Response to Anonymous Referee #2

We appreciate your valuable comments on our manuscript; they have been very helpful in revising and improving our paper. We have carefully considered the comments and have revised the manuscript accordingly. The comments and detailed responses can be summarized as follows:

Comment 1**:** The abstract did not well highlight the innovation of this paper. The innovation of this paper should be put forward in the abstract by briefly mentioning the deficiencies of the previous research.

Response: The innovation was not clearly clarified, so we added the following sentences in the revised version.

In this research, the VWC of rice, as a major crop in China, was taken as the research object. China is well-known for its massive land. The VWC of rice is largely different between regions. The VWC of rice of China should be assessed and the spatial characteristics should be also analyzed.

The total virtual water content is the total volume of freshwater both consumed and affected by pollution during the crop production process including direct and indirect water use. Prior calculation frameworks do not contain all contents of virtual water content of crops.

Comment 2**:** This paper has two main purposes: 1) propose a modified calculation framework of VWC of crops; 2) analyze the spatial characteristics of VWC of rice in China. The Introduction section should focus on the advantages of the modified calculation framework of crop VWC and the significance of the spatial distribution analysis of rice VWC in China.

Response: We fully agree with the reviewer's opinion.

We added the following sentences in the revised version.

There is not any research on the total VWC of rice and spatial distribution

characteristics in China at provincial scale by the actual total water use. China is well-known for its massive land. The VWC of rice is largely different between regions. The VWC of rice of China should be assessed and the spatial characteristics should be also analyzed.

However, prior calculation frameworks of VWC of crops have some defects. Some use the water requirement of crops instead of the actual water use, and others ignore the freshwater affected by pollution during the crop production. Besides, in all calculation frameworks the indirect water use of crops was also ignored.

Comment 3**:** In the introduction, authors should briefly introduce the results of distribution characteristics of virtual water content of rice by sun (2013a).

Response: Thanks for the advice. In the revised version, we added the sentences to briefly introduce the results from sun (2013a).

We added the following sentences in the revised version.

Sun et al. (2013a) used the crop water requirement to calculate the China average VWC of wheat, maize and rice, and found the proportions of green and blue water were 50.98% and 49.02%, 76.27% and 23.73%, 61.90% and 38.10%, respectively. The VWC of rice was relatively low in the eastern part of Northeast China, Middle–Lower Reaches of the Yangtze River and the eastern part of Southwest China. In contrast, the high values of VWC for rice were located in the west of Inner Mongolia and south of Xinjiang Uygur Autonomous Region.

Comment 4**:** Authors divided the VWC into direct water and indirect water, and the direct water was divided into direct green water, direct blue water and direct grey water. Why the indirect water was not divided into indirect green water, indirect blue water and indirect grey water?

Response: The VWC_{total} of a crop is the total volume of freshwater both consumed and affected by pollution during the crop production process. The VWC_{total} of a crop is an indicator of freshwater use that looks at both direct and indirect water use during

the crop production process. The VWC_{direct} of a crop refers to the freshwater both consumed and affected by pollution that is associated with the water use during the crop production process. It is distinct from the $VWC_{indirect}$. The $VWC_{indirect}$ of a crop refers to the freshwater both consumed and affected by pollution that can be associated with the production of the goods and services or the inputs used during the crop production process. The VWC_{direct} of a crop is divided into three components: (1) $VWC_{direct,\ green}$ (the precipitation consumed in crop production); (2) $VWC_{direct,\ blue}$ (the surface water or groundwater consumed in crop production); and (3) $VWC_{direct,\ grey}$ (the freshwater required to assimilate the load of pollutants during the crop production process). Accordingly, the $VWC_{indirect}$ also should be divided into three components: $VWC_{indirect,\ green}$, $VWC_{indirect,\ blue}$ and $VWC_{indirect,\ grey}$. However, we only had the data about the total freshwater use of other economic system sectors. Using the data, we can only calculate the $VWC_{indirect}$. $VWC_{indirect,\ green}$ (the precipitation consumed that can be associated with the production of the goods and services or the inputs used during the crop production process), $VWC_{indirect,\ blue}$(the surface water or groundwater consumed that can be associated with the production of the goods and services or the inputs used during the crop production process) and $VWC_{indirect,\ grey}$ (the freshwater required to assimilate the load of pollutants that can be associated with the production of the goods and services or the inputs used during the crop production process) was not able to calculate. That is the reason why the indirect water was not divided into indirect green water, indirect blue water and indirect grey water.

Comment 5**:** For the sector 2.1.3, the meaning of "actual total irrigation water consumption" should be explained more clearly. Authors should explain the relationship between the irrigation water consumption, irrigation water supply and irrigation coefficient. It will help readers better understand the meaning of "actual total irrigation water consumption".

Response: "Irrigation water supply" is the artificial application of water to the land or soil, which can be groundwater extracted from springs or by using wells, surface water withdrawn from rivers, lakes or reservoirs or non-conventional sources.

“Irrigation water consumption” is the net artificial application of water to the land or soil, which not includes the irrigation water losses during the transport process from the water sources to cropland and the return flows of irrigation water. “Irrigation coefficient” refers to ratio of the net water use by crops and the total water withdrawals in water irrigation system. Irrigation coefficient can be considered as the ratio of irrigation water consumption and irrigation water supply. In this study, the “actual total irrigation water consumption” is the same as the “irrigation water consumption”. We changed the “actual total irrigation water consumption” into “irrigation water consumption”.

The following added sentences in the revised version will help readers better understand the meaning of “actual total irrigation water consumption”.

The irrigation water consumption is the net artificial application of water use by crops, which not includes the irrigation water losses during the transport process from the water sources to cropland and the return flows of irrigation water.

Comment 6**:** The data source of rice fertilizer is not clear, and reference should be added.

Response: We have changed the sentence “*The average amount of fertilization of crops per unit area is taken from Li et al. (2010).*”into “*The average amount of nitrogen fertilizer of rice per unit area is taken from Li et al. (2010), Zhang et al. (2008) and Zhang et al. (2009).*” in the revised version.

The following references have been added.

Zhang, S. D., Zhang W. F., Wang J. Q.: Character of Fertilizer Consumption and Supply- Demand and Strategy for Management in Middle and Lower Reaches of Yangtz River of China, Research of agricultural modernization, 29, 100-103. 2008 (in Chinese).

Zhang, S. D., Zhang W. F., Ma L.: Study on the change of fertilizer consumption structure of main grain crop in Hebei, Jilin and Sichuan of China, Phosphate &

Compound Fertilizer, 24, 89-91, 2009 (in Chinese)

Comment 7**:** It needs to explain the difference among 'irrigation water consumption', 'irrigation water supply' and 'actual total irrigation water consumption'. These similar terms were motioned in the method without the difference which could be confusing for readers. Which data are used in the calculation?

Response: We explain the differences between the similar terms. The same as the Comment 5, "Irrigation water supply" is the artificial application of water to the land or soil, which can be groundwater extracted from springs or by using wells, surface water withdrawn from rivers, lakes or reservoirs or non-conventional sources. "Irrigation water consumption" is the net artificial application of water to the land or soil, which not includes the irrigation water losses during the transport process from the water sources to cropland and the return flows of irrigation water. In this study, the "actual total irrigation water consumption" is the same as the "irrigation water consumption". The data used in this study actually is the irrigation water consumption. We deleted the "irrigation water supply" in the data resource and changed the sentence into "*The irrigation water consumption for the 29 regions is taken from the Water Resources Bulletins(2007) of 29 regions.*"

Comment 8**:** We have combined Comment 8 with Comment 9.

Comment 8, 9**:** It is necessary to intensively analyze the results of the spatial characteristics of rice VWC in China, and clarify the reasons for the spatial characteristics. The paper should discuss how the various virtual water is transferring or transporting regionally and why? The spatial characteristics of various components of VWC show obvious regionally distribution characteristics, and there are also differences among individual regions. Please clarify their causes.

Response: We fully agree with the reviewer's comment. In the *Results*, we should analyze more about the regionally distribution characteristics of VWCs and the differences among individual regions.

We added the following sentences in the revised version.

$VWC_{direct,\ green}$ of rice was increased gradually from northern to southern regions (Fig. 2). The regional variability of $VWC_{direct,\ green}$ of rice was in accordance with the distribution of precipitation in China. The regions with abundant precipitation usually have high $VWC_{direct,\ green}$ of rice. Precipitation in southern regions of China is far greater than that in northern regions of China. Consequently, the $VWC_{direct,\ green}$ of rice in southern regions would be higher than that in northern regions.

Jilin, Shandong and Henan were the other three regions with relatively low $VWC_{direct,\ blue}$ of rice. Limited irrigation water consumption in the three regions might only meet less than 25% of the irrigation requirement of rice. Therefore, the $VWC_{direct,\ blue}$ of rice in Jilin, Shandong and Henan was relatively low.

The rice yield of Shandong, Henan and Chongqing was much higher than the national average. That made the $VWC_{direct,grey}$ of rice in the three regions also relatively low.

The VWC_{total} values showed a roughly three-tiered distribution, gradually decreasing from southeast to northwest of China.

Comment 10**:** The results in this paper need be compared with those by Sun (2013a)?

Response: We fully agree with the reviewer's advice. The following sentences added to compare the results between our research and the research by Sun et al. (2013a).

Our result is large different to the result from Sun et al. (2013a). Follow their calculation the VWC of rice was relatively low in the eastern part of Northeast China, Middle–Lower Reaches of the Yangtze River and the eastern part of Southwest China. In contrast, the high values of VWC for rice were located in the west of Inner Mongolia and south of Xinjiang Uygur Autonomous Region. Their calculation framework only considered the crop water requirement. However, our calculation framework considers the effective precipitation and crop evapotranspiration, irrigation water consumption, freshwater that is required to assimilate the load of pollutants and the indirect water use. The difference of the $VWC_{direct,\ blue}$ and the added $VWC_{direct,\ grey}$ of rice caused the large difference of spatial distribution

characteristic between actual VWC_{total} of rice and the rice water requirement. Our result can be better to describe the spatial distribution characteristic of actual water use of rice in China.

Comment 11**:** The discussion section mentioned the indirect water ratio of some crops will be higher. Can some evidences be given rather than just speculation?

Response: We fully agree with the reviewer's advice. We added the following sentences as the evidences.

For example, the proportion of $VWC_{indirect}$ of strawberry in 27 regions of China in 2007 ranged from 0.8% to 38.0%, with an average of 10.8%. The proportion of $VWC_{indirect}$ of strawberry is higher in the VWC_{total}. We cannot ignore the $VWC_{indirect}$ in the calculation of VWC_{total} of some crops.

Comment12**:** In Table 2, the unit "%" should be marked.

Response: Thank you for the reviewer's detailed comment. We modified the title of Table 2 in the revised version.

Table 2 The volume (m^3 kg^{-1}) and proportion (%) of VWC of rice in Heilongjiang Province by four different frameworks

VWC / *Method*	$VWC_{direct,green}$	$VWC_{direct,blue}$	$VWC_{direct,grey}$	$VWC_{indirect}$	*VWC*
Our method	*0.45 (46.0)*	*0.29 (30.2)*	*0.22(22.9)*	*0.01 (0.9)*	*0.97*
Sun's method	*0.45 (60.5)*	*0.29 (39.5)*	—	—	*0.74*
GBG method	*0.45 (26.6)*	*1.01 (60.1)*	*0.22 (13.3)*	—	*1.68*
CWR method	*0.45 (30.7)*	*1.01 (69.3)*	—	—	*1.45*