Water Footprint of agri-food products from MENA countries vs. EU

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**Abstract:** According to the United Nations (UN), since the 1980s, the global rate of water use has increased by 1% per year and by 2050, humanity's water footprint is projected to exceed 30% of current levels. Water security and resource management issues are particularly evident in the Middle East and North Africa (MENA) region. This area (approx. 14,951,232 km2) is generally arid, with more than 355 million people to date. Therefore, the risk of water stress is among the highest in the world. Of great importance to the economies of MENA countries are the exports of agricultural products, which can reach a gross production value per hectare cultivated of $226,000. In 2004, the European Union launched the European Neighborhood Policy, also with some Countries of the MENA region, to promote stability and economic security of the Countries involved, encouraging, in particular, the exchange of agri-food products from and to these countries. Overall, the EU mainly exports beef, cereals and dairy products, and imports fruit, vegetables and olive oil. Starting from an aggregate analysis of the products most exported from the countries to the EU, the study aims to investigate the water footprint of 1t of these products. Through an analysis of the literature (Scopus, Google Scholar, Web of Science), the analysis of data available on the Faostat, and the implementation of the SimaPro software, the study assesses a basket's water footprint of agri-food products. It highlights that the two main impacting productions in terms of water are avocados, whose production has rapidly increased in the last few years, and dates. To progress towards more sustainable agriculture paths and a more responsible uses of natural resources, it could be crucial for water-stressed regions to narrow those productions that contribute to a high level of water discharge.

**Keywords:** Agri-food products; LCA; Water Footprint; MENA Region; European Union

# Introduction

The agri-food sector can be considered one of the most crucial sectors in many economies, both in developing and Industrialized Countries (Egilmez, G, 2014). Its production has increased exponentially during the last decades. As a consequence of this trend, agri-food supply chains have expanded. With the increase in the global population and the related increase in the global food demand, the agri-food sector will be forced to reshape its production strategies (Horton et al., 2016; Lawrence et al., 2019) to meet the demand that is predicted to increase by +70% by 2050 (FAO, 2019). As a matter of fact, in the last years, the international community has highlighted answers to the challenges that the increase in agri-food production will create. Among the actions taken, it is possible to find the 2030 Agenda for Sustainable Development with the 17 Sustainable Development Goals (SDGs), the European Green Deal and the strategy “Farm to Fork” (European Commission, 2020). The international community is worthy of attention to the impacts that the agri-food sector

generally, has on the environment, such as Green House Gases (GHGs) production, land use, soil erosion, resource depletion etc. In particular, the principal damages are related to agricultural practices that are repeated over time and that compromise the balance of the ecosystems (Kibblewhite et al., 2008); but also to the intensive use of synthetic fertilizers, which can unbalance the mineral and microbiological levels of soil (Lohar et al., 2021), leading to soil erosion (Raclot et al., 2009) and loss of biodiversity (Paredes et al., 2021). Strictly linked to the increase in the agri-food trend of production is the use and depletion of fresh water. It has been calculated that the agricultural sector consumes the 80% of blue water reserves (Souissi et al., 2022), and the water footprint of food consumption is calculated to be more than 86% of the total water footprint. According to the World Health Organization (WHO), water stress is a situation where water availability per capita/year is less than 1700 m3. When the situation worsens to 1000 m3 per capita/year, there is a shortage; when water per capita/year drops to 500 m3, water becomes a constraint to development [WTO, 2015; Siddiqi et al., 2011)]. In 2003, and then renewed in 2021, the EU launched the European Neighborhood Policy (ENP) to govern the relationship with 16 of its closest Eastern and Southern neighbours to reinforce stability and prosperity through economics and trade agreements and bilateral cooperation (European Commission, 2021). Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine as Easter Countries. Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine and Tunisia as Southern Countries. Focusing on the latter, these Countries are some that belong to the so-called Middle East and North Africa (MENA) region. This particular geographical area is classified as arid and semi- arid, and it can be considered the one with the most significant water deficit in the world (Bozorg-Hadda et al., 2020) and is already a water-stressed region (Madani et al., 2014; Luo et al., 2015) (Fig.1).



**Fig. 1.** Global water stress (Luo et al., 2015).

According to projections, water availability could fall to 1000 m3 per capita/year by 2050 (Rijsberman, F.R., 2006). The causes that create this extreme situation can be found both in the increasing population growth (between 2010 and 2050, the population is expected to increase by +20%) and the economic development and the new lifestyle people adopt. It has been estimated that 85% of water in the MENA region is used for irrigation (The World Bank, 2010). Moreover, the situation is exacerbated by the increasing effects of climate change, which increases temperature and decreases rainfall. Local water demand is higher than the local self-sufficient capacity of food production (Souissi et al., 2022). By identifying the most imported agri- food products traded in the context of the ENP during 2019, this paper aims to examine which

products have a higher water footprint to determine the impact on the local environment in terms of water.

# Materials and methods

To assess the study, firstly, it has been investigated which have been the main products imported by the EU from some of the MENA region Countries inside the ENP. To do that, Agri-food Trade Statistical Factsheets for each Country has been analyzed. In particular, the data in the statistical factsheets cover a period of 5 years (2016-2020). For the study, it has been considered the year 2019 to have a pre-pandemic trade situation. Table 1 are reported the main product classes exported from the 10 MENA Countries in the EU in 2019 and the related economic values. Even if Syria is considered in the ENP, no data have been found related to the product class exports.

Table 1. Most exported products from the MENA region to Europe (2019).

|  |  |  |
| --- | --- | --- |
| **Countries** | **Product Category** | **Value (mln €)** |
| Algeria | Tropical fruits, spices, nuts | 40 mln € |
| Sugar beet and sugar cane | 12 mln € |
|  | Vegetables | 402 mln € |
| Egypt | Fruits (except tropical fruits and citrus) | 225 mln € |
|  | Citrus fruits | 102 mln € |
|  | Tropical fruits, spices, nuts | 206 mln € |
| Israel | Vegetables | 119 mln € |
|  | Citrus fruits | 99 mln € |
| Jordan | Vegetables | 6 mln € |
| Tropical fruits, spices, nuts | 3 mln € |
| Lebanon | Tobacco | 17 mln € |
| Tropical fruits, spices, nuts | 5 mln € |
| Libya | - | - |
|  | Vegetables | 959 mln € |
| Morocco | Fruits (except tropical fruits and citrus) | 603 mln € |
| Citrus fruits | 136 mln € |
|  | Tropical fruits, spices, nuts | 57 mln € |
| Syria | - | - |
|  | Olive oil | 277 mln € |
| Tunisia | Tropical fruits, spices, nuts | 105 mln € |
|  | Vegetables | 55 mln € |
| Palestine | Tropical fruits, spices, nuts | 10 mln € |
| Olive oil | 5 mln € |

Since Agri-food Trade Statistical Factsheets report the economic value of classes of products only, for each category products have been selected by using FAOSTAT based on the total production of that particular product in the economy of the Country (Tab. 2).

# Table 2. Major fruit and vegetable production in the MENA Area

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Countries** | **Product****Categories** | **Products** | **Production (Mton)** | **Area (ha)** | **Export (Mton)** | **Export value (1000USD)** |
|  | Tropical | Dates | 1,136,025 | 169,786 | 102,016 | 93,096 |
|  | fruits, | Almonds | 72,412 | 35380 | - | - |
| **Algeria** | spices, nuts | Cashews | 12,602 | 4886 | - | - |
|  | Sugar beet | Sugar beet | - | - | - | - |
|  | and sugarcane | Sugar cane | - | - | - | - |
|  |  | Tomatoes | 6,814,460 | 174,730 | 107,403 | 48,960 |
|  | Vegetables | Cucumbers | 566,155 | 25,734 | 6,028 | 257 |
|  |  | Zucchini | 1,347,230 | 49,897 | 3,659 | 1,812 |
|  | Fruits | Grapes | 1,595,380 | 72,517 | 154,207 | 234,888 |
|  | (except | Melon | 120,400 | 4,459 | 3,445 | 1,669 |
| **Egypt** | tropical | Watermelon | 1,401,300 | 42,464 | 12,254 | 4,606 |
|  | fruits and | Apples | 701,435 | 28,057 | 1,468 | 555 |
|  | citrus | Apricots | 76,650 | 4,509 | 165 | 67 |
|  | fruits) | Strawberries | 545,284 | 14,350 | 38,543 | 88,364 |
|  |  | Orange | 3,067,630 | 122,705 | 1,817,406 | 656,594 |
|  | Citrusfruits | Tangerine | 965,960 | 45,596 | 119,334 | 46,760 |
|  |  | Lemon | 313,540 | 13,064 | 96,207 | 33,330 |
|  | Tropical | Dates | 10,006 | 473 | 104,909 | 203,381 |
|  | fruits, | Almonds | 10,006 | 473 | 95 | 709 |
| **Israel** | spices, nuts | Avocado | 138,766 | 10,520 | 43,121 | 76,890 |
|  | Vegetables | Tomatoes | 299,082 | 4,689 | 642 | 1,318 |
|  | Citrus | Orange | 74,878 | 4,020 | 2,368 | 2,211 |
|  |  | Lemon | 75,565 | 2,575 | 371 | 451 |
| **Jordan** | Vegetables | Cauliflowers | 46,799 | 900 | 11,943 | 6,773 |
|  |  | Cucumbers | 163,484 | 1,585 | 34,944 | 21,458 |
|  | Tropical fruits, spices, nuts | Dates | 23,375 | 3,372 | 6,205 | 22,333 |
|  | Tobacco |  | 9,602 | 7,912 | 8,883 | 29,558 |
| **Lebanon** | Tropical fruits,spices, nuts | Dates | - | - | 422 | 1,609 |
| **Libya** | - | - | - | - | - | - |
|  | Vegetables | Tomatoes | 1,347,085 | 14,861 | 587,819 | 764,876 |
|  |  | Beans | 216,626 | 9,235 | 135,638 | 262,187 |
| **Morocco** | Fruits (except tropical fruits and citrusfruits) | Blueberries | 71 | 16 | 25,201 | 181,816 |
|  |  | Apples | 809,762 | 49,731 | 114 | 86 |
|  | Citrus | Lemon | 44,919 | 3,208 | 15,254 | 8,699 |
|  | Tropical fruits,spices, nuts | Avocados | 54,576 | 5,069 | 19,363 | 51,422 |
| **Syria** | - | - | - | - | - | - |
|  | Olive oil | - | - | - | 163,423 | 466,473 |
| **Tunisia** | Tropical fruits, spices, nuts | Dates | 289,000 | 63,073 | 113,887 | 265,775 |
| **Palestine** | Tropical fruits, | Dates | 7,734 | 710 | 6,274 | 29,233 |
|  | Olive oil | - | - | - | 11,000 | 52,962 |

spices, nuts

Then, to quantify the potential water stress of the various Countries, the Water Footprint (or the direct and indirect use of freshwater required to produce a commodity) was calculated for each product identified. The formula proposed by Mekonnen and Hoekstra et al. (2011) was used for the calculation and is expressed as the sum of the blue, green and grey water footprint of the i-th agri- food products (eq. 1-2).

𝑊𝐹𝑖,𝑇𝑂𝑇𝐴𝐿 = 𝑊𝐹𝑖,𝑏𝑙𝑢𝑒 + 𝑊𝐹𝑖,𝑔𝑟𝑒𝑒𝑛 + 𝑊𝐹𝑖,𝑔𝑟𝑒𝑦 (1)

𝑊𝑎𝑡𝑒𝑟 𝐹𝑜𝑜𝑡𝑝𝑟𝑖𝑛𝑡 = ∑ 𝑊𝐹𝑖,𝑇𝑂𝑇𝐴𝐿 (2)

Where WFblue represents the volume of freshwater withdrawn from the surface and groundwater for agricultural, domestic and industrial uses, used and not returned (or returned at another time), WFgreen indicates rainwater evaporating or transpiring in plants and soils. WFgrey indicates the amount of water needed to dilute the volume of pollutants so that water quality in the environment where the pollution occurred remains above predetermined water standards. WF has been calculated using SimaPro 9.2 software. Due to the unavailability of data, the following products were excluded: cashews, sugar cane, strawberries, tangerines, tobacco and olive oil. In addition, because there are currently no databases specific to agricultural production in MENA countries, the global average production for each commodity was considered for the calculation of WF.

# Results and discussions

The cultivation of 1 ton of product was chosen as the functional unit. As it is possible to note from Table 3, the most water-consuming is the production of avocados, impacting 26.64% of water consumption. The Country that, according to FAOSTAT, has the most significant production of this kind of product among those considered is Israel, with 138,766 tons produced in 2019. In general, avocados' global production and consumption have drastically increased in the last 150 years. This is mainly due to the expansions of markets where the product was not initially consumed in the past, like Europe, China and Japan (Schaffer et al., 2013). Moreover, avocado is not only consumed as a fresh product but is also used by the cosmetic industry (Duarte et al., 2016). To stress the economic importance of the market, in 2018, it reached more than US$ 13 bn with Mexico as the primary producer with 2.1 Mt. Focusing on the Mediterranean area, Israel is the leading producer, followed by Spain with 90,000 t (Kourgialas et al., 2021). The second crucial product in water consumption is dates, with 477.35 m3 of water used to produce 1t. Both avocado and date's water consumption are linked to the cultivations' irrigation phase. The largest producer of dates among the countries considered in the study in Tunisia, with 289,000 t. The Country has limited water resources and is mainly used for animal farming (Soussi et al., 2022). As it is possible to consider from Table 2, among the Countries and productions considered, Egypt has the main producer of oranges and grapes. The related water footprints are 134 m3 and 174m3, respectively.

4000

3500

3000

2500

2000

1500

1000

500

0

**Figure 1.** Water Footprint of major fruits and vegetables in the MENA region.

# Conclusions and future perspectives

Starting from the aggregated value of products exported by some MENA Countries inside the European Neighborhood Policy towards the EU, the paper has analyzed the water footprint of 1 t of the main agri-food productions. Moreover, the paper stresses the importance of the market in leading the increase, or the decrease, in the production of determined products, such as avocado. In this sense, it could be crucial for the economies and for a more sustainable way of production to organize agri- food productions to their water footprint, applying those with the lower one in areas with lower water availability. In this sense, this could be the way to develop a new solution for achieving SDG 6. The study has not focused on the political and governance constraints affecting the Countries considered. Future research could implement this aspect to shape a more detailed situation since these kinds of constraints deeply affect the division of the water resources shares and their uses.

# References

Duarte, P.F., Chaves, M.A., Borges, C.D., Mendonça, C.R.B., 2016. Avocado: characteristics, health benefits and uses. Ciˆencia Rural 46 (4), 747–754. https://doi. org/10.1590/0103- 8478cr20141516.

European Commission. Farm to Fork Strategy. For a fair, healthy and environmentally friendly food system. (2020).

European Commission. Joint communication to the european parliament, the council, the european economic and social committee and the committee of the regions. (2021).

FAO (2019) The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. Rome. Available at: https:/[/www.fao.org/state](http://www.fao.org/state-of-food-agriculture)-[of-food-agriculture](http://www.fao.org/state-of-food-agriculture) /2019/en/. Accessed on May 2022.

G. Egilmez, Y.S. Park. Transportation related carbon, energy and water footprint analysis of US manufacturing: an eco-efficiency assessment. Transp. Res. Part D: Transp. Environ., 32 (2014), pp. 143-159, 10.1016/j.trd.2014.07.001

[Horton, P.,](https://www.scopus.com/authid/detail.uri?origin=resultslist&authorId=57203184101&zone) [Koh, L.,](https://www.scopus.com/authid/detail.uri?origin=resultslist&authorId=24824748600&zone) [Guang, V.S.](https://www.scopus.com/authid/detail.uri?origin=resultslist&authorId=56820251900&zone) [An integrated theoretical framework to enhance resource](https://www.scopus.com/record/display.uri?eid=2-s2.0-84960805243&origin=resultslist&sort=plf-f&src=s&st1=An%2Bintegrated%2Btheoretical%2Bframework%2Bto%2Benhance%2Bresource%2Befficiency%2csustainability%2Band%2Bhuman%2Bhealth%2Bin%2Bagri-food%2Bsystems&sid=7a3d411cebc347caea304b9127474fff&sot=b&sdt=b&sl=135&s=TITLE-ABS-KEY%28An%2Bintegrated%2Btheoretical%2Bframework%2Bto%2Benhance%2Bresource%2Befficiency%2c%2Bsustainability%2Band%2Bhuman%2Bhealth%2Bin%2Bagri-food%2Bsystems%29&relpos=0&citeCnt=36&searchTerm) [efficiency, sustainability and human health in agri-food systems.](https://www.scopus.com/record/display.uri?eid=2-s2.0-84960805243&origin=resultslist&sort=plf-f&src=s&st1=An%2Bintegrated%2Btheoretical%2Bframework%2Bto%2Benhance%2Bresource%2Befficiency%2csustainability%2Band%2Bhuman%2Bhealth%2Bin%2Bagri-food%2Bsystems&sid=7a3d411cebc347caea304b9127474fff&sot=b&sdt=b&sl=135&s=TITLE-ABS-KEY%28An%2Bintegrated%2Btheoretical%2Bframework%2Bto%2Benhance%2Bresource%2Befficiency%2c%2Bsustainability%2Band%2Bhuman%2Bhealth%2Bin%2Bagri-food%2Bsystems%29&relpos=0&citeCnt=36&searchTerm) [Journal of Cleaner Production](https://www.scopus.com/sourceid/19167?origin=resultslist) 120, pp. 164-169 (2016)

Kibblewhite, M.G.; Ritz, K.; Swift, M.J. Soil health in agricultural systems. Philos. Trans. R. Soc. B Biol. Sci. 2008, 363, 685–701.

[Kourgialas, N.N.,](https://www.scopus.com/authid/detail.uri?origin=resultslist&authorId=35317691000&zone) [Dokou, Z.](https://www.scopus.com/authid/detail.uri?origin=resultslist&authorId=34876630000&zone) [Water management and salinity adaptation approaches of Avocado](https://www.scopus.com/record/display.uri?eid=2-s2.0-85105690936&origin=resultslist&sort=plf-f&src=s&st1=Water%2Bmanagement%2Band%2Bsalinity%2Badaptation%2Bapproaches%2Bof%2BAvocado%2Btrees%3a%2BA%2Breview%2Bfor%2Bhot-summer%2BMediterranean%2Bclimate&sid=1fa4cd49bab1668cdb19aed108a70507&sot=b&sdt=b&sl=130&s=TITLE-ABS-KEY%28Water%2Bmanagement%2Band%2Bsalinity%2Badaptation%2Bapproaches%2Bof%2BAvocado%2Btrees%3a%2BA%2Breview%2Bfor%2Bhot-summer%2BMediterranean%2Bclimate%29&relpos=0&citeCnt=3&searchTerm) [trees: A review for hot-summer Mediterranean climate](https://www.scopus.com/record/display.uri?eid=2-s2.0-85105690936&origin=resultslist&sort=plf-f&src=s&st1=Water%2Bmanagement%2Band%2Bsalinity%2Badaptation%2Bapproaches%2Bof%2BAvocado%2Btrees%3a%2BA%2Breview%2Bfor%2Bhot-summer%2BMediterranean%2Bclimate&sid=1fa4cd49bab1668cdb19aed108a70507&sot=b&sdt=b&sl=130&s=TITLE-ABS-KEY%28Water%2Bmanagement%2Band%2Bsalinity%2Badaptation%2Bapproaches%2Bof%2BAvocado%2Btrees%3a%2BA%2Breview%2Bfor%2Bhot-summer%2BMediterranean%2Bclimate%29&relpos=0&citeCnt=3&searchTerm). [Agricultural Water Management](https://www.scopus.com/sourceid/35824?origin=resultslist) 252,106923. (2021)

Lohar, R.R.; Hase, C.P. Sustainable Agricultural Practices for the Improvement of Growth and Yield of some Important Crops popular in Walwa-tehsil, district Sangli (Maharashtra) A Review. J. Plant. Sci. Res. 2021, 37, 133–143.

Luo, T., R. Young, and P. Reig. 2015. "Aqueduct projected water stress rankings." Technical note. Washington, DC: World Resources Institute, August 215. Available online at <http://www.wri.org/publication/aqueduct-projected-water-stress-country-rankings>.

M. M. Mekonnen and A. Y. Hoekstra. The green, blue and grey water footprint of crops and derived crop products. Hydrol. Earth Syst. Sci., 15, 1577–1600. (2011)

M.A. Lawrence, P.I. Baker, C.E. Pulker, C.M. Pollard. Sustainable, resilient food systems for healthy diets: the transformation agenda. Public Health Nutr., 22 (16) (2019), pp. 2916-2920, 10.1017/S1368980019003112

Madani, K. Water management in Iran: what is causing the looming crisis? Journal of Environmental Studies and Sciences 4 (4), 315–328. (2014)

O. Bozorg-Haddad et al. | Evaluation of water shortage crisis in the Middle East. [Journal of](https://www.scopus.com/sourceid/17536?origin=resultslist) [Water Supply: Research and Technology - AQUA](https://www.scopus.com/sourceid/17536?origin=resultslist) 69(1), pp. 85-98. (2020)

Paredes, D.; Rosenheim, J.A.; Chaplin-Kramer, R.; Winter, S.; Karp, D.S. Landscape simplification increases vineyard pest outbreaks and insecticide use. Ecol. Lett. 2021, 24, 73–83.

Raclot, D.; Le Bissonnais, Y.; Louchart, X.; Andrieux, P.; Moussa, R.; Voltz, M. Soil tillage and scale effects on erosion from fields to catchment in a Mediterranean vineyard area. Agric. Ecosyst. Environ. 2009, 134, 201–210.

Rijsberman, F. R. Water scarcity: fact of fiction? Agricultural Water Management 80 (1–3), 5– 22. 2006.

Schaffer, B., Wolstenholme, B.N., Whiley, A.W., 2013. The Avocado Botany, Production and Uses 2nd Edition. ISBN: 978 1 84593 701 0.

Siddiqi, A; Diaz Anadon, L. The water–energy nexus in Middle East and North Africa. Energy Policy. (2011).

Souissi, A.; Mtimet, N.; McCann, L.; Chebil, A.; Thabet, C. Determinants of Food Consumption Water Footprint in the MENA Region: The Case of Tunisia. Sustainability 2022, 14, 1539. https://doi.org/ 10.3390/su14031539

The World Bank (2010). Available at: <http://web.worldbank.org/archive/website01414/WEB/0> MEN-2.HTM, accessed on May 2022.

World Health Organization. Investing in Water and Sanitation: Increasing Access, Reducing Inequalities;World Health Organization: Geneva, Switzerland, 2015.