Earth System Science Data

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Dear editor and reviewer:

We are grateful to you for your constructive comments and suggested amendments on our manuscript entitled: "**High-resolution mapping of global winter-triticeae crops using a sample-free identification method**" (essd-2023-432). Your comments provide valuable insights for improving the contents and analysis. We have carefully studied the comments and revised our manuscript accordingly.

Here are our detailed responses to your comments. Please note that the comments from you are in **bold font** followed by our responses in regular font, changes/additions to the manuscript are <u>underlined</u>.

Sincerely yours,

Wenping Yuan on behalf of all co-authors

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Detailed responses to reviewer' comments

This is needed and important research. However, some of the used methods are not clear enough, and in fact, the accuracy assessment may be not reliable. This makes the manuscript not appropriate for publication in ESSD in its current form.

Response: Thanks for your comments. We deeply appreciate your time for reviewing the manuscript. Your suggestions are very useful for us to improve our manuscript. We have revised our manuscript according to your comments, and we also attached a point-by point letter to you. The detailed responses are listed below.

My main concerns:

1). National datasets used for validation are not described at all, and I am not sure if they are reliable sources. The questions arise if these datasets are robust and/or detailed enough to perform accuracy assessment for the presented map? Did you only compare the area reported by country statistics and areas obtained in your maps? If so, that is not enough. Maybe, as a validation dataset it would be better to include USA CDL dataset.

Response: Thanks for your suggestion. We have added a table (Table S1) to display the sources of agricultural statistical data for each country. This study used state (or province) scale statistical area to determine the WTCI thresholds for China, Brazil, India, Australia, and the United States, and evaluated the accuracy of each state (or province) using municipal or county scale statistical area. A state (or province) can contain dozens or hundreds of municipalities or counties. The national scale statistical area was used to determine the WTCI thresholds for other counties, and the statistical area of all states or provinces or municipalities or counties included in each country was used to evaluate accuracy. We hope that this comparison can be used to verify the spatial distribution of winter-triticeae crops map. We have added some details to describe the use of statistical area for accuracy assessment in the revised manuscript:

"In this study, we considered each state (or province) as an identification unit in China, Brazil, India, Australia <u>and US, and the threshold of WTCI was determined based on statistical area at state (or province) scale.</u> For the remaining countries, we treated each country as an identification unit, <u>and the threshold of WTCI was calculated relied on statistical area at</u>

national scale."

"At the regional scale, we obtained the identified areas of winter-triticeae crops based on the total pixel area of winter-triticeae crops on the identification maps. In China, Brazil, India, Australia and the US, we used the statistical area at municipal or county scale to validate the accuracy of identified area at state (or province) scale. For other counties, the statistical area of all states or provinces or municipalities or counties included in each country was used to evaluate the accuracy at national scale."

Additionally, we added validation data from USA CDL dataset and the Land Parcel Identification System (LPIS) dataset. The details are as follows:

"In addition, we used CDL and LPIS datasets to further evaluate the performance of WTCI method. The CDL released annually has high accuracy in capturing crop distribution in US and has been widely used as a base map for crop dynamic monitoring and production estimation. We thus treated CDL labels as ground truth and randomly selected 7,500 winter-triticeae crops samples and 12,500 non-winter-triticeae crops samples in 2020 to validate the accuracy of our method in US (Fig. 1). The LPIS dataset produced by European Union, accurately records and describes field geometry and landcover in EU countries. We thus collected and selected 10 countries with data clearly labelled with winter-triticeae crops, including winter spelt, winter barley, winter durum hard wheat, winter common soft wheat, winter triticale, winter rye and winter oats (https://zenodo.org/records/10118572). These data cover the period from 2018 to 2021, from which we randomly extracted 2,000 winter-triticeae crops samples and 3,000 non-winter-triticeae crops samples to assess the result of WTCI method in Europe (Fig. 1)."

The validation results of the WTCI method using CDL and LPIS datasets can be seen in 3.3 section in the revised manuscript.

2). Another dataset for comparison/validation comes from Google Earth imagery. However, how is it possible to check or distinguish if there are winter crops indeed if for some years only single image is available, and may be not acquired during the time when it is possible to assess?

Response: We guess that the winter crops mentioned by the reviewer may refer to winter-triticeae crops in our study. The purpose of selecting samples based on Google Earth imagery is to assess the identification accuracy of WTCI method. Therefore, we select samples in the regions where there are available images to ensure the exactitude of the samples. At the same time, most of the planting areas of winter-triticeae crops are not perennial rainy areas, and the proportion of effective satellite observation is relatively high. Based on the actual situation of the selected samples, we can obtain a suitable number of samples in various winter-triticeae crops planting areas around the world. Here, we have added some content to explain how we selected samples from Google Earth imagery, the details are as follows:

"For other provinces in China and other countries (except US), we relied on high-resolution images from Google Earth from 2019 to 2020 for visual interpretation. We first chose regions with available images during the study period and selected samples from these regions based on the texture features. In order to ensure the accuracy of the samples, we then validated the selected samples on GEE platform by checking whether the NDVI temporal features of these samples matched the characteristics of winter-triticeae crops, and finally obtained 7,029 winter-triticeae crops samples and 8,897 non-winter-triticeae crops samples (Fig. 1)."

Previous studies (Yang et al., 2017; Zheng et al., 2022) have also adopted the approach that selecting samples from visual interpretation of high-resolution images when ground truth samples cannot be obtained. To increase the reliability of our methods and results, we further collected samples from CDL and LPIS datasets to validate the performance of our method. Detailed information can be seen in 2.2.2 and 3.3 sections in the revised manuscript, also can be found in response to Q1.

References:

Yang, D., Chen, J., Zhou, Y., Chen, X., Chen, X., Cao, X.: Mapping plastic greenhouse with medium spatial resolution satellite data: Development of a new spectral index, ISPRS J. Photogramm. Remote Sens., 128, 47–60, https://doi.org/10.1016/j.isprsjprs.2017.03.002, 2017.

Zheng, Y., dos Santos Luciano, A. C., Dong, J., Yuan, W. P.: High-resolution map of sugarcane cultivation in Brazil using a phenology-based method, Earth Syst. Sci. Data., 14, 2065–2080, https://doi.org/10.5194/essd-14-2065-2022, 2022.

3). The methodology is sometimes not clear. And what is also important, the data should be described firstly, before the methods used! For example, the methodology behind integration of Sentinel-2 and Landsat imagery is not clear. Do you used any harmonization techniques, which are needed in such combination between two satellite sources?

Response: Thanks for your suggestion. We have moved the data section to the front of the method section, and we have added a detailed description of the integration of Sentinel-2 and Landsat imagery in the Data section of the revised manuscript:

"In this study, we used Landsat 7 collection 2 data and Landsat 8 collection 2 data, as well as Sentinel-2 data on the Google Earth Engine (GEE) platform to obtain NDVI from 2016 to 2022, all of which were surface reflectance (SR) products and have undergone atmospheric correction. The SR products of Landsat 7 and Landsat 8 have a spatial resolution of 30 m and a temporal resolution of 16 days. The spatial and temporal resolution of Sentinel-2 is 10 m and 5 days, respectively. To reduce the impact of clouds and ensure the quantity and quality of effective observation data, we first removed the pixels with clouds. The quality band BQA was used to remove pixels with clouds from Landsat 7 and Landsat 8, and the quality band QA60 was used to remove pixels contaminated by clouds from Sentinel-2. Then, based on nearest neighbour method, we resampled the NDVI of Sentinel-2 to 30 m to keep the same spatial resolution as Landsat data. Furthermore, we obtained NDVI of all cloud-free pixels, and chose the maximum values of monthly composites with 30 m spatial resolution, which has been proven effective for crop mapping and displaying crop growth stage (Huang et al., 2022). Last, we used linear interpolation and the Savitzky-Golay filter methods (Chen et al., 2004) to fill the missing values and smooth the NDVI series to reduce the contamination from cloud, rain and snow (Zheng et al., 2022). The above processes were run on the GEE platform."

We did not use harmonization techniques to combine Landsat and Sentinel data. There are differences in band wavelengths among different sensors of Sentinel-2 and Landsat, but the difference between NDVI calculated by Landsat and Sentinel products is small (Claverie et al., 2018). Moreover, some studies (You and Dong., 2020; Dong et al., 2020) have successfully classified different crops using unharmonized vegetation index from Landsat and Sentinel products.

Here, we have also added some contents to discuss the difference in the Discussion section:

"Besides, the wavelength difference between Sentinel-2 and Landsat sensors may affect the quality of synthesized NDVI. It is still a challenge to completely eliminate the impact from this difference (He et al., 2018)."

References:

Claverie, M., Ju, J., Masek, J. G., Dungan, J. L., Vermote, E. F., Roger, J. C., Skakun, S. V., Justice, C.: The Harmonized Landsat and Sentinel-2 surface reflectance data set, Remote Sens. Environ., 219, 145–161, https://doi.org/10.1016/j.rse.2018.09.002, 2018.

He, M., Kimball, J. S., Maneta, M. P., Maxwell, B. D., Moreno, A., Beguería, S., Wu, X.: Regional crop gross primary productivity and yield estimation using fused landsat-MODIS data, Remote Sens., 10(3), 372, https://doi.org/10.3390/rs10030372, 2018.

You, N., Dong, J.: Examining earliest identifiable timing of crops using all available Sentinel 1 / 2 imagery and Google Earth Engine, ISPRS J. Photogramm. Remote Sens., 161, 109–123, https://doi.org/10.1016/j.isprsjprs.2020.01.001, 2020.

4). Checking the dataset for my country shows that a large part is in fact located in the agricultural areas (however I cannot say if these are winter, not winter or not triticeae crops). However, there are also large parts located in the forests, and large areas with "stripes" probably related to not proper processing of Landsat 7 imagery. This should be for sure addressed in future, and methods should be refined. I also checked the area of the Mediterranean Sea, where many areas of maquis /shrublands were indicated as winter crops.

Response: Thanks for your comments and deep thought. Overall, our sample-free WTCI method performs well in the main winter-triticeae crops planting regions, while the accuracy of the regions with complex crop planting types needs to be improved. The principle of the WTCI method is to use the NDVI characteristics of winter-triticeae crops from heading to harvesting stages to distinguish other land covers. These stages occur in spring and summer, the other land covers are basically in the growing season with increased NDVI while the NDVI of winter-triticeae crops shows an obvious downward trend (Figure 2 in the revised manuscript). There should be significant differences and distinctions in theory. Therefore, we supposed that the poor performance might be related to the quality of data, which cannot effectively reflect the characteristics of land cover types, leading to misclassification of maquis/shrublands as winter-triticeae crops. We have discussed these questions in the Discussion section of the revised manuscript:

"Second, although we used synthetized images from Landsat and Sentinel productions to increase the amount of effective data, there are still large differences in the available images among the study area. A previous study highlighted that the availability of effective data greatly affected crop identification accuracy (Dong et al., 2015). In this study, the error between the identified area and statistical area of winter-triticeae crops was relatively high in the south of China and in some regions of India and South America, where the RMAE was greater than 35%. One potential reason for this is the quality of the satellite data. For example, cloud and rain contaminations introduce noise in the NDVI data and consequently dampen the winter-triticeae crops detection signal (Song et al., 2017; Xiao et al., 2014). Additionally, due to the scan line corrector failed of the Landsat 7 sensor, the striping issues and reduced data availability may also impact the accuracy of NDVI time series (Ju and Roy., 2008), leading the errors in identification results. Besides, the wavelength difference between Sentinel-2 and Landsat sensors may affect the quality of synthesized NDVI. It is still a challenge to completely eliminate the impact from this difference (He et al., 2018). In the future, identifying useful bands or vegetation indexes that eliminate interferences from other land covers, as well as increasing the availability and quality of satellite data, will further promote the performance of the WTCI method."

Some other comments related to specific lines:

5). Line 28 – this sentence should be rephrased, mapping cannot monitor something

Line 28: Crop mapping can monitor crop information by providing detailed location and near-real time crop area (Skakun et al., 2017).

Response: Thank you for your suggestion. We have revised this sentence as follows:

“Crop mapping can provide detailed location and analyse spatiotemporal dynamics of crops (Skakun et al., 2017).”

6). Line 58 – add information which satellite imagery did you use.

Line 58: Here, this study developed the Winter-Triticeae Crops Index (WTCI), a sample-free method for identifying the global distribution of winter-triticeae crops.

Response: Thank you for your suggestion. We have added the used satellite information:

“Here, based on Landsat 7, Landsat 8 and Sentinel-2 satellite data, this study developed the Winter-Triticeae Crops Index (WTCI), a sample-free method for identifying the global distribution of winter-triticeae crops.”

7). Figure 1 – samples should have different, more distinguishable colours

Response: Thank you for your advice. We have revised Figure 1:

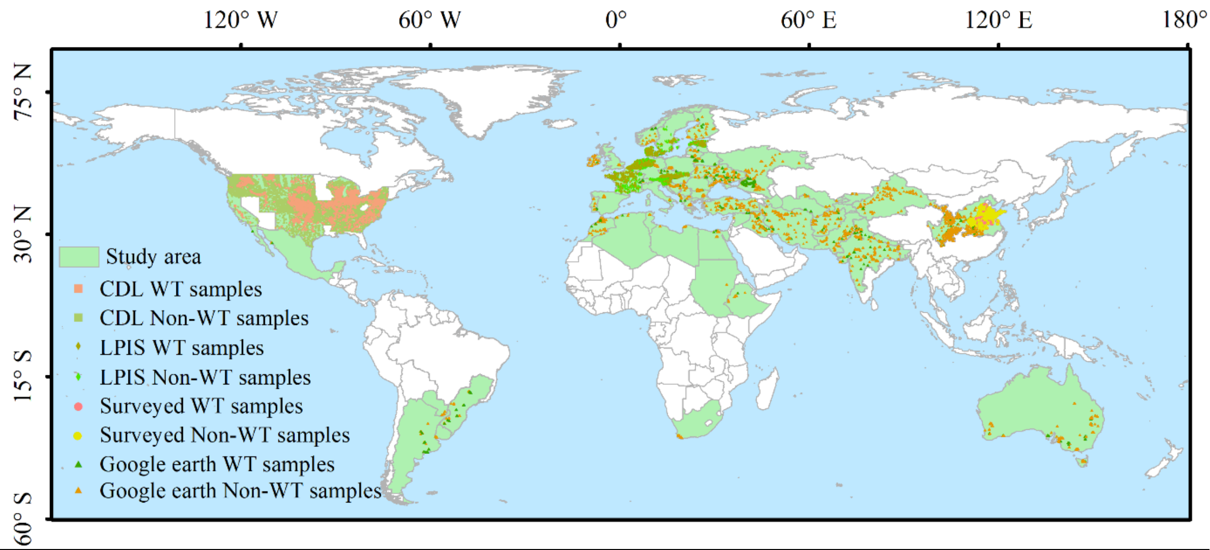

Figure 1: Distribution of the study area and validation samples. The study area is the region covered in green; The legend indicates the winter-triticeae (WT) crops samples and non-winter-triticeae (Non-WT) crops samples from Cropland Data Layer (CDL) dataset of the United States, the Land Parcel Identification System (LPIS) dataset of Europe, and field survey in China, as well as visual interpretation base on Google Earth images, respectively.

8). Line 80 – As mentioned above, data should be described first, before methodology.

Response: Yes, we have moved the data section to the front of the method section.

9). Line 88 – 91 – what about evergreen forests? They are not described or shown on Figure 2, while they are usually also characterized by high values during winter, for example. I think they should be taken into consideration when determining thresholds/methodology. Also, the vegetation in, for example, Mediterranean zones such as maquis may also be examined. Furthermore, what about the snow impact on the indices values?

Line 88: There are significant differences in the temporal variations of NDVI among winter-triticeae crops, forest, and grassland.

Response: Thank you for your suggestion. First, we have modified Figure 2 and added NDVI time series of other land cover types (including evergreen forests) for comparison with winter-triticeae crops. This study determined the WTCI method based on the characteristic that the NDVI of winter-triticeae crops declines from heading to harvesting stage, which occurs between spring and summer. Although evergreen forests have high NDVI in winter, the NDVI values do not decrease between the heading and harvesting stages of winter-triticeae crops. Therefore, our method can accurately differentiate evergreen forest from winter-triticeae crops. Meanwhile, we have also made improvements to the Method section of the revised manuscript. The details are as follows:

"There are significant differences in the temporal variations of NDVI between winter-triticeae crops and natural vegetation types (i.e., deciduous forest, evergreen forest, and grassland) during the growing season of winter-triticeae crops (Fig. 2). Specifically, in the period from seedling to tillering stages, winter-triticeae crops are in a state of slow growth, with their NDVI gradually increasing. In contrast, natural vegetation types are in the deciduous stage, and exhibit a continuous decrease in NDVI during this period (Fig. 2). From the regreening to the heading stages, the NDVI of winter-triticeae crops rapidly increases and reaches its maximum value, while the NDVI increase of natural vegetation types tends to lag behind that of winter-triticeae crops (Fig. 2). Furthermore, winter-triticeae crops show a downward trend and reach their lowest value during the harvesting stage. However, natural vegetations enter their growth season at this time, and their NDVI values rapidly increase (Fig. 2). Additionally, except for winter rapeseed, there are significant differences in the growth season of maize, rice, and soybean compared to that of winter-triticeae crops. Although the NDVI time series characteristics of these crops share similarities with winter-triticeae crops, they do not interfere with the identification of winter-triticeae crops."

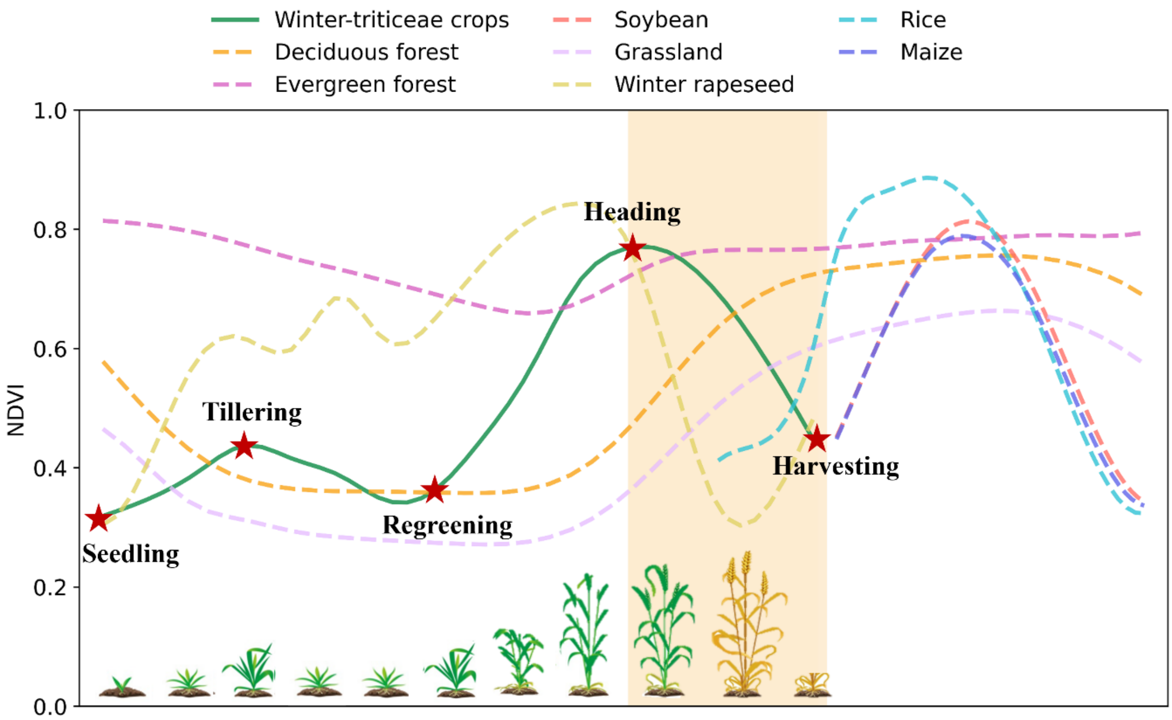

Figure 2: NDVI time series characteristics of different land cover types. The red five-pointed stars represent the different phenological stages of winter-triticeae crops.

Second, thank you for your reminder, we did not consider the maquis in Mediterranean zones when analyzing the NDVI differences of different land cover types, which may lead to errors in the identification results. As mentioned in the Discussion section, we will work to solve the uncertainties of WTCI method and improve the identification accuracy in the future. In addition, we used the maximum values of monthly composites to obtain NDVI, and further employed linear interpolation and the Savitzky-Golay filter methods to fill the missing values and smooth the NDVI series to reduce the contaminations from cloud, rain and snow. Moreover, we used NDVI time series from spring to summer to identify winter-triticeae crops, therefore, the impact of snow on indicator values is very small.

10). Figure 2 – what about southern hemisphere?

Response: Thank you for your reminder. We have modified and improved Figure 2, which can be found in response to Q9. There are seasonal differences between northern and southern hemispheres, but crops and land cover types are basically the same. Therefore, we used the phenological period of winter-triticeae crops to represent temporal variation to make the figure more concise.

11). Lines 172-176 – use of SAR VH-derived thresholds is not clear.

Lines 172-176: Therefore, the VH thresholds set by these studies were further employed to distinguish winter rapeseed and winter-triticeae crops. Specifically, in regions of Asia where winter rapeseed is planted, this study provides smaller WTCI values for pixels with VH values greater than -15.5 in March or April. In some European countries, pixels with VH values greater than -15.5 in May were assigned smaller WTCI values to reduce their probability of becoming winter-triticeae crops.

Response: We have clarified the content regarding the use of SAR VH-derived thresholds, and the details are as follows:

"Therefore, we distinguished winter rapeseed and winter-triticeae crops based on the methods of these studies, and the VH threshold set by Dong et al. (2020a), which was obtained by comparing filed samples, was employed in this study. Specifically, in regions of India where winter rapeseed is planted, we calculated the VH values from Sentinel-1 images in March considering the lower latitude and earlier harvest period of these regions. In other Asian regions where winter rapeseed is grown, this study obtained VH values for April. Then this study identified these pixels with VH values greater than -15.5 in March or April as non-winter-triticeae crops. Similarly, in some European countries, we calculated VH values for May, and considered that pixels with VH values greater than -15.5 were non-winter-triticeae crops (Huang et al., 2022)."

12). Line 184 and further – what method for harmonizing the Sentinel-2 and Landsat data did you use? What collection from GEE were utilized? How did you remove pixels with

clouds?

Line 183-187: In this study, we obtained NDVI for 2016 – 2022 from reflectance data of Landsat 7, Landsat 8 and Sentinel-2 images on the Google Earth Engine (GEE) platform. To reduce the impact of clouds and ensure the quantity and quality of effective observation data, we first removed the pixels with clouds and acquired the maximum values of monthly composites with 30 m spatial resolution. Then, we used linear interpolation and the Savitzky-Golay filter methods (Chen et al., 2004) to fill the missing values and smooth the NDVI series (Zheng et al., 2022). The above processes were run on the GEE platform.

Response: We have added details information to reply these questions and the details can be found in response to Q3.

13). Line 200 – how did you distinguish winter crops based on Google Earth imagery?

Line 200: we relied on high-resolution images from Google Earth from 2019 to 2020 for visual interpretation and obtained 7,029 winter-triticeae crops samples and 8,897 non-winter-triticeae crops samples (orange triangles in Fig. 1).

Response: We have added some content to descript how we distinguish winter crops based on Google Earth imagery. The details can be found in 2.2.2 section in the revised manuscript, also can be seen in response to Q2.

14). Equations 5-9 are redundant; they are commonly used and well-known.

Response: Yes, we have deleted these equations.