Earth System Science Data

Paper # essd-2023-432

Apr. 9, 2024

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 underlined.

Sincerely yours,

Wenping Yuan on behalf of all co-authors

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Detailed responses to reviewer' comments

This manuscript deals with the important challenge of mapping winter triticeae crops at a global scale, a group of crops which is crucial for ensuring global food security. Conventional methods typically require a large number of reference samples to train supervised models that learn to map these crops. In many regions around the world, the availability of such samples is limited to non-existent. The proposed approach works independently from any reference data and therefore does not suffer from this drawback, providing an interesting alternative. The method is based on the temporal behavior of NDVI, where winter triticeae crops are said to be having unique characteristics that allows them to be mapped out against other crops or land cover.

While this is an attractive idea, the authors do not provide sufficient proof of the ability of such a simple approach to really result in high-quality maps at the global scale. There are several major shortcomings and lack of methodological details based on which I cannot recommend the manuscript for publication in its present form. Given its submission to ESSD, I would also expect more attention to the published data itself.

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.

Major comments:

1). The main methodology is based on NDVI values of bare land vs. vegetation and the timing of these events. Looking at equations (2), (3) and (4), it seems that the only timing-related requirement is that the max NDVI should occur before the min NDVI. In Fig. 2 the winter triticeae temporal behavior is only compared to natural vegetation such as forest and grass. The most competing classes to map out from winter triticeae crops are of course other crop types! Why were these omitted from Fig. 2? How much of the reasoning still holds when compared to other crops? For example maize would be slightly

delayed wrt winter cereals in the Northern Hemisphere, but as far as I can tell from the provided equations, maize pixels would also have a high WTCI because their max NDVI occurs before the min NDVI and those values will be similar to vegetation and bare signals, respectively. What am I missing here?

Response: Thanks for your comments. We have added NDVI time series of other land cover types in Figure 2 for comparison with winter-triticeae crops, and we have also made modifications and improvements to the corresponding content:

"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."

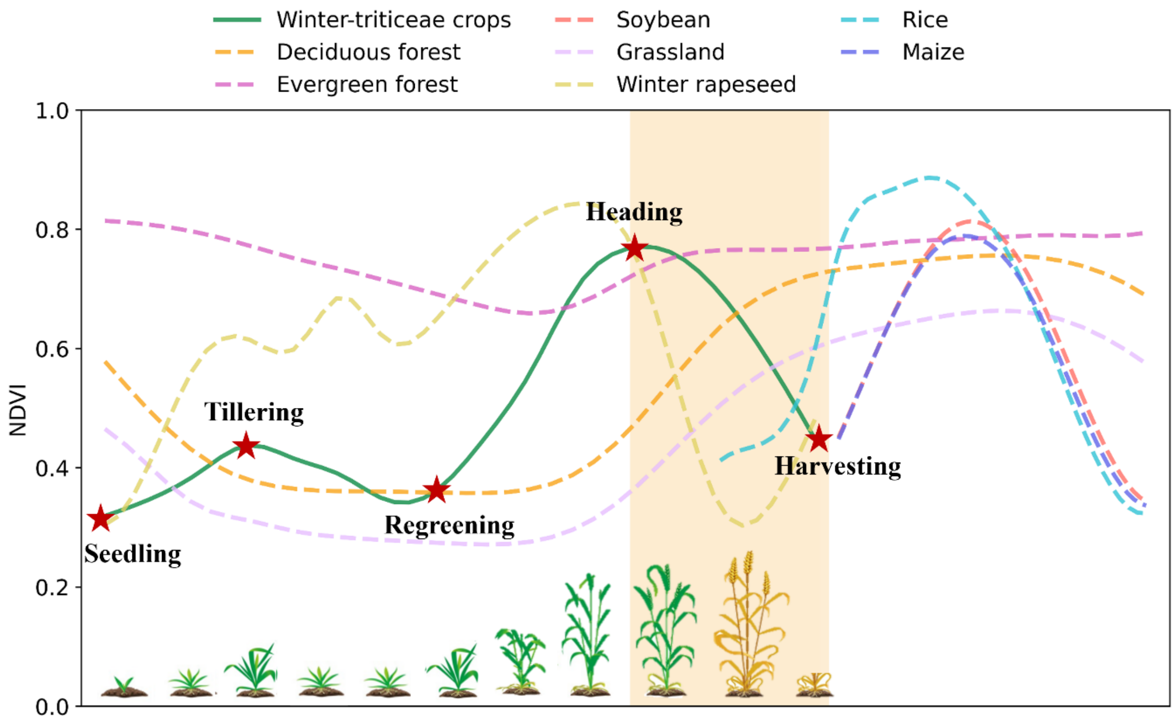


Figure 2: NDVI time series characteristics of different land cover types. The red five-pointed stars represent the different phenological stages of winter-triticeae crops.

"The NDVI time series of winter rapeseed shows a downward trend from the heading to harvest stages of winter-triticeae crops, which is resemble winter-triticeae crops (Fig. 2). Tao et al. (2023) have also demonstrated that winter rapeseed and winter-triticeae crops have similar NDVI characteristics, making it difficult to distinguish them only based on optical images (Veloso et al., 2017). Fortunately, previous studies have indicated that the VH (vertical transmit and horizontal receive) band can effectively eliminate the interference from winter rapeseed in the identification of winter-triticeae crops in China and Europe (Dong et al., 2020a; Huang et al., 2022). 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).”

In addition, it should be noted that although there are similarities in the NDVI time series characteristics between corn and winter-triticeae crops, the growing seasons of these crops do not overlap. We mentioned in section 2.2.1 of the original manuscript that our method is based on the time range from heading to harvesting stages of winter-triticeae crops.

Reference:

Tao, J. B., Zhang X. Y., Wu, Q. F., Wang, Y.: Mapping winter rapeseed in South China using Sentinel-2 data based on a novel separability index, J Integr Agric., 22(6), 1645-1657, https://doi.org/10.1016/j.jia.2022.10.008, 2023.

2). The method relies on max NDVI occurring before min NDVI. But how do you decide on the reference period for which to analyse the curve? This should be different for northern and southern hemisphere at least. This reference period is a crucial choice for the outcome of the method.

Response: Thank you for your reminder. We added some contents to clarify these questions, and the details are as follows:

“Specifically, this study referred to crop calendar data provided by the United States Department Agriculture (USDA) (https://ipad.fas.usda.gov/ogamaps/cropcalendar.aspx) to determine the growth season of winter-triticeae crops in each country. Then, we extracted the maximum and minimum NDVI of all potentially identified pixels during the growing season of winter-triticeae crops. Meanwhile, different percentiles (5%, 20%, 40%, 60%, 80%, and 95%) of all maximum and minimum NDVI were collected, and the values corresponding to the percentile of the maximum and minimum NDVI were chosen as v and b, respectively. After the above steps, we conducted winter-triticeae crops identification for all countries in 2020 based on the calculated WTCI, with each identification unit having its corresponding V line (v) and B line (b). When calculating WTCI, we searched for the maximum and minimum NDVI values between the regreening and harvesting stages of winter-triticeae crops. In this study, the regreening stage was based on the start time of spring in the northern (March) and southern

(September) hemispheres (Ren et al., 2019), and the harvesting stage referred to the crop calendar provided by USDA. We first determined the maximum NDVI value and its occurrence time of each potentially identified pixel, then looked for the minimum NDVI value in the period after the maximum NDVI appears, and further calculated WTCI. Pixels that do not meet this condition are identified as non-winter-triticeae crops."

Reference:

Ren, S. L., Qin, Q. M., Ren, H. Z.: Contrasting wheat phenological responses to climate change in global scale, Sci Total Environ., 665, 620–631, https://doi.org/10.1016/j.scitotenv.2019.01.394, 2019.

3). This study uses agricultural statistical data to determine the threshold of WTCI where statistical data is available. This way, mapping is tuned towards matching these statistical numbers. In the validation results, comparisons are made between the resulting maps and the same statistical data, where correlation coefficients are reported between mapped area and the reported area. This is not an independent analysis and if thresholds were tuned to match statistical numbers, high correlation coefficients with these same numbers seem obvious. In addition, how are planted areas computed from the resulting maps? Area estimates from maps have to be done carefully to avoid biased estimates. This is not discussed here.

Response: Thanks for your suggestion. First, the statistical data used to determine the threshold and the statistical data used for accuracy validation are independent of each other. Specifically, 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 crop map. Second, given that the spatial resolution of each pixel is 30 m ×30 m under the projection of Albers Equal Area Conic, we calculated the sum of the pixel area of winter-triticeae crops on the resulting map to obtain the identified area. We have added some details in the revised manuscript:

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

In addition to verifying the identified area at regional scale through agricultural statistical area, we also used Google Earth samples for accuracy evaluation at the pixel scale. Besides, we have added the Cropland Data Layer (CDL) dataset and Land Parcel Identification System (LPIS) data to perform independent validation for our results. 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 or in the response to Q4.

4). USA is excluded from the analysis because "highly accurate and annually CDL" is already available. This seems odd. A study aiming for global mapping should include USA for completeness and consistency of the maps as well. In fact, USA could be excellent to compare your results to the CDL and report agreement and differences. Also with respect to proving your method is not triggered by other crops than winter triticeae.

Line 69-70: However, due to its high accuracy and annually updated CDL, the study area did not include the United States.

Response: Thank you for your suggestion. We have deleted this sentence and added the US as our study area, and further validated our results using CDL dataset. The details are as follows:

“**3.3 The performance of the WTCI method validated using CDL and LPIS datasets**

Based on CDL and LPIS datasets, we further validated the performance of the WTCI method in the US and Europe. In 2020, the OA and F1 score in the US were 86.84% and 0.82, respectively, and the PA and UA were 76.96% and 88.13%, respectively (Fig. 10). The performance of the WTCI method varied by state. For all states planting winter-triticeae crops, the OA varied from 70.42% to 94.24%, and the F1 score ranged from 0.67 to 0.91 (Fig. 10a-10c). In major planting states, such as Kansas, Oklahoma and Texas, the planting area of winter-triticeae crops account for approximately 50% of the total area of winter-triticeae crops in the US, displaying high accuracy with OA and F1 score over 92% and 0.85, respectively (Fig. 10a). The identified area of WTCI method exhibited good consistency with official statistical data. At national scale, the R^2 and RMAE were 0.89 and 28.9%, respectively (Fig. 11a). At state scale, the R^2 varied between 0.52 to 1, and the RMAE was in 9.01%-57.84% (Fig. 11b-11w). In Europe, the PA, UA and OA in 10 countries were 73.18%, 86% and 83.88%, respectively, and the F1 score was 0.79 (Fig. 10d). The PA and UA ranged from 63.68% to 84.77%, and 71.43% to 96.24% over the various countries, respectively. The OA and F1 score varied from 71.22% to 94.79% and 0.68 to 0.9, respectively (Fig. 10d). In general, the OA and F1 score in most of regions of US and Europe were higher than 80% and 0.75, implying that the WTCI method exhibited satisfactory results compared to the CDL and LPIS datasets. Additionally, we presented spatial detail information of the identification map produced by the WTCI method in US and Europe for comparison with CDL and LPIS datasets (Fig. 12). The results indicate that the identification map and can effectively capture the field distribution of winter-triticeae crops in the US and Europe (Fig. 12)."

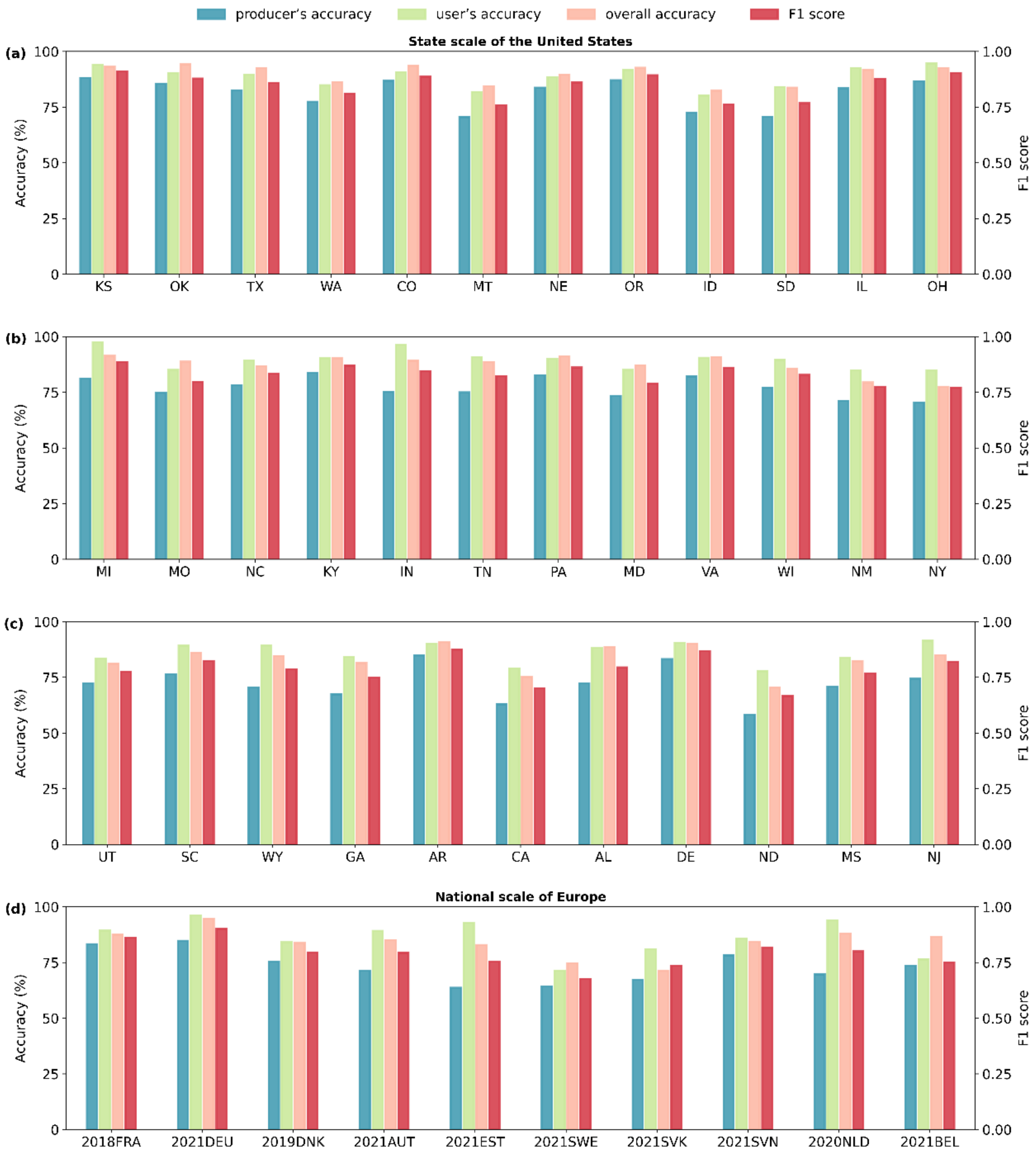


Figure 10: The producer's accuracy (PA), user's accuracy (UA), overall accuracy (OA) and F1 score of the identification maps of winter-triticeae crops in the US and Europe. The abbreviations of countries and states are shown in Table S2 and S3 in the supplement. 2018FRA indicates the identification accuracy of the country in 2018.

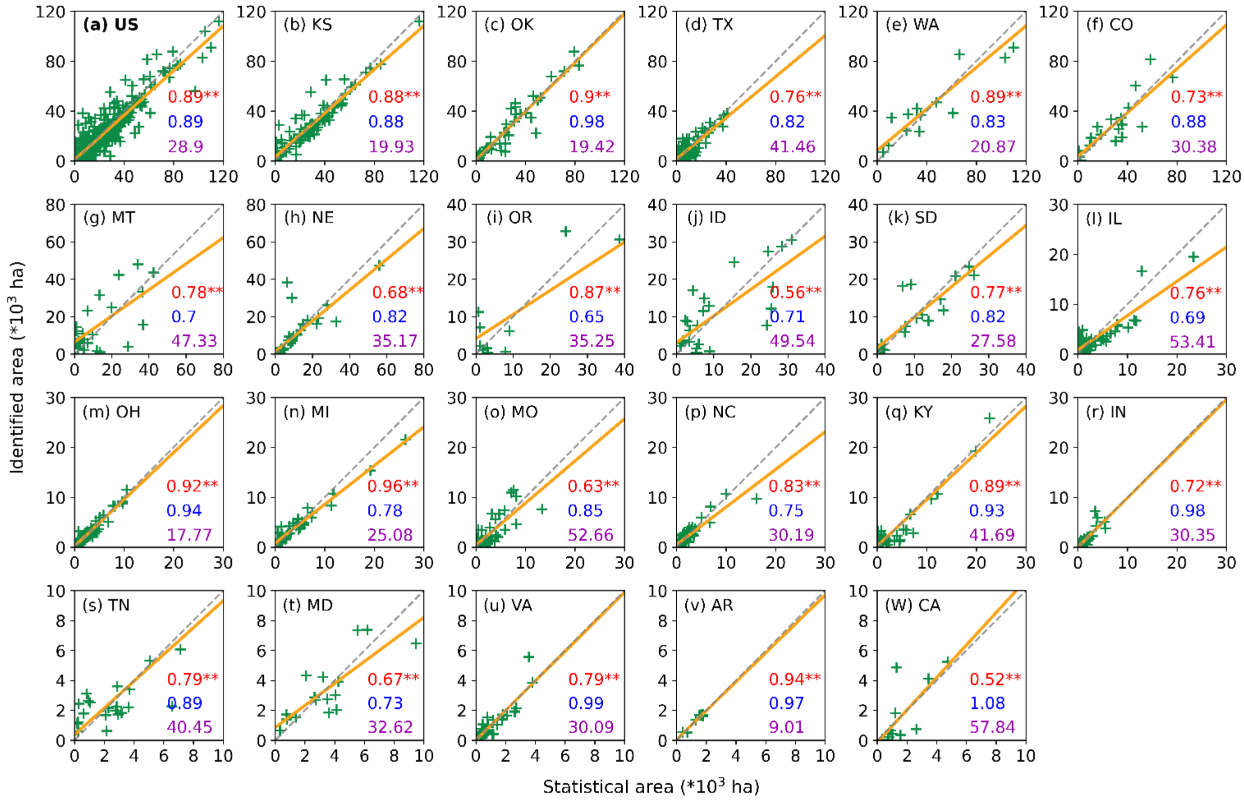


Figure 11: Comparison between identified and statistical areas of winter-triticeae crops in 2020 in the US. (a) show the results between identified and statistical areas at national scale; (b-w) show the results between identified and statistical areas for each state, respectively. The green symbols represent the counties of each state. The yellow solid lines are the regression lines, and the grey short-dashed lines are the 1:1 lines. The red, blue and purple numbers represent R^2, slope and RMAE values between identified and statistical areas, respectively.

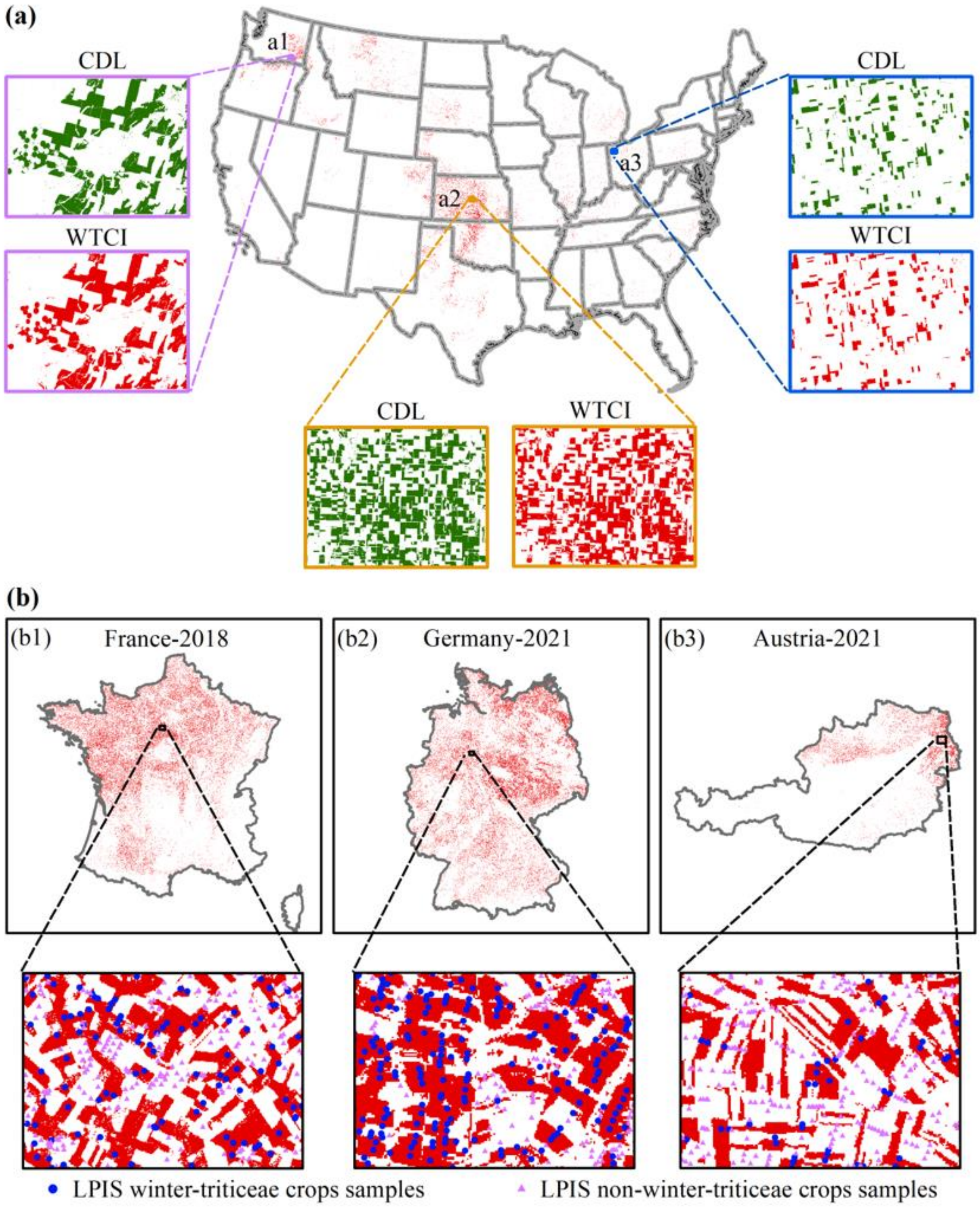


Figure 12: Comparison of the identification maps of winter-triticeae crops with CDL and LPIS datasets. (a) shows the comparison results between the identification maps and CDL dataset in the US; (b) shows the comparison results between the identification maps and LPIS samples in Europe.

5). The study discusses (also in the title) global mapping, while the study area actually contains just 65 countries (Fig. 1). It is stated that 99% of the global winter triticeae crops are covered referring to FAO 2020 which does not appear in the reference list. How did the authors determine the 99% in the first place? Russia is not included while it grows a

major part of the global wheat production. I would recommend in any case to be more careful with the "global" terminology.

Response: Thank you for your suggestion. We have listed the official website and reference of the data sources, and revised some content:

"The study area covers 66 countries, including 36 European countries, 15 Asian countries, 8 African countries, 2 North American country, 4 South American countries, and 1 Oceania country (Fig.1). The area of global triticeae crops (including spring and winter varieties) is 278.87 million ha in 2020 (https://www.fao.org/faostat/en/#data), with winter-triticeae crops accounting for about 75% (i.e., 209.15 million ha) of the global triticeae crops area (Zhao et al., 2018). According to the statistics of the winter-triticeae area provided on official websites of various countries (Table S1), the total area of winter-triticeae in our study area in 2020 is 207,45 million ha, occupying 99.19% of the global winter-triticeae crops area."

In addition, thank you for your reminder about the terminology of global. In order to accurately show the scope of our study area, we only display the planting regions of winter-triticeae crops in Russia, China, India and Brazil rather than the whole country in Figure 1 in the original manuscript. Besides, we have also added US as our study area. In the revised manuscript, the winter-triticeae crops area in our study area accounts for 99.19 % of the global winter-triticeae crops area in 2020. Thus, we used global in the manuscript.

Reference:

Zhao, G. C., Chang, X. H., Wang, D. M., Tao, Z. Q., Wang, Y. J., Yang, Y. S., Zhu, Y. J.: General Situation and Development of Wheat Production, Crops., 4, 1-7, doi: 10.16035/j.issn.1001-7283.2018.04.001, 2018.

6). The validation section is insufficient. A field survey was conducted in China but for all other countries, visual interpretation of Google Earth images was performed. How can the latter be done reliably? How do you identify winter triticeae from a Google Earth picture? Why can't this be another crop? In regions such as Europe, many LPIS datasets are freely available, providing an excellent validation resource for the maps. I strongly suggest the authors to compare to such data instead of interpreting Google Earth pictures,

especially where such high quality data is available. This is crucial to prove that the method doesn't detect other crops.

Response: Thank you for your suggestion. 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 responses to Q3 and Q4.

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.

7). Satellite data is hardly described. Why is Landsat 7 still part of the analysis knowing its striping issues and knowing that for the temporal range of the study it's not essential? How were reflectance data from the different sensors harmonized? Is this an existing

collection? If not, more detail is required here. Based on what were clouds masked for the different sensors?

Response: Thank you for your advices. First, in order to obtain more observation data, we used Landsat 7 satellite and performed linear interpolation and the Savitzky-Golay filter to improve data quality. However, there are still inevitable striping issues in a few regions, which affect our identification results. This is also the part that we need to make improvements and enhancements in our future work, and we have discussed this issue in the discussion section of the revised manuscript:

"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."

Second, we have added some details to display the process of integrating Landsat 7, Landsat 8 and Sentinel-2 data in the Data section:

"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.

Ju, J. C., Roy, D. P.: The availability of cloud-free Landsat ETM+ data over the conterminous United States and globally, Remote Sens. Environ., 112(3), 1196-1211, https://doi.org/10.1016/j.rse.2007.08.011, 2008.

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.

8). The section on Data should really come before the explanation on the methodology

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

Data comments:

9). GeoTIF files are called e.g. F*rance_classify_2021_WTCI_Bline20_Vline05* or

***Belgium_classify_2021_WTCI_Bline60_Vline80*. This naming convention needs to be explained. Two neighboring countries where *Vline* value changes from *05* to *80*? What are these values and why do they differ so much?**

Response: Thank you for your suggestion. We have modified the file name in our dataset. In order to make the WTCI method more stable in different regions, we use an automatic method to determine the optimal identification result through different percentile combinations of V and B lines in each identification unit. The details can be found in section 2.3.3 of the revised manuscript. Here, The NDVI value corresponding to Vline05 in France is 0.62, which is the *v* value in the WTCI method, and the NDVI value corresponding to Vline80 in Belgium is 0.9. We discussed the potential reasons for the differences in percentile combinations of V and B lines in different regions in the Discussion section of the original manuscript. We also display the differences of F1 score in different percentile combinations of V and B lines in France and Belgium (Fig. R1). The results indicate that the different percentile combinations of V and B lines have little impact on F1 score in France where winter-triticeae is dominant crop (Fig. R1a), while in Belgium with less winter-triticeae crops planting area, there is a significant difference in F1 score under different percentile combinations of V and B lines (Fig. R1b). We consider this is one of the potential reasons for the differences in percentile combinations of V and B lines among different regions. This conclusion is consistent with the study of Xu et al. (2023), who analysed the reasons for the differences in rice identification accuracy in different regions based on similar method. We will continue to explore more reasons of this phenomenon in future work.

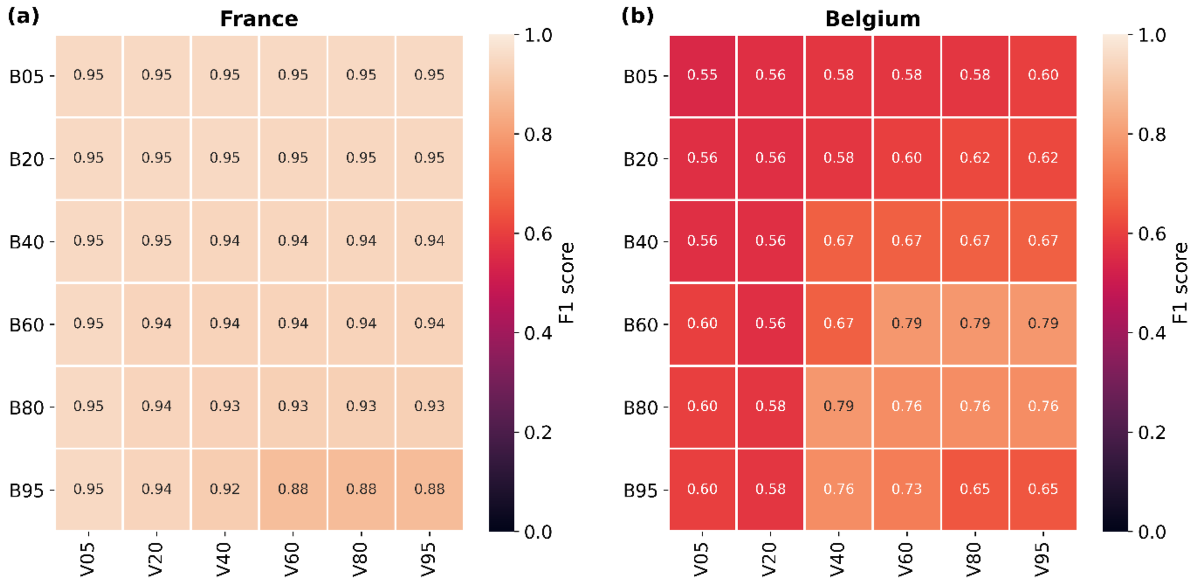
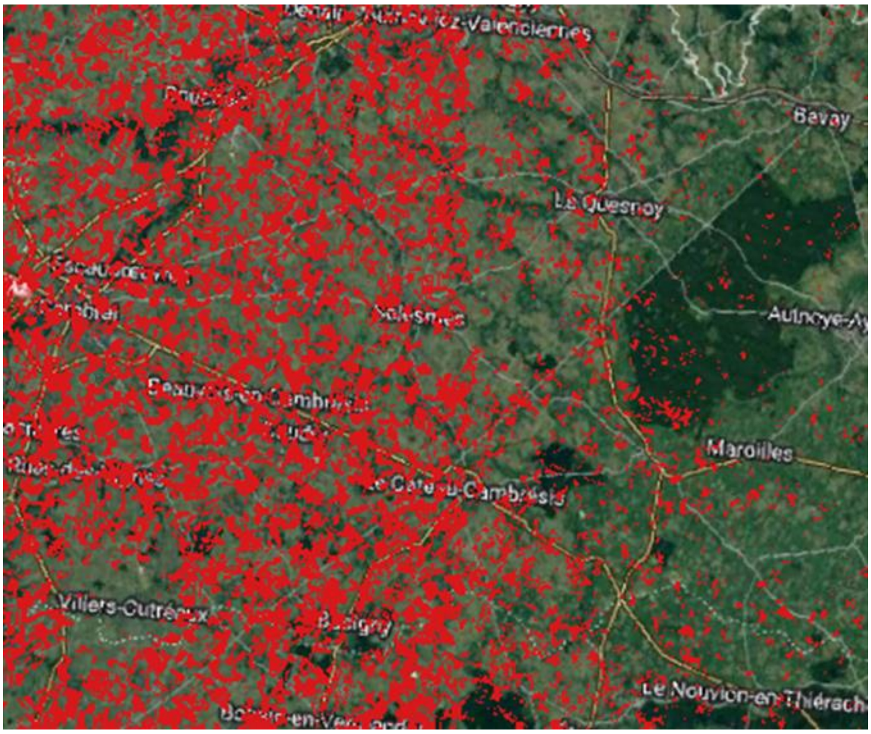


Figure R1: Identification accuracy under different percentile combinations of V line (v) and B line (b). V05 and B05 represent the 5% percentile of the V and B lines, respectively.

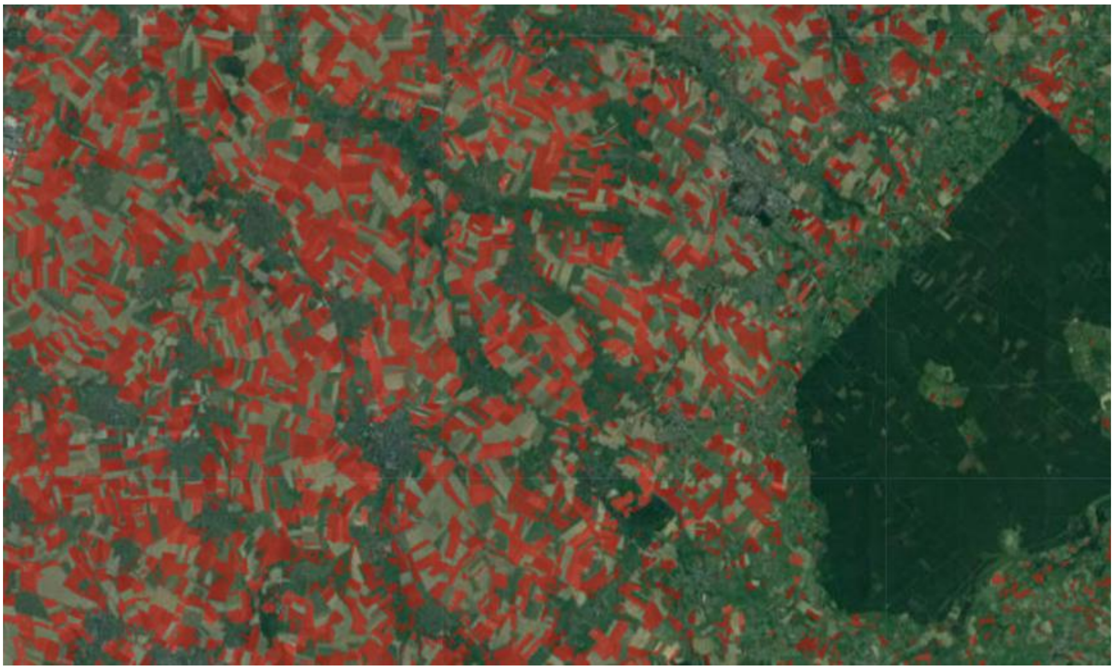
10). For the files I checked I was unable to get a correct georeferencing, cfr. this screenshot. More checks on the data format are required so a user can actually make use of them.

Response: We have checked these GeoTIFF files and found that the reason for the above situation is a problem with spatial projection. After converting it to GCS 1984 (EPSG:4326), we obtained the correct display in the following picture. In addition, we have added a documentation with the dataset to introduce the spatial projection, so that users can use the data correctly.

11). Even within single files, strange spatial artefacts appear, like this one in Northern France. Where does this come from?



Response: This reason is the same as question 10. The following picture shows the enlarged details in the same area after converting the GeoTIFF file to GCS 1984 (EPSG:4326).



Other comments:

12). L28: no area estimates follow naturally from crop maps. Suggest to use another term than "crop area"

Line28: Crop mapping can monitor crop information by providing detailed location and nearreal 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)."

13). L33: Rephrase "warning global food security"

Line33: Closely monitoring the spatial distribution information of winter-triticeae crops is therefore beneficial for evaluating yield, optimizing land use, and warning global food security (Fu et al., 2021; Nelson and Burchfield, 2021; Wardlow et al., 2007).

Response: Thanks, we have revised this sentence as follows:

"Closely monitoring the spatial distribution information of winter-triticeae crops is therefore beneficial for evaluating yield, optimizing land use, and assessing food security (Fu et al., 2021; Nelson and Burchfield, 2021; Wardlow et al., 2007)."

14). L35-36: Please have a look at the recently released WorldCereal global 10m maps of winter triticeae. Some of the statements in the manuscript are outdated. Please revise the introduction accordingly.

Line 35-36: Few studies have attempted to produce global triticeae crop maps (You et al., 2014), but efforts have been limited to coarse resolutions.

Response: Thank you for your reminder. We have added some new contents in the Introduction section of the revised manuscript, and the details are as follows:

"The WorldCereal project proposed by European Space Agency (ESA) has released a global crop maps with a spatial resolution of 10 m for 2021, addressing the limitations of spatial resolution in global-scale crop mapping (Van Tricht., 2023). However, this product is currently only available for one year, which will affect the demand for long time-scale."

Reference:

Van Tricht, K., Degerickx, J., Gilliams, S., Zanaga, D., Battude, M., Grosu, A., Brombacher, J., Lesiv, M., Bayas, J. C. L., Karanam, S., Fritz, S., Becker-Reshef, I., Franch, B., Mollà-Bononad, B., Boogaard, H., Pratihast, A. K., Koetz, B., and Szantoi, Z.: WorldCereal: a dynamic open-source system for global-scale, seasonal, and reproducible crop and irrigation mapping, Earth Syst. Sci. Data, 15, 5491–5515, https://doi.org/10.5194/essd-15-5491-2023, 2023.

15). L67: see main comments: why these 65 countries. It's a bit strange that because CDL is available in US, this country is not mapped. This would actually be an excellent reason to do it nonetheless and compare your results with the CDL.

Line 67: The study area covers 65 countries, including 36 European countries, 15 Asian countries, 8 African countries, 1 North American country, 4 South American countries, and 1 Oceania country (Fig.1).

Response: Thank you for your comments. We have added the US as our study area, and made some modifications to 2.1 section of the revised manuscript. In addition, we validated and compared the results of the proposed method using the CDL dataset. Detailed information can be seen in 2.1, 2.2.2 and 3.3 sections in the revised manuscript, also can be found in responses to Q3, Q4 and Q5.

16). L72: see main comments. Please provide more information on where this number comes from.

Line 72: with the winter-triticeae crops area occupying about 99% of the global (excluding the United States) winter-triticeae crops area (FAO, 2020).

Response: Yes, we have revised some contents and listed the source of this number, and the details can be found in response to Q5.

17). L91: what with evergreen trees? And grassland not necessarily exhibits this continuous decrease in NDVI.

Line 91: In contrast, natural vegetation types (i.e., forest and grassland) are in the deciduous stage, and exhibit a continuous decrease in NDVI during this period (Fig. 2).

Response: Thank you for your suggestion. We have added land cover types (include evergreen trees) to analyze the characteristics of NDVI time series, and the details can be found in response to Q1. Xu et al. (2023) have demonstrated that in mid-latitude, where is the main distribution areas of winter-triticeae crops worldwide (Zhao et al., 2018), the NDVI time series of grassland in most areas showed a decrease trend from autumn to winter. Most important, the WTCI method is depends on the NDVI characteristics of land cover types in spring and summer. During this period, the variation trend of NDVI of grassland and winter-triticeae is opposite (Figure 2 in the revised manuscript), which will not affect the identification of winter-triticeae crops.

References:

Xu, X. F., Tang, J. K., Zhang, N., Zhang, A. A., Wang, W. H., Sun, Q.: Remote Sensing Classification of Temperate Grassland in Eurasia Based on Normalized Difference Vegetation Index (NDVI) Time-Series Data, Sustain., 15, 14973, https://doi.org/10.3390/su152014973, 2023.

18). L120: See main comments. Max before min with respect to what? How do you enforce this? How do you treat calendar years? A maximum will always be before some minimum later on. What's your reference period in which you make this analysis?

Line 120: the maximum NDVI should appear before the minimum NDVI.

Response: Thank you for your suggestion. The design concept of the WTCI method is to use the NDVI time series characteristics of winter-triticeae crops from the heading to harvesting stages to distinguish other land cover types. This stage occurs in the spring and summer of a year and the NDVI of winter-triticeae crops reaches its maximum during the heading stage of winter-triticeae crops, then gradually decreases until harvest (Figure 2 in the revised manuscript). Thus, we could use the condition that whether the maximum NDVI occur before the minimum NDVI during the stage from the heading to harvesting in a year. More details analysis can be found in response to Q1 or 2.3.1 section in the revised manuscript. Second, the process of winter-triticeae crops identification and calendar years or reference period used in this study can be found in response to Q2.

19). L119: how is this done in practice for the southern hemisphere, i.e. how do you take

into account cyclical dates?

Line 119: It should be noticed that Eq. (1) was used to identify the winter- triticeae crops only when $n1<n2$,

$$WTCI = f(D) \times f(V) \times f(B), n1 < n2 \quad (1)$$

Response: We referred to crop calendar data provided by the United States Department Agriculture (https://ipad.fas.usda.gov/ogamaps/cropcalendar.aspx) to determine the growth season of winter-triticeae crops in southern hemisphere. The details can be found in response to Q2.

20). L157: which accuracy is meant here based on which to decide the optimal threshold?

L157: the optimal combination was decided solely based on the accuracy at the pixel scale.

Response: Thank you for your reminder. We have modified this sentence:

"In addition, we determined the optimal combination of V and B lines according to the identification accuracy at the pixel scale (F1 score) and the relative mean absolute error (RMAE) between identified and agricultural statistical areas. For countries lacking agricultural statistical data, the optimal combination was decided solely based on the F1 score."

21). L160: why only these two crops?

L160: The identification of winter-triticeae crops in the study area may be affected by winter rapeseed and garlic.

Response: Because winter rapeseed and garlic have similar growth season and spectral characteristics to winter-triticeae crops. We have revised this sentence:

"The identification of winter-triticeae crops in the study area may be affected by winter rapeseed and garlic, as these crops have similar growth season and spectral characteristics with winter-triticeae crops (Fu et al., 2023b; Tian et al., 2021)."

Reference:

Tian, H. F., Wang, Y. J., Chen, T., Zhang, L. J., Qin, Y. C.: Early-Season Mapping of Winter Crops Using Sentinel-2 Optical Imagery, Remote Sens., 13, 3822, https://doi.org/10.3390/rs13193822, 2021.

22). L172-176: this lacks detail. The tresholds seem arbitrary and are computed on what exactly?

L172-176: 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: Thank you for your suggestion. The threshold is derived from the study of Dong et al. (2020), which was obtained through the analysis of filed samples. The details can be found in response to Q1.

23). L366: Or other land covers

Line 366: The product is provided in Geotiff format with pixel values of 1 for winter-triticeae crops and 0 for non-winter-triticeae crops.

Response: Yes, we have revised this sentence:

"The product is provided in GeoTIFF format with pixel values of 1 for winter-triticeae crops and 0 for other land covers."