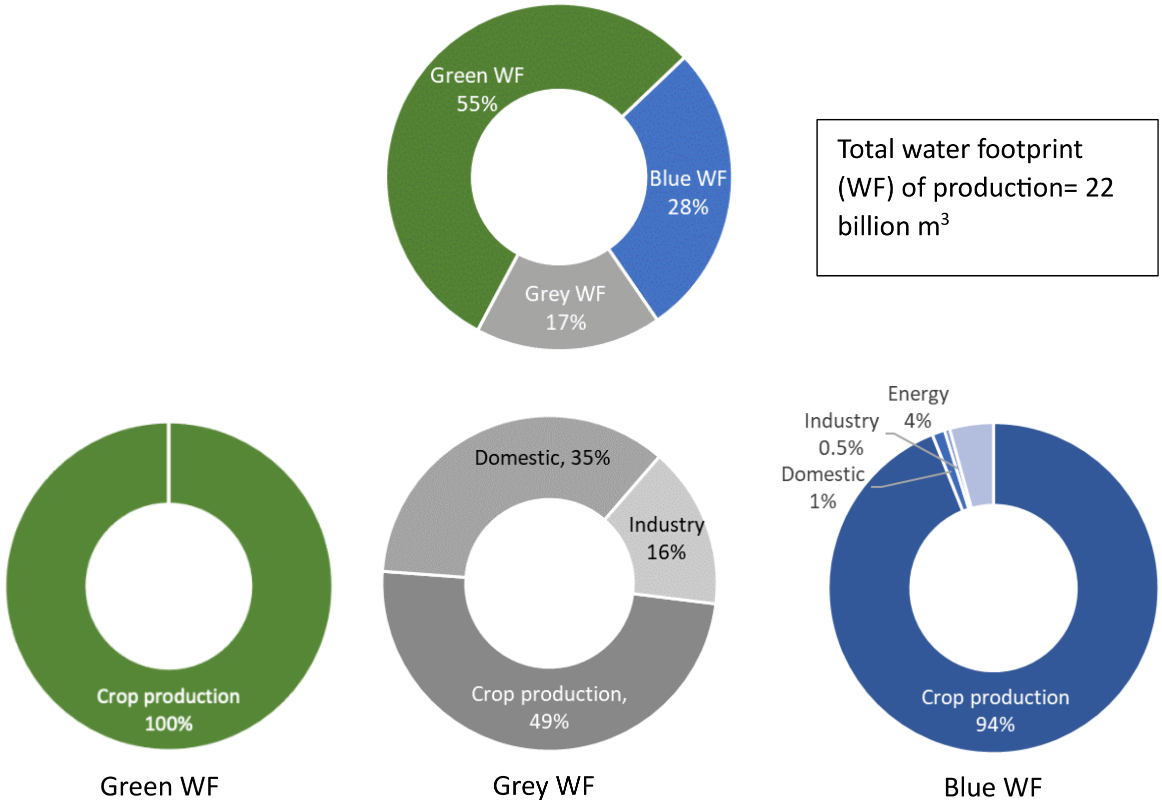


*Figure A 29: Allocation of the water footprint (WF) components is illustrated in the upper figure, while the lower figures depict sectoral breakdowns (green WF on the left, grey WF in the middle, and blue WF on the right), all represented as a percentage of the total water footprint in Syria (for the average of 2012-2021).*

On an annual basis, the estimated water footprint of production in Syria has shown a decreasing trend up to the mid 2010's followed by an increase, bringing the total water footprint value of 2022 almost the same level as in 2012.

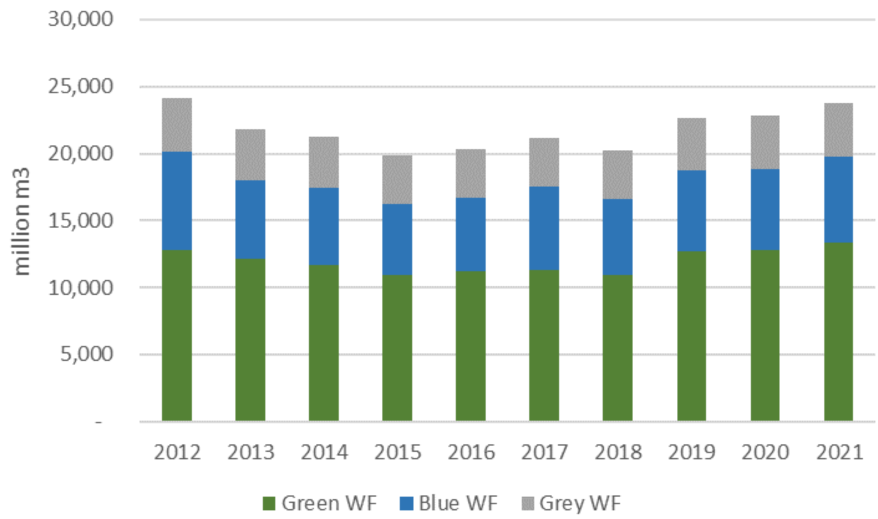


*Figure A 30: The water footprint (WF) of production in Syria per year between 2012 and 2021, per green, blue and grey components.*

## The water footprint of crop production in Syria

The green water footprint of crop production is 12 billion m$^3$ annually (10-year average). Figure A 31 illustrates the yearly distribution of green, blue and grey water footprints across various crops, emphasizing the proportional contributions each crop makes to the overall footprint. The largest share of the green water footprint is related to Wheat production at 37%, followed by Barley at 30% and Olives at 20%. The largest share of the blue water footprint can be attribute to Wheat at 24% , Olives at 21% and various Spices at 10%. Barley, Wheat and Olives are the largest contributors to the grey water footprint at 40%, 35% and 18% respectively.

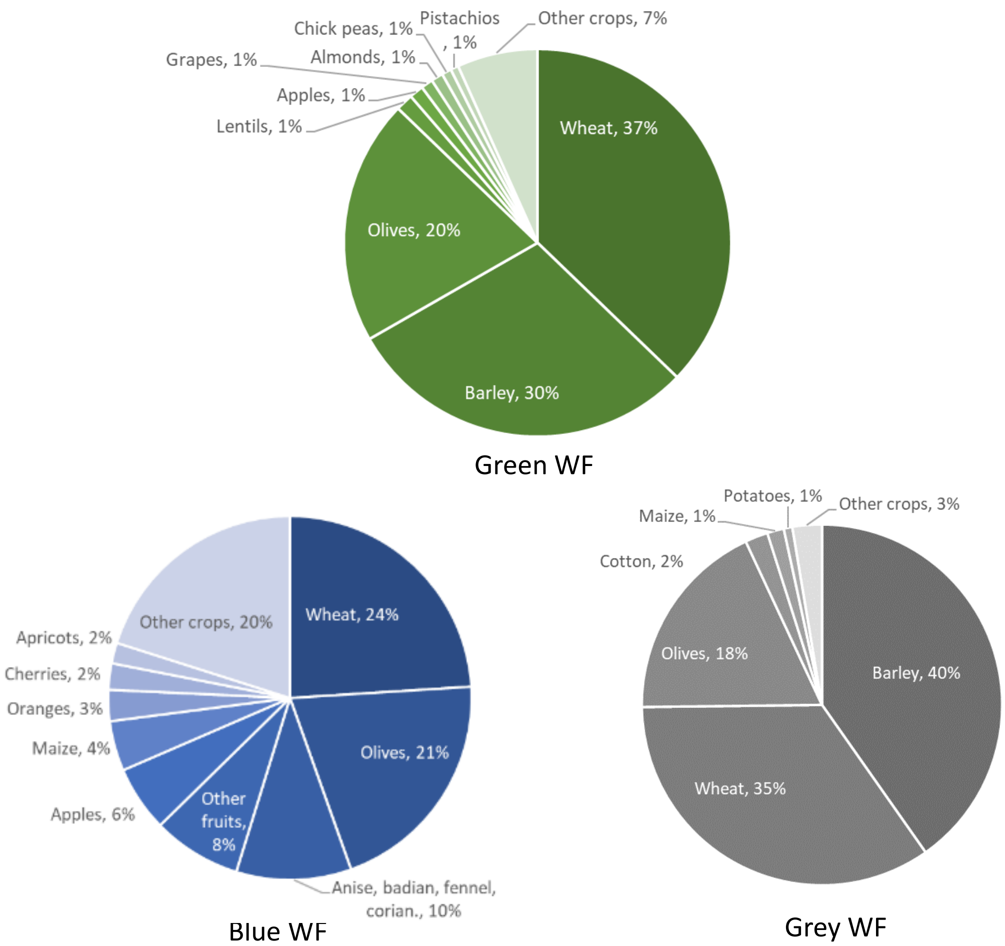


*Figure A 31: Allocation of the water footprint (WF) components per crop (green WF on the top, blue WF on the bottom left, and grey WF on the bottom right), all represented as a percentage of the total of crop production in Syria (for the average of 2012-2021).*

## The water footprint of other sectors: industry, domestic water use and energy in Syria

In the industrial sector, the blue water footprint was calculated as 0.03 billion m³. The domestic water use sector, encompassing household and public water supply, exhibits a blue water footprint of 0.07 billion m³. The energy sector has a more significant blue water footprint of 0.3 billion m³. The grey water footprints of the industry and domestic water use stand at 0.6 and 1.3 billion m³.

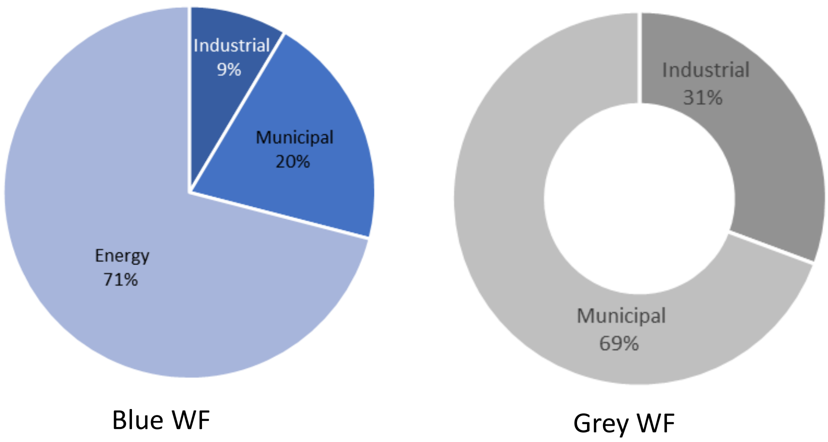


*Figure A 32: Blue (on the left) and grey (on the right) water footprint allocation, represented as a percentage of total water footprint for industrial use, municipal use and energy production in Syria (for the average of 2012-2021).*

The percentages in Figure A 33 represent the distribution of various energy types within the blue water footprint of the energy sector. It can be seen that Oil represents 71% of the total water footprint of energy, followed by Natural Gas at 27% and Hydropower at 2%.

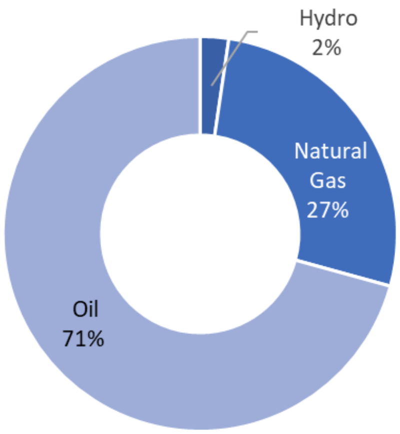


*Figure A 33: The blue water footprint of energy, shares of energy production type in Syria.*

### A1.5.3. Virtual water trade of Syria

Syria annually imports 3.6 billion $m^3$ of green water and 0.5 billion $m^3$ of blue water in relation to import of agricultural products. Wheat claims the largest portion of green virtual water imports at 25%, trailed by sunflower (12%), sugar cane (8%), soybean, coffee and cacao (each 6%), maize (5%) and rice (4%). Green virtual water imports are distributed among several countries, with Türkiye taking the lead at 19%, followed by Russia at 14%, Ukraine at 10%, Brazil at 8%, India at 5%, Argentina, Malaysia and Romania at 4% each, and Sri Lanka 3% (Figure A 34, top left and right).

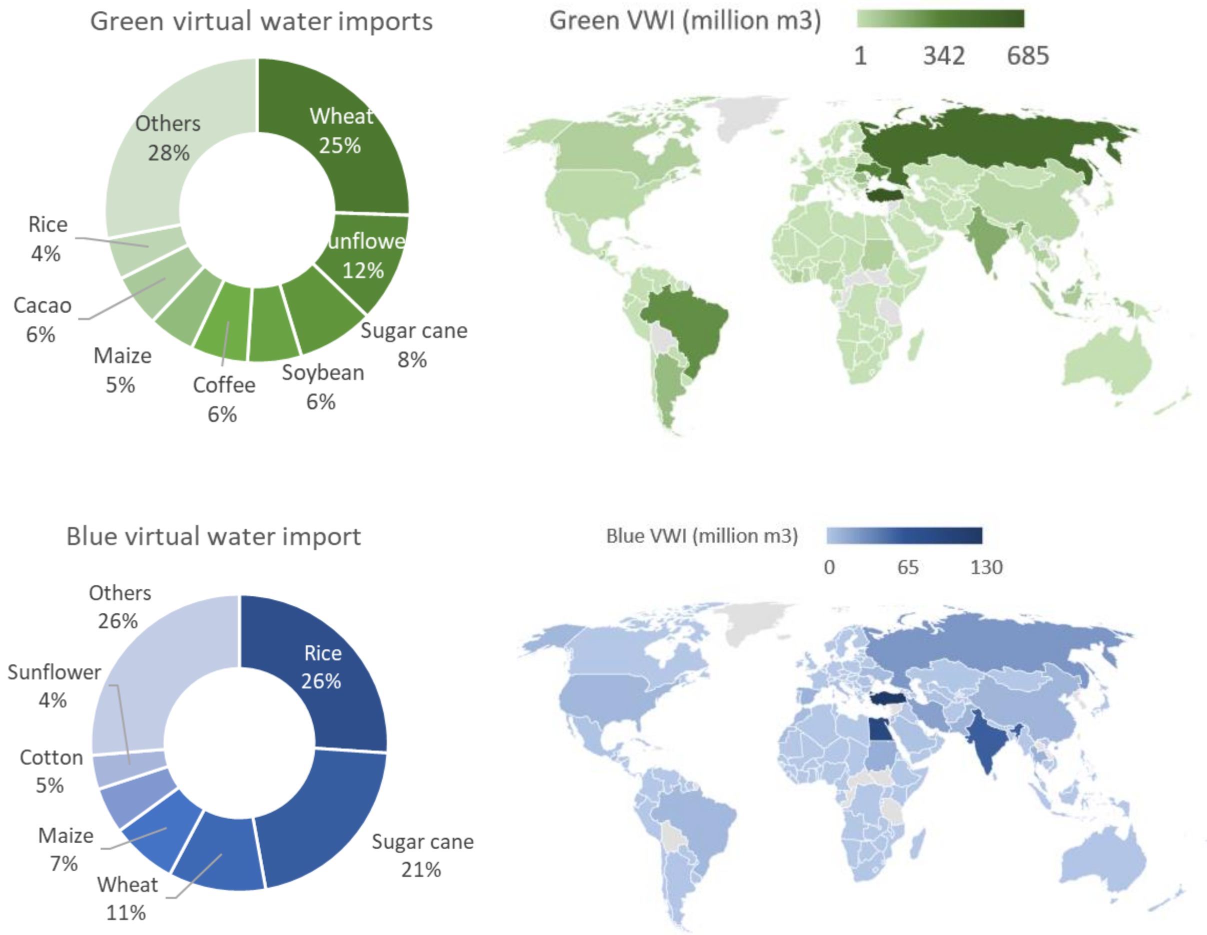


*Figure A 34: Percentage breakdown of virtual water import (VWI) for each crop for Syria in relation to the total green and blue virtual water imports.*

The breakdown of crops for blue virtual water imports is as follows: Rice accounts for the highest share at 26%, followed by sugar cane at 21%, wheat at 11%, maize at 7%, cotton at 5% and sunflower at 4%. In terms of country shares, Türkiye leads with 26%, tailed by Egypt at 19%, India at 12%, Russia at 5%, Iran at 4%, and Sudan at 3% (Figure A 34, bottom left and right).

Syria annually exports a total of 1.1 billion m$^3$ of green water and 1.3 billion m$^3$ of blue water embedded in its exported goods. The breakdown of green virtual water export shares for various crops is as follows: olives dominate with the largest portion at 58%, trailed by barley at 18%, apples at 11%, wheat at 3%, herbs and spices as well as lentils at 2% and other stimulants at 1%. The destination of green virtual water exports is as follows: Türkiye takes the lead with 39%, followed by Saudi Arabia at 16%, Egypt at 14%, Spain at 8%, the United Arab Emirates at 7%, Lebanon at 5%, and Iran as well as Kuwait at 3% (Figure A 35, top figures).

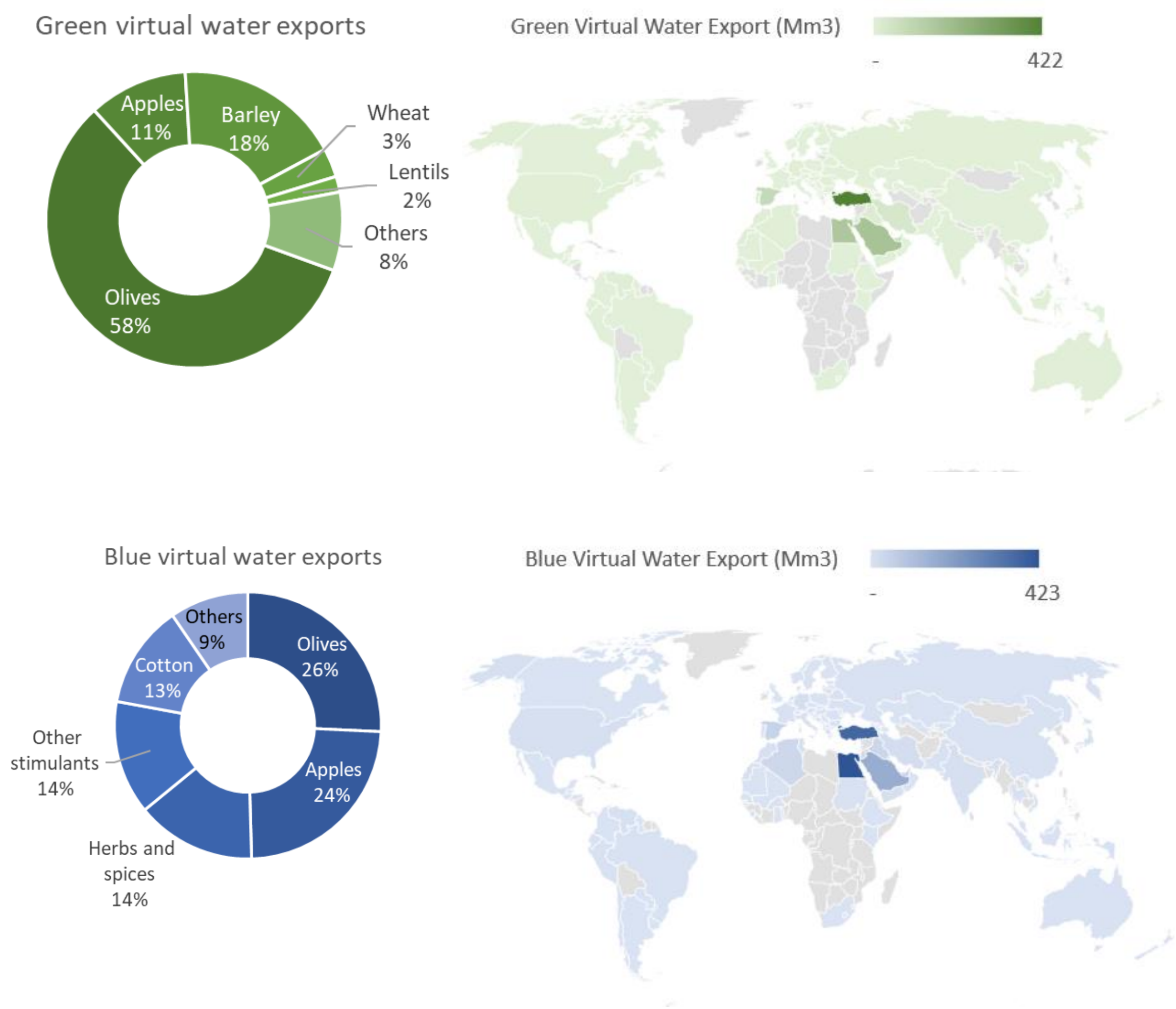


*Figure A 35: Percentage breakdown of virtual water export for each crop for Syria in relation to the total green and blue virtual water exports.*

The distribution of blue virtual water exports per crop highlights distinct contributions, with apples commanding the highest share at 27%, followed by apples at 25%, herbs and spices as well as other stimulants at 15%, cotton at 13%, plums and sloes at 3%, and other fruit as well as wheat at 1%. Complementing this crop-specific breakdown, the corresponding country shares in blue virtual water exports depict Egypt in the lead at 33%, followed by Türkiye at 29%, Saudi Arabia at 13%, the United Arab Emirates and Spain each at 4%, and Lebanon as well as Jordan at 3% (Figure A 35, bottom figures).

## A2.6. Türkiye

### A2.6.1. Water availability overview

Türkiye has access to around 211.6 billion $m^3$ of renewable water resources per year. This translates into an amount of 2,536.27 $m^3$ per capita per year. Of this amount, surface water provides access to 171.8 billion $m^3$ renewable surface water per year. Furthermore, Türkiye has access to 67.8 billion $m^3$ of renewable groundwater per year (FAO, 2020). This means that out of the total renewable water resources, around 71.7% is provided by surface water, and 28.3% is provided by groundwater. Türkiye is geographically divided into 25 distinct hydrological basins, each characterized by varying catchment sizes and a wide spectrum of annual precipitation, evaporation, and surface runoff factors. Consequently, river discharges in these basins are hard to predict (Fanack Water, 2022). Within Türkiye's borders, 16 rivers originate in the mountains and flow into the Marmara Sea, Mediterranean Sea, Black Sea, and Aegean Sea. Meanwhile, the Konya Basin, Akarçay Basin, Burdur Lakes, and Lake Van are classified as closed basins, indicating that they lack any natural outflow to the sea. On the other hand, the Maritza, Orontes , Araks-Kura, Euphrates-Tigris, and Çoruh basins are the primary transboundary basins, extending beyond Türkiye's boundaries (Fanack Water, 2022).

An increasing population, urbanization, climate change, water mismanagement, and inefficient irrigation techniques are having adverse effects on the amount and quality of water resources. The consequences of drought in Türkiye were prominently evident in the drought reports released by the

State Meteorological Service in July 2021. Notably, the presence of 'extremely arid' and 'very arid' regions stands out in the drought evaluation covering the 12-month period from October 2020 to September 2021 (Ministry of Environment, Urbanization and Climate Change, 2022). As per the findings of the drought assessment conducted by the General Directorate of Meteorology, the year 2021 marked the driest year in the past two decades and the second driest year in the last 41 years (Iklim, 2021).

### A2.6.2. The water footprint of production in Türkiye

The total water footprint of production in Türkiye, averaged between 2012 and 2021, is approximately 103 billion $m^3$ per year (10-year average). Within this total, 66% is attributed to the green water footprint, which signifies rainwater utilization. The blue water footprint constitutes 19% of the total water footprint, indicating the use of ground and surface water resources in the region. The remaining 15% is related to the grey water footprint, representing the volume of water that is polluted (Figure A 36).

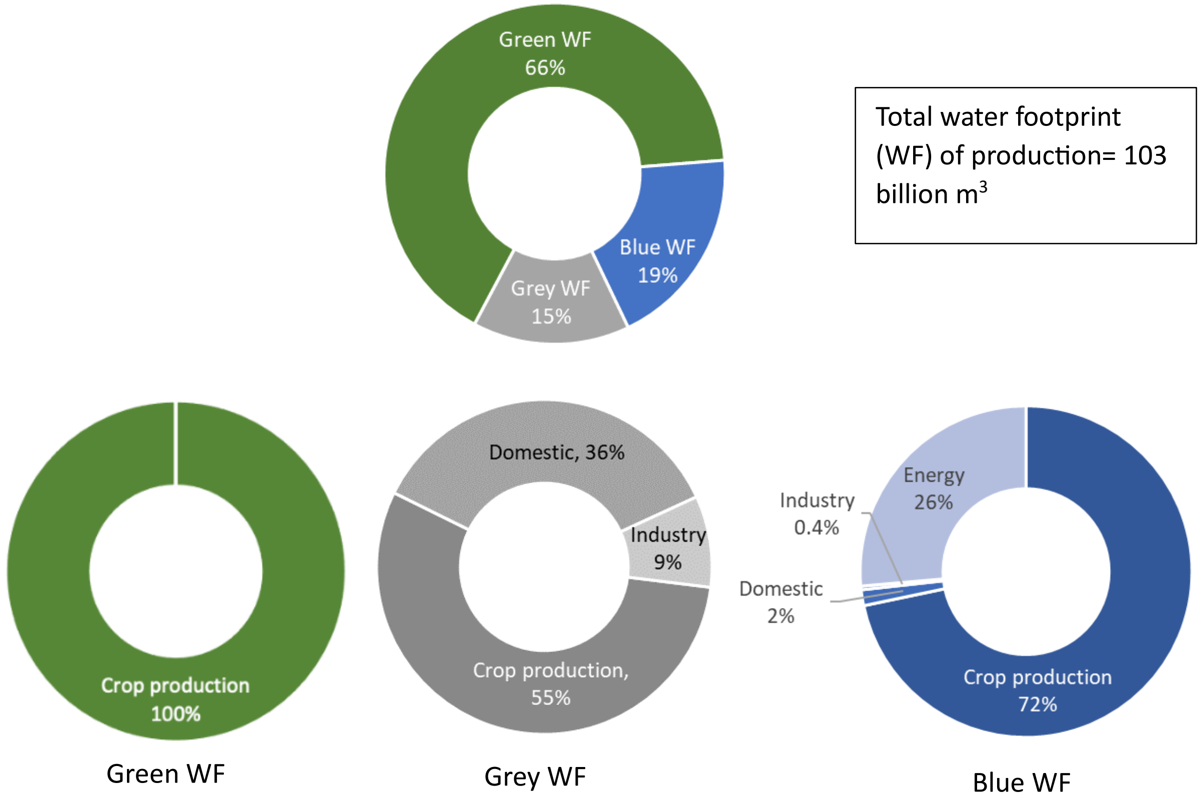


*Figure A 36: Allocation of the water footprint (WF) components is illustrated in the upper figure, while the lower figures depict sectoral breakdowns (green WF on the left, grey WF in the middle, and blue WF on the right), all represented as a percentage of the total water footprint in Türkiye (for the average of 2012-2021).*

On an annual basis, the estimated water footprint of production in Türkiye has shown a very slight increase between 2012 and 2022.

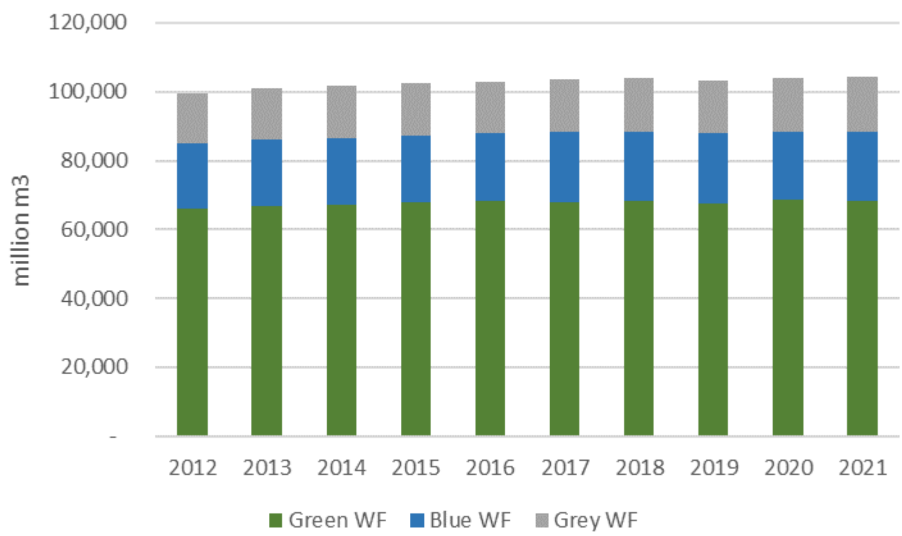


*Figure A 37: The water footprint (WF) of production in Türkiye per year between 2012 and 2021, per green, blue and grey components.*

## The water footprint of crop production in Türkiye

The green water footprint of crop production is 68 billion m$^3$ annually (10-year average). Figure A 38 illustrates the average distribution of green, blue and grey water footprints across various crops, emphasizing the proportional contributions each crop makes to the overall footprint. The largest share of the green water footprint is related to Wheat production at 48%, followed by Barley at 14% and Olives at 6%. The largest share of the blue water footprint can be attribute to Cotton at 25% , Wheat at 15% and Sugar Beet at 8%.  Wheat, Maize and Barley are the largest contributors to the grey water footprint at 37%, 10% and 9% respectively.

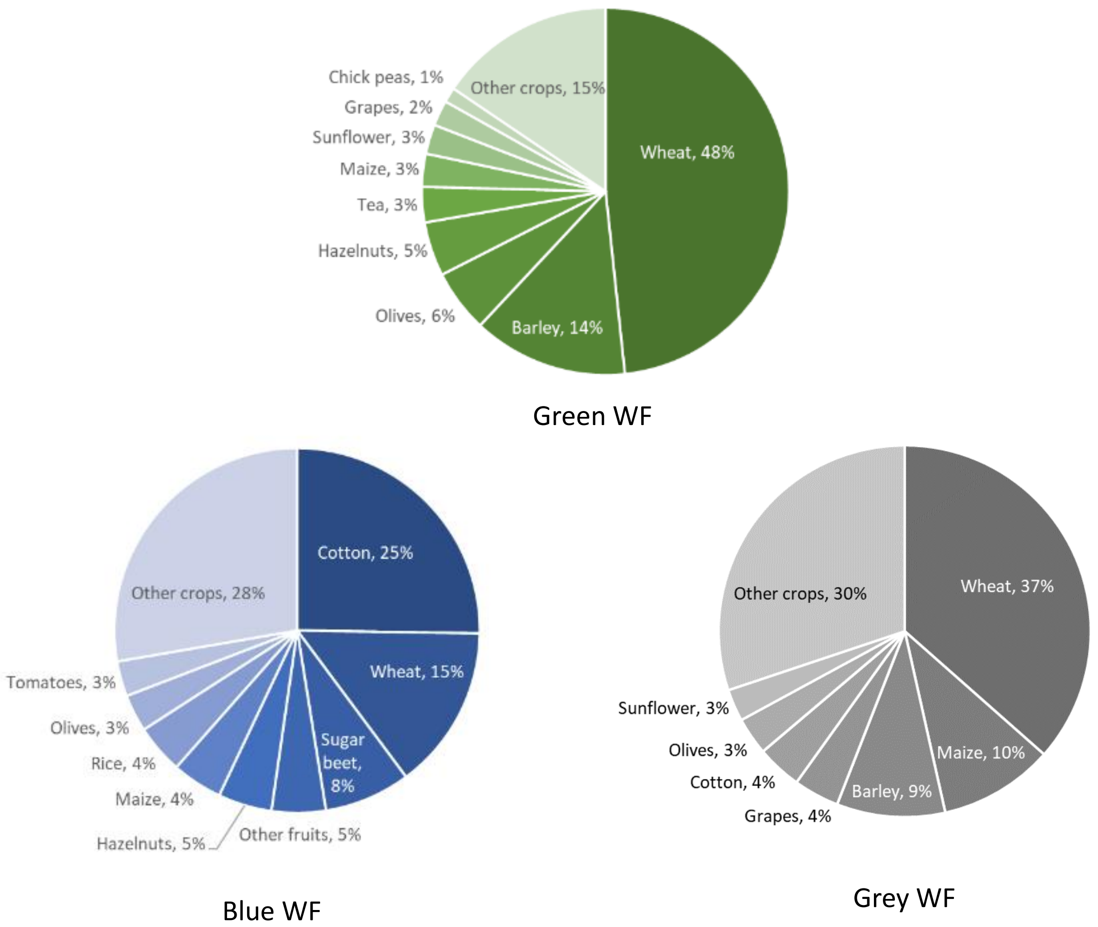


*Figure A 38: Allocation of the water footprint (WF) components per crop (green WF on the top, blue WF on the bottom left, and grey WF on the bottom right), all represented as a percentage of the total of crop production in Türkiye (for the average of 2012-2021).*

## The water footprint of other sectors: industry, domestic water use and energy in Türkiye

In the industrial sector, the blue water footprint was calculated as 0.07 billion m$^3$. The domestic water use sector, encompassing household and public water supply, exhibits a blue water footprint of 0.3 billion m$^3$. The energy sector has a significant blue water footprint of 5.2 billion m$^3$. The grey water footprints of the industry and domestic water use stand at 1.3 and 5.4 billion m$^3$.

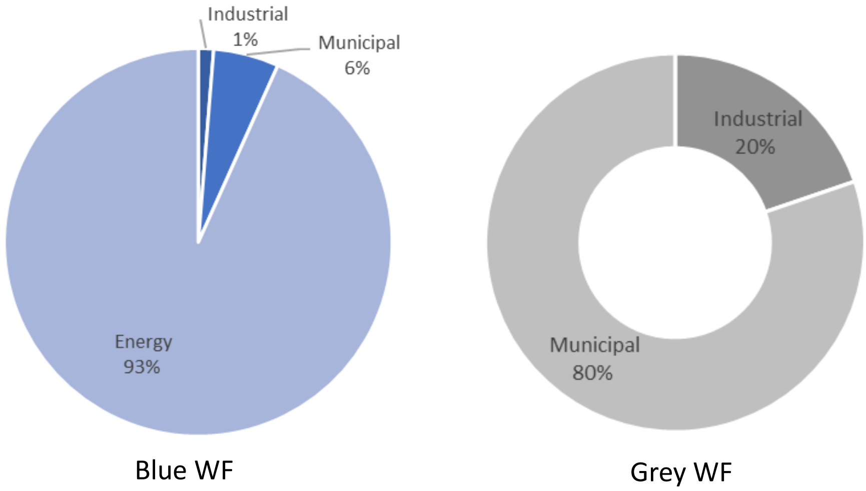


*Figure A 39: Blue (on the left) and grey (on the right) water footprint allocation, represented as a percentage of total water footprint for industrial use, municipal use and energy production in Türkiye (for the average of 2012-2021).*

The percentages in Figure A 40 represent the distribution of various energy types within the blue water footprint of the energy sector. Türkiye has a more balanced mix of water footprints per type of energy source, led by Coal at 35%, Oil and 24%, Natural Gas at 21%, followed by Hydro at 19% and Wind & Solar at 0.99%.

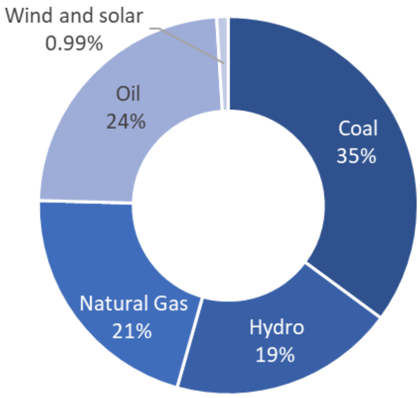


*Figure A 40: The blue water footprint of energy, shares of energy production type in Türkiye.*

### A2.6.3. Virtual water trade of Türkiye

Türkiye annually imports 41.6 billion m$^3$ of green water and 6.9 billion m$^3$ of blue water in relation to import of agricultural products. Wheat claims the largest portion of green virtual water imports at 22%, trailed by soybean (13%), sunflower (11%), cotton (10%), cacao and oil palm (each 7%), rubber (6%) and maize (4%). Green virtual water imports are distributed among several countries, with Russia taking the lead at 28%, followed by Ukraine at 8%, Indonesia and Brazil at 6%, Malaysia, the USA and Ivory Coast at 5%, and Argentina as well as India at 3% (Figure A 41, top left and right).

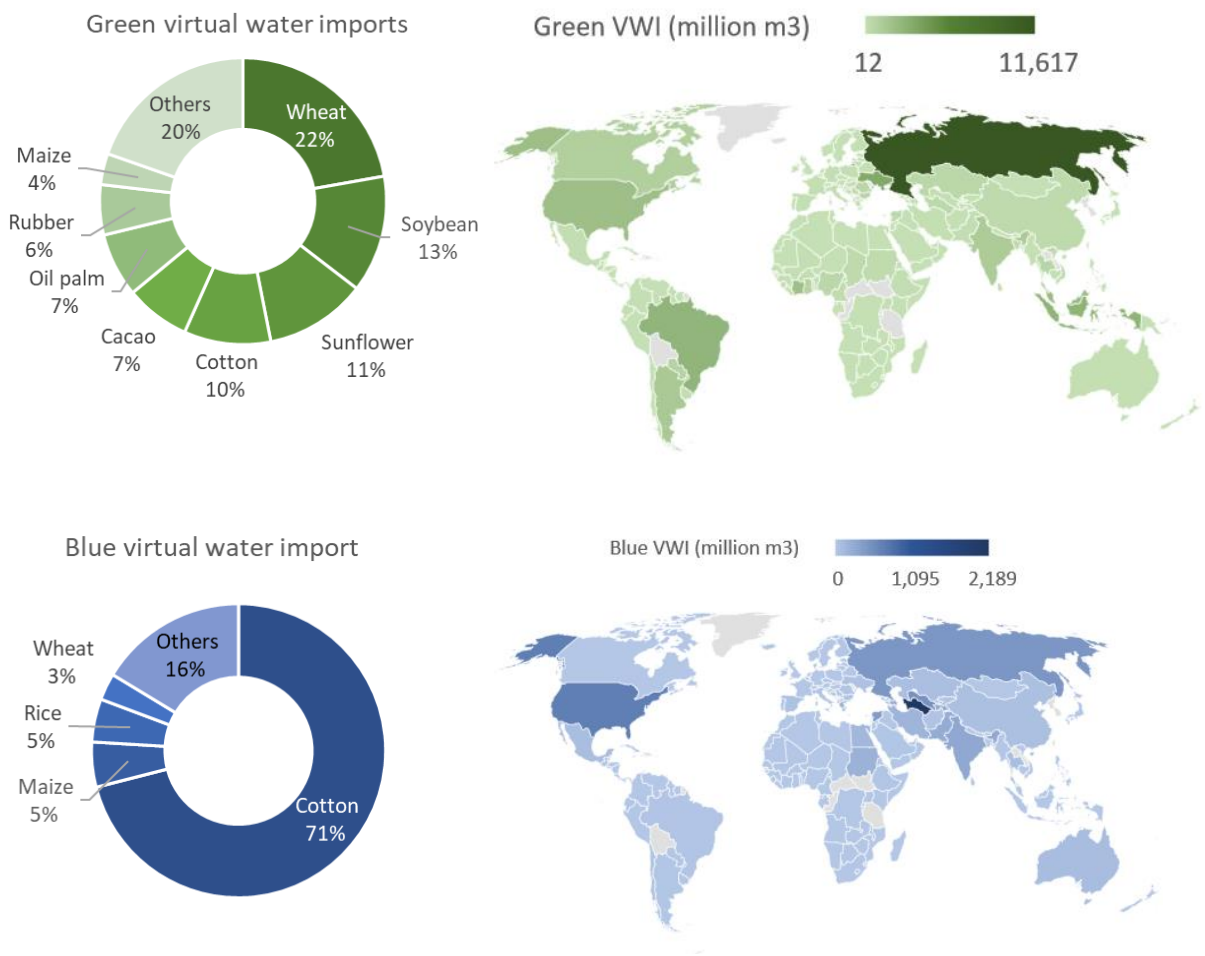


*Figure A 41: Percentage breakdown of virtual water import for each crop for Türkiye in relation to the total green and blue virtual water imports.*

The breakdown of crops for blue virtual water imports is as follows: Cotton accounts for the highest share at 71%, followed by maize and rice at each 5%, wheat at 3%, olives at 2% and walnuts in shell at 1%. In terms of country shares, Turkmenistan leads with 32%, tailed by The USA at 10%, Uzbekistan and Russia at each 7%, Tajikistan, Pakistan and India at each 4%, Greece, Azerbaijan and Sudan at each 3% (Figure A 41, bottom left and right).

Türkiye annually exports a total of 11.4 billion $m^3$ of green water and 2.8 billion $m^3$ of blue water embedded in its exported goods. The breakdown of green virtual water export shares for various crops is as follows: wheat dominates with the largest portion at 47%, trailed by hazelnuts at 16%, sunflower at 5%, grapes at 4%, and maize, chick peas as well as cotton at each 2%. The destination of green virtual water exports is as follows: Iraq takes the lead with 22%, followed by Italy at 7%, Syria at 6%, Germany at 5%, the USA and Angola at 3% and Russia, France, Yemen, Benin, the United Kingdon, Sudan, Somalia, Spain, Israel as well as the Netherlands at 2% (Figure A 42, top figures).

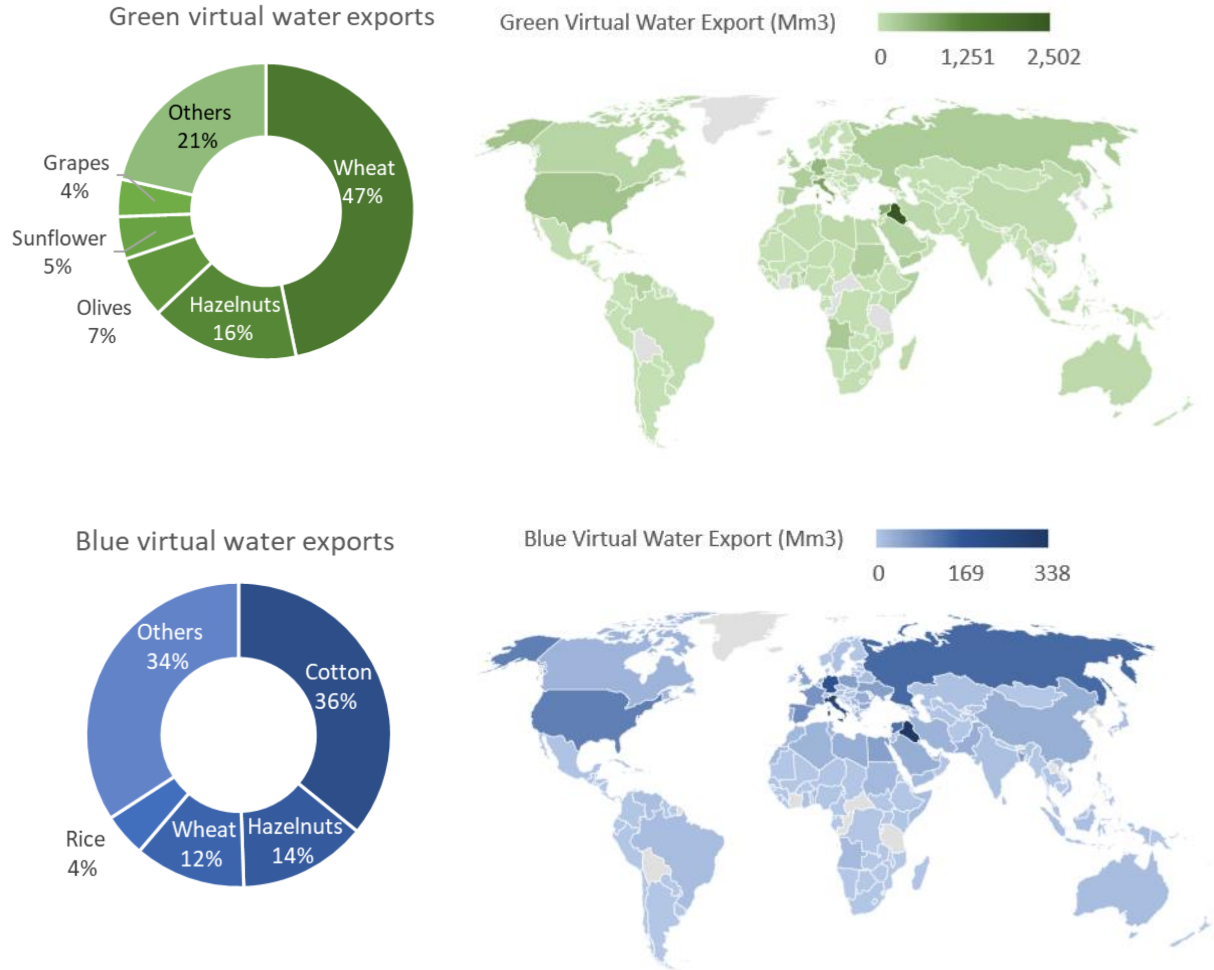


*Figure A 42: Percentage breakdown of virtual water export for each crop for Türkiye in relation to the total green and blue virtual water exports.*

The distribution of blue virtual water exports per crop highlights distinct contributions, with cotton commanding the highest share at 46%, followed by hazelnuts at 17%, wheat at 15%, rice at 6%, and olives, sunflower, 'tangerines, mandarins, clementines' as well as maize at each 4%. Complementing this crop-specific breakdown, the corresponding country shares in blue virtual water exports depict Iraq in the lead at 12%, followed by Italy at 10%, Germany at 7%, Russia at 5%, Syria and the USA at 4%, and Spain as well as France at 3% (Figure A 42, bottom figures).

# Appendix III: Water scarcity maps

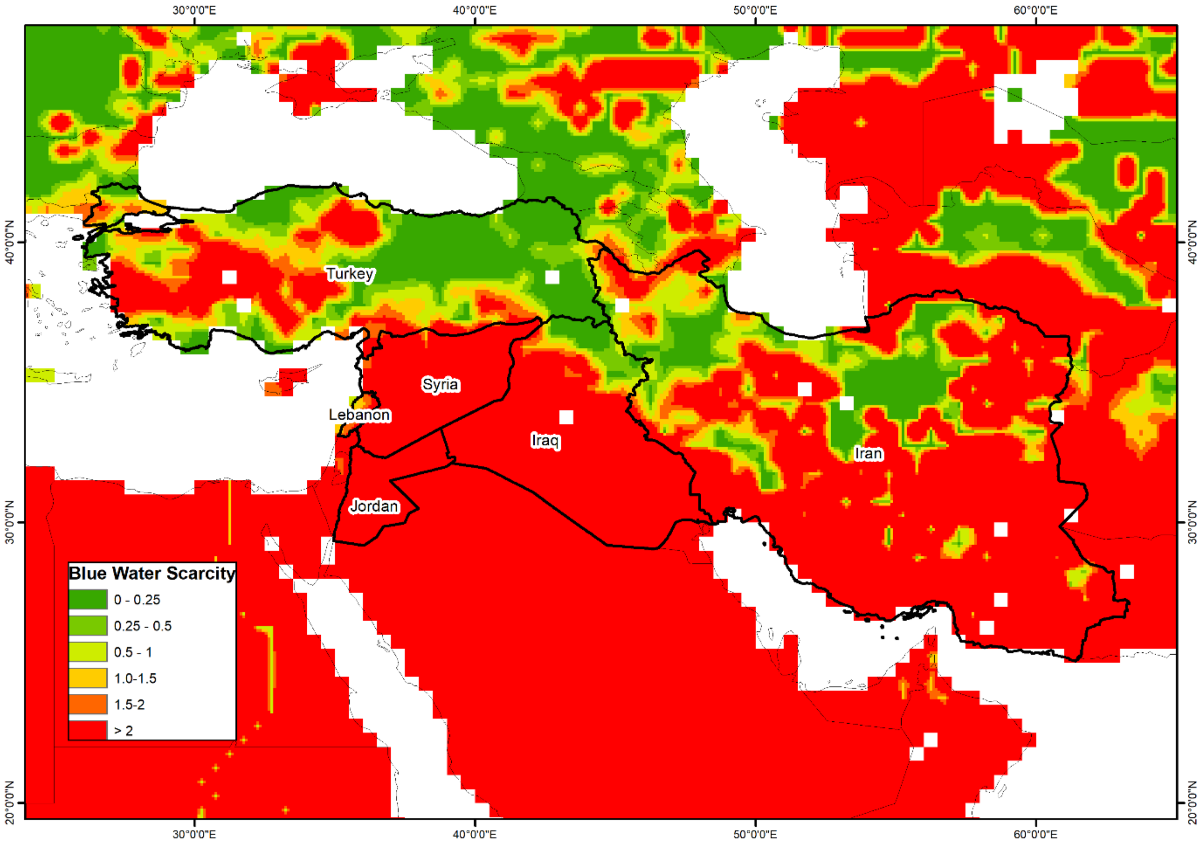


*Figure A 43: Historical annual average water scarcity in the Middle East.*

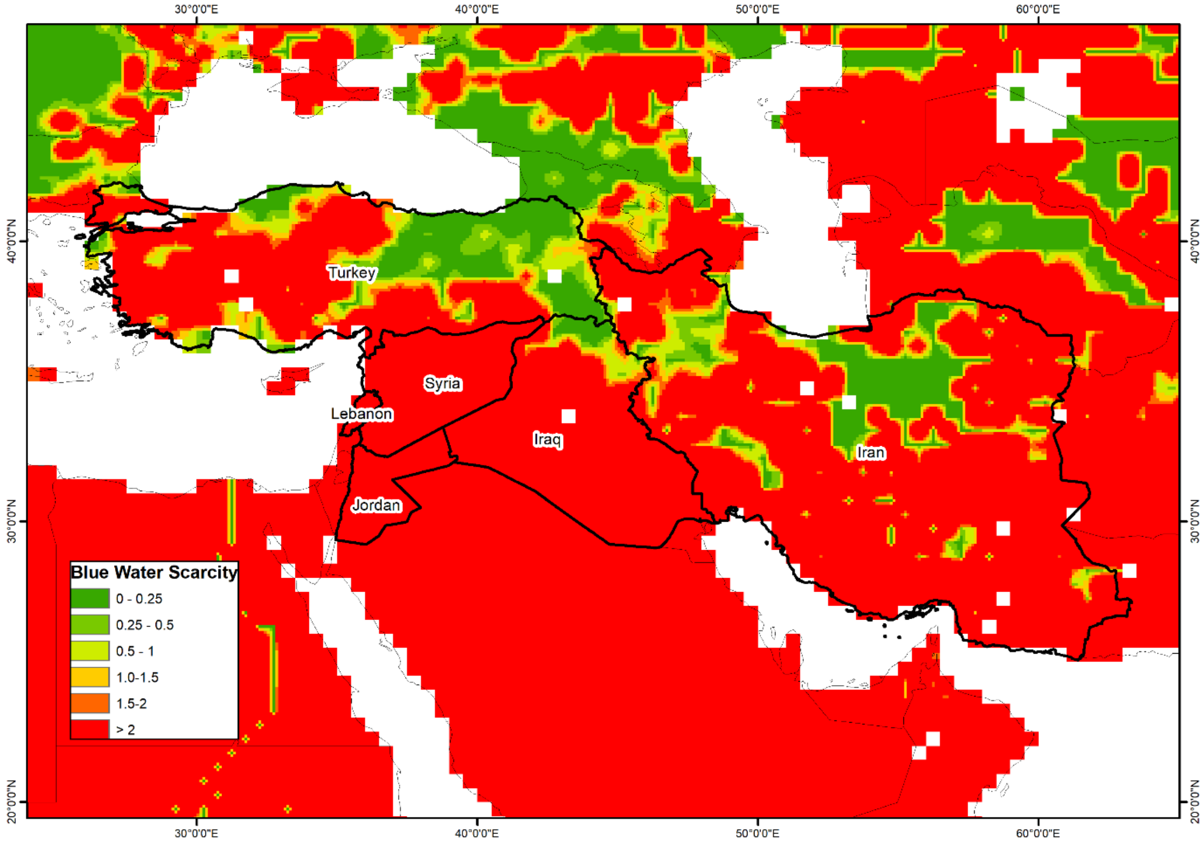


*Figure A 44: Historic August average water scarcity map for the Middle East.*