Dear Editor and Reviewer

We revised the previous paper with reflection of reviewer's comments.
Most of the comments were related to the limitation of this study, and more explanation for clarifying the methodology and results.
We tried to incorporate our responses to these comments within the revised manuscript.
Please find the revision note and we explained the detailed change in it.
We appreciate the feedback and comments and we believe that these comments improved this paper.

Major Comments 1	
Reviewer's comments	Abstract: the abstract is somewhat impenetrable. It would be nice to have a bit more explanation on some of the concepts/jargon used.
Response Line 8-20	I agree. We worked on revising the abstract, and added more statement before mentioning the aim of the study. The Middle East and North Africa (MENA) region has the largest water deficit in the world; it also has the least food self-sufficiency. Increasing food imports while decreasing domestic food production can contribute to water savings and hence to greater water security. However, increased domestic food production is better way to achieve food security, even if irrigation demands increase under projected climate changes. There is trade-off between food security and the savings of water and land through food trade, and this trade-off is a significant factor, especially in the MENA. This study analyses the impact of food trade on food security and water-land savings in the MENA region and in terms of virtual water trade (VWT). We estimate the total volume of virtual water imported for four major crops - barley, maize, rice, and wheat – between 2000 and 2012 to assess the impact on water and land savings, and food security. The largest volume of virtual water was imported by Egypt (19.9 billion m^3/year), followed by Saudi Arabia (13.0 billion m^3/ year). We concluded that Egypt could save 13.1 billion m^3 in irrigation water and 2.0 million ha of land area by importing food rather than producing crops. In addition, the study revealed that the MENA region focused more on increasing the volume of virtual water imported during the period 2006-2012 with little attention to the expansion of connections with country exporters through VWT network analysis. The study sheds light on opportunities and risks associated with VWT and its role in food security and land management in the MENA region.
Reviewer's comments	Introduction: So, the introduction provides a strong argument for the need to look at VWT, but then (after the objective is introduced) provides limited rationale for how this particular effort then feeds back into how it could be used for policy analysis/development. What is the rationale for this particular study within context of the broader VWT area of research?
Response	We revised the introduction part, and tried to show the rationale for this study.
Reviewer's comments	L31-32: To what extent was the energy sector (and impacts to the environment, such as increased greenhouse gas concentrations) considered in the recommendation that water stress could be relieved through increased global food trade? I.e., there are negative consequences when considering this recommendation from the perspective of the food-energy-water(-environment) nexus. This should be mentioned somewhere.
Response Line 71-75	We agreed with your comment and added the sentence mentioning trade-off among food, water, and energy in terms of Nexus concept. However, the high dependency on food import can be the risk of food security even if it can bring domestic water, energy, and land savings in water scare region. Therefore, we should consider trade-off between food security and resources savings, with a holistic approach such as water-energy-food nexus, and the VWT can be suggested as relevant to the water policy of a nation (Schyns and Hoekstra, 2014), providing a new point of view from which both food security and sustainable water management are considered (Novo et al., 2009).
Reviewer's comments	L35: It would be helpful when giving this background information to include mechanisms. What is the reason for the ag water deficit? To support growth in population and need for food? Or is this for existing irrigated lands and the fact that climate change is causing increased vulnerability of these water rights in some locations?
Response	We added more explanation from the study executed by Falkenmark and Lannerstad (2010).

Line 32-36	Falkenmark and Lannerstad (2010) estimated that it would be necessary to double the VWT by 2050 to compensate for agricultural water deficits because of climate change, population increase, and the pattern of food supply per capita. For example, an average of 20% of the per capita food energy supply was assumed to originate from animal foods to ensure sufficient protein content, and more water was required to produce animal foods than other foods (Falkenmark and Lannerstad, 2010).
Reviewer's comments	L39-43: This is confusing. Is VWT quantified as the water that would have been needed to grow the food if it were grown locally? Otherwise, I don't understand how there can be an imbalance between VWT and "Real Water". BTW, "Real Water" should be defined. It might be nice to have a table of definitions somewhere: VWT, real water, blue water, green water, etc. L51: blue water has not been defined, nor its relationship to VWT described.
Response	Therefore, we changed the sentence to make it clear.
Line 39-41	Oki and Kanae (2004) investigated that approximately 1140 km^3/year of virtual water could be used for altering the import of food products to domestic products e,g., cereals, soybeans, and meat; however, 680 km^3/year of water was used to produce those foods in exporting areas.
Line 99-104	The water footprint for a crop is divided into green and blue water footprints, based on the water resources (Hoekstra and Chapagain, 2008). Green water footprint indicates that water supplied by precipitation is retained in the soil of the root zone (Falkenmark, 1995), and blue water footprint is the water stored at the surface or in the ground. Therefore, green water footprint is related to rain-fed agriculture and blue water footprint is related to irrigation water provided by aquifers or surface bodies of water. Based on green and blue water footprints, we estimated the of four major crops—barley, maize, rice, and wheat—in the MENA region from 2000 to 2012, which was divided into green and blue water trade by footprints.
Reviewer's comments	L82-83: Why is this a particularly critical issue in the Arab world?
Response	We thought most of Arab countries have low food self-sufficiency and it could be critical issue in terms of food security. Therefore, we added more explanation as followed:
Line 242-243	Food import can cause a decrease in local food production, which can be particularly a critical issue in the MENA region because Arab countries have very low food self-sufficiency and it can be problem in terms of food security.
Reviewer's comments	L83-84: This is a little bit confusing, possibly because the methods have not been presented yet, so it is not clear at this point what is meant by increasing 1% of self-sufficiency.
Response	Self-sufficiency is defined as the ratio of domestic production to total consumption. The ratio of imported crops to total consumption is related to negative self-sufficiency. Therefore, the increase of 1% self-sufficiency drives the requirement of domestic production. We added paragraph about food self-sufficiency as followed:
Line 243-250	Accordingly, we applied the concept of self-sufficiency as the index of food security, which is defined as the ratio of domestic production to total consumption, and estimated water requirement of increasing 1 % self-sufficiency of study crops in comparison to average self-sufficiency from 2000 to 2012. In order to increase self-sufficiency of crop, the increase of domestic production should be accompanied, and it derives additional water and land requirement which can be issue of trade-offs between food security and water-land savings. For example, if average self-sufficiency of wheat is 70% in a specific country, the increase of 70% to 71% should accompany the increase of domestic production; therefore, water for increasing 1 % self-sufficiency indicates the water requirement for that increase of domestic production.
Reviewer's comments	L86: Is there a citation that can go with "degree centrality" to insert here for those looking for background on it? Same with "eigenvector centrality". It would be nice if there would be a brief explanation of what these are, esp. given the broad readership of this journal.
Response	We revised the paragraph explaining degree and eigenvector centralities.
Reviewer's comments	L90 - "is as comparison as". Also, please provide an explanation for this statement - why these two tasks are both critically important, rather than just referring readers to recent literature for the explanation.
Response	We revised this paragraph.
Line 122-127	Understanding the VWT structure is important as quantifying the amount of import and export because VWT structure can represent whether it would be the sustainable or vulnerable. For example, if a country imports a lot of virtual water through food trade from just a few exporters,

	the structure of VWT in this country might be impressionable by exporters. However, if a country has connection with many exporters in VWT, it can have resilient structure for global changes. In addition, recent literature has emphasized the change in structure of the VWT in terms of a network approach (Dalin et al., 2012; Konar et al., 2012; Lee et al., 2016).
Reviewer's comments	L99 - there are problems with the indices of the variables in the text (i.e. no subscript). It is also helpful to italicize the variables so it is clear that they are variables.
Response Line 94-96	We changed this paragraph as followed: in which variable VWT denotes the virtual water trade from the exporting country, n_e, to the importing country, n_i, in year t, as a result of trade in crop c; CT represents the crop trade from the exporting country, n_e, to the importing country, n_i, in year t as a result of trade in crop c; and WFP represents the water footprint of crop c in the exporting country, n_e.
Reviewer's comments	L101 - so this goes back to my earlier confusion on if VWT is determined based on the WFP of the importing or exporting country. Here, it looks like it is calculated on the exporting country (is this true for regardless if it is import VWT or export VWT?), in which case I am still confused on why there is a not a net zero of VWT at the global scale (i.e., import VWT - export VWT = 0 if WFP is determined always in the place where it is grown versus the place it would have been grow if there was no import). Certainly at the scale of a region or country, this would not need to be a net zero (because there could be, e.g. more imports than exports), but it is unclear in the context of where that was described if it is regional or global. This is likely to confuse several readers and so should be more clearly explained in the introduction.
Response Line 87-90 Line 106-112	We added more explanation in the introduction. The VWT represents the water embedded in international trade, and it indicates the water used in the exporting country to produce crops for export. Therefore, virtual water export in exporting country is considered as virtual water import in importing country. However, a regional VWT is different from global one; for example, virtual water import is much larger than virtual water export in each Arab country. The import of crops in MENA region could affect the domestic water and land management in terms of water and land savings. Water saving has different meaning from virtual water import. For example, Saudi Arabia imported wheat from various exporters and virtual water import was calculated by multiplying the quantity of imported wheat with the respective water footprint of each exporter. However, water saving indicates the amount of water to produce the same quantity of imported wheat but as domestic production. Accordingly, the failure of trade could cause water and land shortages in the importing country. Although this assumption about water and land savings considers an extreme trade situation, these results could be used to understand the importance of the international crop trade in the MENA region in terms of water and land savings. In this study, we consider only blue water as resource which can be saved; therefore, the national water and land savings indicated the amount of blue water and land requirements for substituting crops imported to domestic production.
Reviewer's comments	L117 - why is only blue water considered in the water saving quantification? Green water should also be considered because most of the irrigation applied to crops is consumptively used, so lost to the system. This results in less water available for other uses. To be most robust, however, the water saving should be based on just the consumptive use portion of the sum of green and blue water.
Response	In this study, water saving indicates water use for producing products domestically which are imported, and it is calculated by water footprint of importing country. Green water indicates that water supplied by precipitation is retained in the soil of the root zone (Falkenmark, 1995), and blue water indicates the irrigation water supplied by artificial facility such as pump or reservoir. Therefore, we more focused on irrigation water use which is blue water in importing country, and that is why we only consider blue water as water saving.
Reviewer's comments	L125 - define what is meant by "edge" versus "node" in the context of this study
Response	We changed edge to degree.
Reviewer's comments	L126 - explanation should be provided for what is meant by in-degree versus out-degree. i.e. "depending on the direction of trade (in = import; out = export)."
Response Line 129-134	We added more explanation about degree centrality as followed: In addition, degree centrality is divided into in- and out-degree centralities, depending on the direction. In-degree is based on the number of lines (or volume) directed to the node and out-

	degree is based on the number of lines (or volume) that the node directs to others (Figure 1). The in-degree centrality of each Arab country was calculated because we focused more on the import of virtual water in the MENA region. An importer accompanying a high in-degree centrality has expanded connectivity with exporters, meaning that this importer could cope with an accidental disconnection from a certain exporter.
Reviewer's comments	L132: Why (N-1)? is this like the Bessel correction for standard deviation?
Response	Each node has each degree centrality, and "N-1" is used for removing the node itself.
Reviewer's comments	L144-146: Not all of the variables in equations 6 and 7 are defined in the text.
Response Line 161-162	We added explanation of all variables in Equations 6 and 7 as followed: This type of equation is solved using eigenvalues and eigenvectors, where A is a square matrix and is a scalar, known as the eigenvalue associated with the eigenvector c by a column vector.
Reviewer's comments	L162: Although other data sources were used to estimate the water and land footprints of food production, there should still be a discussion of the limitations to the utilized datasets/approaches in terms of what these limitations mean for the conclusions derived from this study. L173-174: awkward phrasing: "and the part of periods for water footprint is overlapped with the period of trade data" L174-175: It is good to mention limitations, but it is even more useful to mention how these limitations may bias results/conclusions.
Response Line 186-191	We removed that sentence and added a sentence about the limitation of datasets. However, time scales of international trade were different from water footprint data. For example, water footprints used in this study were based on data from 1995 to 2005; however, we applied the food trade data from 2000 to 2012. Therefore, the application of average water footprint to time-series trade data can cause a false estimate of the effects of VWT. For example, the water footprint used in this study was average value for certain period (1995-2005), and the extreme climate situation could not be applied to virtual water trade analysis. Therefore, the results of VWT in this study represented generalized climate situation as a limitation.
Reviewer's comments	L194-195 - because of a relative low population in the UAE relative to the other Arab countries? Might be helpful to state that.
Response Line 211-215	We added more explanation as followed: We also considered the amount of virtual water import per capita (VWIcap), which shows the differing viewpoints regarding food and water securities. If we consider only total amount of virtual water imported, the UAE might be not considered to be a significant importer because the population and area of UAE is much smaller than that of other countries such as Saudi Arabia. However, the virtual water import per capita in the UAE is larger than that of Saudi Arabia, indicating that the dependency on virtual water imported from exporters in the UAE is much more significant than in Saudi Arabia.
Reviewer's comments	L197-200 - there are grammatical issues with this sentence.
Response	We removed this sentence because we added the explanation about the application of virtual water and results in this study in Conclusion part.
Reviewer's comments	L222 - this sentence also has grammatical issues.
Response	We removed this sentence.
Reviewer's comments	L228 - not all ag lands are appropriate for growing every type of crop - this is going to be important to mention as a limitation. Also, some ag lands may produce very high yields of a particular crop than other land area in other country, even if receiving full water requirement. The role of temperature and soil characteristics play a strong role here and this should be mentioned in the discussion and in limitations. Therefore, this is not an apple-to-apple comparison in terms of the amount of food produced in each region given the water and land needs. This will be important to consider if policies are developed or analyzed given this information. Table 5 - wouldn't increasing self sufficiency also create a hit on land requirement as well? Another limitation related to increasing self sufficiency is that there is no analysis done on whether or not arable land and water are available to do this. So I'm not sure how this can be useful for policy analysis without at least describing these constraints as potentially major

	limitations.
Response Line 267-269	We agreed with your comment. Therefore, we mentioned more limitation about land saving as followed: However, the saved land is now always suitable for agricultural area. Some crops are required for the specific type of land and also the productivity is different by soil. Even if we can save lands, there is the limitation for considering the land saving from this study as agricultural land savings.
Reviewer's comments	L254-255 - nowhere in the methods is there discussion on how the InDC metrics are scaled. It is not clear from the current text what this is or how it was done (or even why). Therefore, I find it difficult to comment on the results from this analysis.
Response Line 141-147	Scaled degree centrality indicates the application of volume of each line as connection between nodes which is the amount of import or export depending on in- or out-degree centralities. We added more explanation for degree centrality as followed: The in-degree centrality based on the number and volume of links in VWT network, which expressed to non-scaled in-degree centrality (NSInDC) which is based on the number of links, and scaled in-degree centrality (SInDC) which is based on the volume of links (Figure 1). Through degree centrality, we analyzed the vulnerable expansion (or reduction) and robust expansion (or reduction) in the VWT network in the MENA region. Therefore, the vulnerable expansion in network indicates that the amount of flow to a node increases but the number of connection to other nodes decrease, and it is represented by high level of SInDC and low level of NSInDC. The importer who has vulnerable expansion has increased the amount of products from only a few exporters.
Reviewer's comments	Figure 5 - it is not clear what the black numbers are versus the red numbers. Also, the country numbers are given - do those refer to the red numbers? Why don't the black numbers have country numbers - or do they? except that some of the numbers are very large (e.g., 50, 100) - or is that the y-axis? It's very confusing...
Response Line 284-289	We changed the Figure 5 and added more explanation about Figure 5 (now it is Figure 6). The number in Figure 6 represents each Arab country, for example 1 is assigned to Algeria. The shapes of each number indicate the rate of increase of in-degree centrality from 2000 to 2006 and from 2006 to 2012, respectively, in each Arab country. X-axis indicates the NSInDC and y axis indicates SInDC, therefore, if the specific country in the MENA region is located high level in x axis and low level in y axis, this country has made the connection with more exporters but decreased amount of virtual water import.
Reviewer's comments	L271 - what is meant by "bring the security of import"?
Response Line 296-297	For example, if a country imports a lot of virtual water through food trade from just a few exporters, the structure of VWT in this country might be impressionable by exporters. However, if a country has connection with many exporters in VWT, it can have resilient structure for global changes. We changed the sentence as followed: The expanded structure of VWT indicates that the Arab countries is connected to various exporters and it can be resilient structure for global changes.
Reviewer's comments	Figure 6 - what are the units of these? It's hard to see the light text on each line - what do they say?
Response	In Figure 6 (now it is Figure 7), bn is billion m^3 and the thickness of each flow indicates the amount of virtual water export to the MENA region.
Reviewer's comments	L300-301 - this is a very awkward sentence. These results might contribute to understanding the key player in entire VWT centering the Arab World and other countries in the Arab World should observe the behavior of influential countries closely.
Response	We removed this sentence.
Reviewer's comments	L304-306 - this sentence is important and relates back to the fact that the water/land footprints in the exporting country are very unlikely to match those (for the same food produced) in an importing country. I'd say this is the most important limitation to this study and should be discussed with respect to how this is likely to bias the results (esp. given that Arab countries are relatively hot and yields often are smaller in hot climates and require more water).
Response	We added more explanation as followed:

Line 109-114	However, water saving indicates the amount of water to produce the same quantity of imported wheat but as domestic production. Accordingly, the failure of trade could cause water and land shortages in the importing country. Although this assumption about water and land savings considers an extreme trade situation, these results could be used to understand the importance of the international crop trade in the MENA region in terms of water and land savings. In this study, we consider only blue water as resource which can be saved; therefore, the national water and land savings indicated the amount of blue water and land requirements for substituting crops imported to domestic production.
Reviewer's comments	L330 - but HOW should policy makers do this? What is this missing step in translating the knowledge gained from this study towards analyzing/developing policy (without becoming policy prescriptive of course)?
Response Line 368-375	We added the paragraph emphasizing the role of virtual water and this study for sustainable development in terms of Nexus system. In particular, the interlinkages across key natural resource sectors and improved efficiency of production is considered a win-win strategy for environmental sustainability, whether for current or future generations (Ringler et al., 2013). Nexus frameworks identify key issues in food, water and energy securities through the lens of sustainability, seeking to predict and protect against future risks and resource insecurities (Biggs et al., 2015). The core of the Nexus concept is that the production, consumption, and distribution of water, energy, and food are inextricably inter-linked: decisions made in one sector typically impact the other sectors (Mohtar and Daher, 2014). Therefore, we believe that virtual water can be useful connector among water, food, and land in Nexus system. In addition, VWT and water-land savings by trade in this study can be used for supporting decision through Nexus system.
Reviewer's comments	Figure 7: "Impoters" and "Expoters" are misspelled in the figure.
Response	We make it correct.
Reviewer's comments	Table 4: The caption says that these values are ratios but the values have units - so are they ratios or are they the absolute values of the water/land saved?
Response	We changed the caption of Table 4. Table 4 The ratio of saved blue water and lands to internal water resources and agricultural land area in the MENA region
Reviewer's comments	Table 5: Caption needs to reflect that there are values given for both percent change and magnitude of change.....
Response	We changed the caption of Table 5. Table 5 Average self-sufficiency and water requirement for increasing 1 % self-sufficiency of study crops in the MENA region from 2000 to 2012