

Interactive comment on “Assessment of food trade impacts on water, food, and land security in the MENA region” by Sang-Hyun Lee et al.

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Comments on the manuscript Assessment of food trade impacts on water, food, and land security in the MENA region submitted to Hydrology and Earth System Sciences by Lee, Mohtar and Yoo

The manuscript analyzes the virtual water trade network for import and export of blue and green water of four crop types for the MENA region. The analysis is carried out with a number of indices (water footprints, in-degree centralities) and eigenvectors and utilizes data from previous studies. The main conclusions highlight food sector securities for the countries of the MENA region and their temporal development over the years 2000 - 2012. I consider this study to be a timely and viable approach. I acknowledge

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the discussion of water availability through food security and land availability.

Generally, the methods are concisely described, figures are mostly meaningful, tables support the text, yet both of the two latter can be enhanced. There are some occasions where statements are unnecessary or unproven which should be revised (see specific comments below). The introduction cites many valid references, but I think that the manuscript should discuss many more. I had a very quick search for "food nexus MENA" in ScienceDirect which brought the following results that definitely should be discussed:

F. Saladini, G. Betti, E. Ferragina, F. Bouraoui, S. Cupertino, G. Canitano, M. Gigliotti, A. Autino, F.M. Pulselli, A. Riccaboni, G. Bidoglio, S. Bastianoni, Linking the water-energy-food nexus and sustainable development indicators for the Mediterranean region, *Ecological Indicators*, Volume 91, 2018, Pages 689-697, ISSN 1470-160X, <https://doi.org/10.1016/j.ecolind.2018.04.035>.

Mohammad Al-Saidi, Diana Birnbaum, Renata Buriti, Elena Diek, Clara Hasselbring, Andres Jimenez, Désirée Woinowski, *Water Resources Vulnerability Assessment of MENA Countries Considering Energy and Virtual Water Interactions*, *Procedia Engineering*, Volume 145, 2016, Pages 900-907, ISSN 1877-7058, <https://doi.org/10.1016/j.proeng.2016.04.117>.

Afreen Siddiqi, Laura Diaz Anadon, *The water–energy nexus in Middle East and North Africa*, *Energy Policy*, Volume 39, Issue 8, 2011, Pages 4529-4540, ISSN 0301-4215, <https://doi.org/10.1016/j.enpol.2011.04.023>.

Lanouar Charfeddine, Zouhair Mrabet, *The impact of economic development and social-political factors on ecological footprint: A panel data analysis for 15 MENA countries*, *Renewable and Sustainable Energy Reviews*, Volume 76, 2017, Pages 138-154, ISSN 1364-0321, <https://doi.org/10.1016/j.rser.2017.03.031>.

Khalil Lezzaik, Adam Milewski, Jeffrey Mullen, *The groundwater risk index: Devel-*

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opment and application in the Middle East and North Africa region, *Science of The Total Environment*, Volumes 628–629, 2018, Pages 1149-1164, ISSN 0048-9697, <https://doi.org/10.1016/j.scitotenv.2018.02.066>.

I am sure, there are many more, but I tend to leave this research to the authors. I also miss a discussion of the analysis that is solely based on the data from the last years with different societal, political and environmental aspects; currently, the manuscript only shows the changes in food supply security and interprets the results without considering the bounding conditions for the MENA countries, which strongly differ. Finally, I think that especially the conclusions section should be more detailed and overhauled - currently, this is only a collection of vague statements, but the analysis and the presented results show much more potential of detailed conclusions; for example, the results could be synthesized for all the countries of focus in a comparable way.

If the authors can address the issues above (broader coverage/discussion of relevant publications, country-specific aspects influencing food trade, clearer conclusions) together with the specific comments listed below, I suggest the editors to accept the manuscript for publication. If the authors consider my comments to be valuable, I would be available for a second revision.

Specific comments

Line 27: Please add adequate sources to state that the primary resource gaps will grow. (Maybe, the ones in L69 will work?)

L29: What do you mean by saying "the food portfolio [...] has been complicated by and increased degree of risks..."?

L30: Please provide sources that the MENA region shows tendencies for an inability to satisfy needs with domestic production.

L32: You say that (food) trade has been understudied - one might argue that as trade is a central part of food security (which you likewise support), it is quite well understood

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by the relevant trading actors.

L29, 33: I think, MENA & VWT (and all other abbreviations) should be defined in the text (not in the abstract).

Concerning the meaning of VWT: if a product uses 1000 l/kg water to be produced in one region, it might have a much more severe impact in an arid climate than in a humid one (you cannot grow coffee in Lybia, but in Chile). If the value is to be interpreted locally, doesn't it lose its meaning and transferability?

L56: You say that Fader et al (2011) show water savings of 263 km³/a due to beneficial agricultural production in other countries; does this calculation include the additional costs that arise from transport? Additionally, I am wondering how much the import of exotic products to western countries (an unnecessary trade in comparison to the import of basic crop products to arid countries) contributes to in the large savings (17 billion m³ blue water, L65) of global extent?

L111: please add units to WS/LS.

L114/115: Two sentences starting with "In addition" - please revise. I also do not understand the meaning of "In addition, each variable is dependent on local characteristics."

L118: If you irrigate a crop with rain harvested water, either directly as water is used from the reservoir or indirectly as the reservoir water is used for enhanced groundwater recharge, is this blue or green water?

L120: "Thus, the study for national water footprint should be executed for each country, basin, or specific area; however, this was outside the scope of the current study." - this sentence is unclear to me, especially the first part: what is the difference between "national" and "country"? For which regional unit did you carry out your study?

Can you please name the countries of the MENA region that you studied in the beginning, e.g. around L87ff?

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L127: What is the "limited water footprint"?

Table 1: - Do I understand it correctly that the information in Table 1 is taken from Mekonnen and Hoekstra (2010)? If so, please add this information in the table caption. - Please add the time period of the data in the caption. - Can you please explain why the blue water footprint is larger than the green water footprint? Why does a plant need less rainwater than groundwater? - Which footprint did you use to calculate the land footprint?

Table 2: - Again, please add the source of this data in the caption. - This data is shown for the years 2000-2012; I assume there are all mean values - please add this information. - If these are mean values, what was the standard deviation of the data? Is there a trend in the data? - Can you please add how this data was acquired and certain this data is? - Can you add a row showing the sums of the individual columns?

L154: It is good that you list previous network-based approaches that investigated VWT structures, but you should not only mention the citations and rather shortly summarize their works and how your work contributes to this.

Equations 6 & 7: - is "j" in the sums as the starting counter equal to 1? I think, the usage of "j" is misleading, as it also refers to exporting countries. - is N (total number of countries) constant for all i (importing countries)? What if a country i only trades with one other country, i.e. $N = 1$; then, the equation gives a division by zero, correct?

Equation 7: Why is the S_{inDC} not related to the total volume of virtual water traded but to the number of total number of countries?

L172 & 173: I think, it should be "high levels" and "low levels".

Eq 8: What is α_{ij} ?

L196ff - Please revise this paragraph: - The first sentence rather belongs to a summary, after you showed results, but you did not at this place in the manuscript. - The second sentence is given without reference/citation. - The third sentence contradicts the first

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two sentences. - The fourth sentence does not state whether Egypt imports from MENA countries or somewhere else. - The fifth sentence is not justified by the one example you state. - I also do not understand the intension of this paragraph, what do you want to convey here? Even the following sentence in L202 starts with "however" as if you wanted to say "but I actually want to talk about something else".

L206: "This means that the contribution of import of barley, maize, and wheat on water security in Saudi Arabia was significant." - how do you come to this conclusion?

A general comment: for example in L209, you state that Egypt would suffer from water shortage if the exporting countries banned wheat export to Egypt. I think that this is only partly true, i.e. only in those cases where the respective crops would actually grow in the individual countries. Considering rice, for example: I am sure that none of the MENA countries would be able to grow this crop even if the virtual water equivalent would be available. Please elaborate on this comment.

L208: The statement of 1.8 billion m³/a water available for Egypt is missing a source.

L210: "The crop import could result in a large amount of land savings." - this is an unnecessary statement. Likewise in L215: "These results can elicit useful information for analyzing the trade-off between food and water-land securities in the MENA region in terms of sustainable development."

L210ff: "In Saudi Arabia, land savings based on the import of barley, maize, and wheat, amounted to 1.6 million ha/year, and Lebanon was also strongly influenced by the impact of crop import on land savings. For example, approximately 0.24 million ha could be saved by crop imports, comprising 36% of the agricultural area in Lebanon, that indicates that the crop trade in Lebanon has significant benefits in terms of land resources compared to water resources." - please revise and do not mix two different countries in different sentences.

L216: What do you mean by this: "However, water saving indicates the virtual water

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saving, and sometimes it is larger than the total water resources in some countries. "

L216/217: "However" twice as starting word.

L217: "However, these results showed that the increase of food security is accompanied by numerous water requirements in the MENA region." - I do not understand this. Please revise.

L218ff: "Additionally, the saved land is not always suitable for agricultural areas." - The "saved land", i.e. the equivalent required area to grow imported crops, is probably not available. Do you have information on this?

"Some crops are required for the specific type of land, ..." - It is rather the other way: you require a specific soil for this or that crop.

"...and the productivity is also different based on soil." - Do you mean "the productivity is varies with different soils"?

"Even if we can save land..." - Why do you think, the reason to import is to save land? - Why do you write "we"?

"...there is the limitation for considering the land saving as an agricultural land saving in accordance to this study." - What do you mean by this?

Table 3: - Please check for unnecessary line breaks (eg. Saudi Arabia, Blue water, Barley). - Do I understand it correctly that table 3 shows the results from the product of water footprint (table 1) and the annual import (table 2)? If so, how could you fill the gaps for the water footprint in blue water barley and green water maize? -> Oh, I see you wrote "0" for partly - please correct this and write "-".

Section 3.1 should be shortened; often, statements are given that are unnecessary, unproven or uncited. The information from table 3 can and should be offered in a much more compact way.

L227: Are the numbers for annual water import average values?

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Fig 1: - The grey scale (ie the total water import) uses uneven separating numbers and unequal intervals; I suggest to use even numbers (e.g. 1500 - 15000 instead of 1495 - 15410 for the first green water import interval) and evenly spaced intervals. - I cannot read the number in the legend for annual water import - Some pie charts are very small (Qatar, Oman, Bahrain, Lebanon) - Why do the pie charts vary in size?

Table 3 vs 4: I do not understand the difference between "water savings due to imported crops" (table 3) and "imported water" (table 4) - can you please explain this difference and describe why both values are different?

Section 3.2.2 / figure 3: how could you determine which water (blue or green) was used to grow the crops in the exporting countries?

Fig. 3: Why do you give the numbers here in Gm³ while all other volumes are given as volume / time (Mm³/y)? I suggest to be consistent for comparability especially with such large numbers which are hard to imagine.

Fig. 4: the width of the countries should be identical in a and b; please correct this (I assume, the y-axis numbers need to have the same number of digits, then the figures should show the same size).

Fig. 5: This is a very nice interpretation, but I have a suggestion: you could combine a and b and connect the individual countries' marks with arrows; currently, one has to search for a long time before a country's performance can be compared.

Fig. 6: - Please check for non-discribed countries and/or add them to "others". - The numbers of the individual eigenvectors are too small and cannot be read. - Can you show this figure also for the whole MENA region? Or in other words: why did you choose Lebanon here? Is the figure similar for the other countries?

L359: If you write "Since the introduction of the virtual water concept, various studies have been conducted to quantify the volume of the VWT." you should provide proper citations and describe how you contribute to an extension of their findings.

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L361: As above, the statement "The amount of imported virtual water is regarded as the most important factor in determining water and food security," should be backed up by citations or proof.

L364: "...the interlinkages of key natural resource sectors and the improved production efficiency are considered a win–win strategy for environmental sustainability..." - I do not understand why you address production efficiency here; that was not part of your previous analysis. Can you please explain this?

L368: "Thus, decisions made in one sector typically impact the other sectors." - I think that this statement here does not belong to your core message of the paper: you never discuss / analyze how different sectors influence each other. You also do not show how virtual water or changes in virtual water fluxes may influence whatever sector.

L372: "...policy makers can benefit..." - how should they benefit? What would be the key parameter policy makers can use? How should they decide on the future if your study is only based on the analysis of data from the past? Also: you compared the different countries of the MENA region among each other and derived values for SInDC and NSInDC. The comparison is thus only a qualitative comparison. How should a single country decide now whether its food import strategy generally is stable? Finally: considering political differences in the MENA region, do you think that any singular country or a coalition of countries could use your evaluation to increase its food stability?

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2018-398>, 2018.