Earth System Science Data

Paper # essd-2023-432

Sep 10, 2024

Dear editor and reviewers:

Thank you for taking time out of your busy schedule to review the 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 are in **bold font** followed by our responses in normal font, changes/additions to the manuscript are <u>underlined</u>.

Sincerely,

Wenping Yuan on behalf of all co-authors

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Detailed responses to editor and reviewers' comments

 # Editor

Thank you for your efforts in revising your manuscript titled "Global Winter-Triticeae Crops Mapping Using a Sample-Free Method." The reviewers acknowledge the improvements made but have highlighted several concerns that need to be addressed. We invite you to carefully revise your manuscript based on their detailed comments.

Reviewer 1 notes the progress made but still has several concerns. They suggest providing a map showing the spatial pattern of WTCI thresholds to illustrate variations among identification units. Additionally, they recommend discussing how multiple winter-triticeae crops in an administrative unit might impact threshold suitability and data accuracy. Clarification is needed on whether using USDA's national-level crop calendar affects the reliability of WTCI thresholds at the province/state level. Reviewer 1 also requests an explanation of whether the NDVI change curves can represent all winter-triticeae crops and surrounding vegetation. They advise including a comparison statistical analysis of WTCI values between winter-triticeae and non-winter-triticeae crops. Finally, they suggest revising the titles and content focus of Sections 3.4 and 4.3.

Reviewer 2 appreciates the significant contributions of your work but points out areas for improvement in methodology and accuracy evaluation. Detailed explanations are needed on how provincial or state-level statistics are used to set the WTCI threshold and how consistency is determined across years. The global applicability of the NDVI>0.4 threshold should be validated with more references or experiments. They also recommend elaborating on the index threshold determination method and using crop reference layers to verify accuracy. Reviewer 2 suggests improving the design of figures and tables, particularly reconsidering Figure 3(a) and adding results from crop reference layers in Figure 6.

Reviewer 3, while acknowledging improvements, still has concerns, especially regarding data provision. They advise updating terminology to reflect official terms, such as using GSAA instead of LPIS. Justification is needed for the choice of the nearest neighbor resampling method. Reviewer 3 also raises questions about validating

commission errors in non-crop land covers and addressing projection issues in data files to ensure correct visualization in software like QGIS.

Please refer to the reviewers' detailed reports for specific comments and suggestions. We look forward to receiving your revised manuscript and believe these revisions will significantly enhance the quality of your work.

Response: We appreciate you for giving us this opportunity to revise this paper. We try to address the issues raised as best as possible and have responded to them one by one. The detailed responses are listed below.

Reviewer #1

Winter-triticeae crops are among the most important grain crops in the world, thus mapping its distribution is helpful for crop yield estimation, crop planting pattern optimization, and food security assessment. This study developed a new global winter-triticeae crops map by using a sample-free method, and has a relative high accuracy validated by using the field samples, CDL, LPIS data, and agricultural statistical data. I have reviewed the revised manuscript and the point-by-point responses to the comments from the other reviewers. The authors worked well in addressing the comments. However, I still have some concerns for the revised manuscript and provides as follows:

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

1). This study used the planted area to determine the threshold of WTCI at administrative units. So, are there large variations in the thresholds among all the identification units? I suggest providing a map in the supplementary materials to show the spatial pattern of WTCI threshold.

Response: Thank you for your suggestion. We have added a figure (Figure. S2) in the supplementary to display the spatial pattern of WTCI threshold. Overall, the spatial differences between the WTCI thresholds of all identification units are relatively small, and these thresholds mainly range from 0.3 to 0.6.

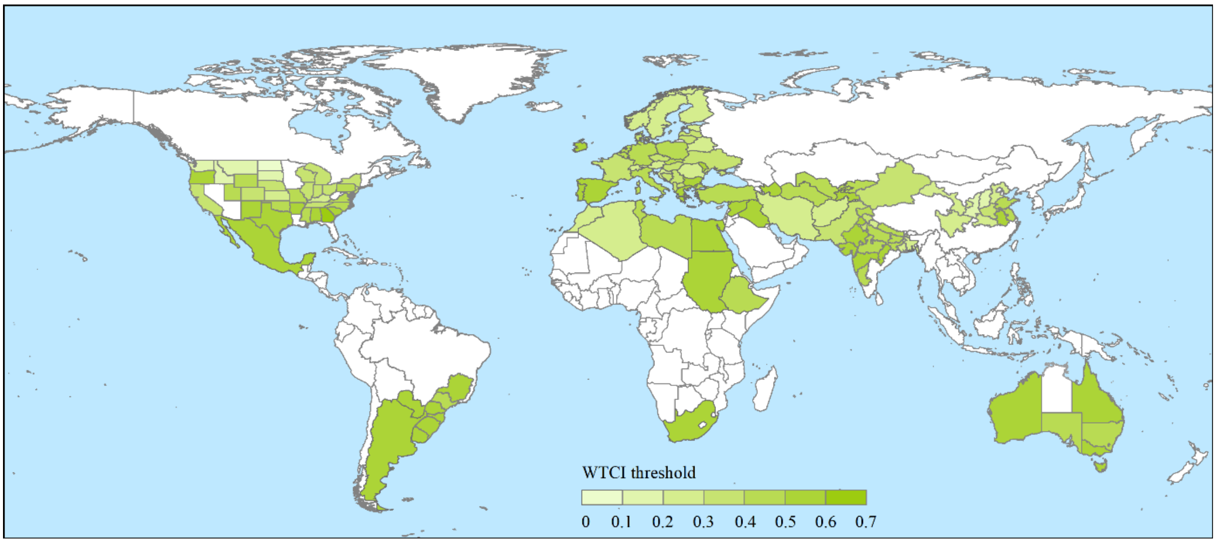


Figure S2: The spatial distribution of WTCI thresholds in all identification units in 2020.

2). In this study, winter-triticeae crops include winter wheat, winter barley, winter rye, and triticale. If there are multiple types of winter-triticeae crop in an administrative unit, the threshold may not suitable for some crops and further impact on the data accuracy.

Response: Thank you for your deep thought. Previous studies indicated that winter-triticeae crops, including winter wheat, winter barley, winter rye and triticale, have similar seasonal change curves of NDVI and phenological characteristics (Huang et al., 2022; Xu et al., 2017). Therefore, we identified them as a whole. There may be differences between these crops, leading to differences in threshold and affecting identification accuracy. We have added some discussion in the Discussion section of the revised manuscript, and the details are as follows:

"Besides, this study ignored the internal differences between winter wheat, winter barley, winter rye and triticale due to their similar NDVI time series and phenological characteristics (Huang et al., 2022; Xu et al., 2017), which may affect the identification accuracy." (Line 471-473)

"In the future, identifying useful bands or vegetation indexes that eliminate interferences from other land covers, further subdividing each winter-triticeae crop, as well as increasing the availability and quality of satellite data, will further promote the performance of the WTCI method." (Line 476-478)

3). Line 239-241: USDA only provides national-level crop calendar, would it influence the

reliability of WTCI threshold at province/state level?

Line 239-214: 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.

Response: Thank you for your careful consideration. We use the national level crop calendar as a reference for phenological periods, which only defines the range of phenological periods in a country. Importantly, our method can consider the phenological differences in different regions within a country. Specifically, the parameters of WTCI method are determined automatically during the winter-triticeae crops growing season, for example, the maximum and minimum values of NDVI and their occurrence times are automatically searched during the regreening to harvesting stages of winter-triticeae crops. It should be noted that the time when the maximum and minimum values of NDVI appear is not fixed, but is flexibly determined based on the NDVI curve characteristics of each pixel, which considering the phenological differences between different regions. Therefore, although we used the national level crop calendar as a reference to determine the WTCI threshold at province (or state) level in some countries, the advantage of the WTCI method can effectively balance the phenological differences between regions. Moreover, our results further demonstrate the reliability of WTCI threshold at province (or state) level, despite the lack of detailed crop calendar information in these regions.

4). Figure 3 shows the time series of winter-triticeae crops and other natural vegetation, can these NDVI change curves represent all winter-triticeae crops, other crops and surrounding natural vegetation around the study area (i.e., 66 countries)?

Response: According to the record of statistical data and prior knowledge, the main winter crops are winter-triticeae and winter rapeseed in the study area. The variety of summer crops is relatively abundant, but their phenological period is significantly different from that of winter crops, which will not affect the identification of winter-triticeae crops. Therefore, the crops shown in the Figure 3 are representative and widely planted in the study area, and the natural vegetation types are also typical and widely distributed. In addition, the key point of the WTCI method is to distinguish winter-triticeae crops based on the phenological characteristics of different land cover types. The NDVI time series in Figure 3 can accurately reflect the phenological characteristics of different land cover types during their growing seasons. Most importantly, they can clearly distinguish winter-triticeae crops from them. We believe that this is the main message that Figure 3 intends to deliver. We also added the NDVI times series of wetland and shrub based on the suggestion from another reviewer to further support our study.

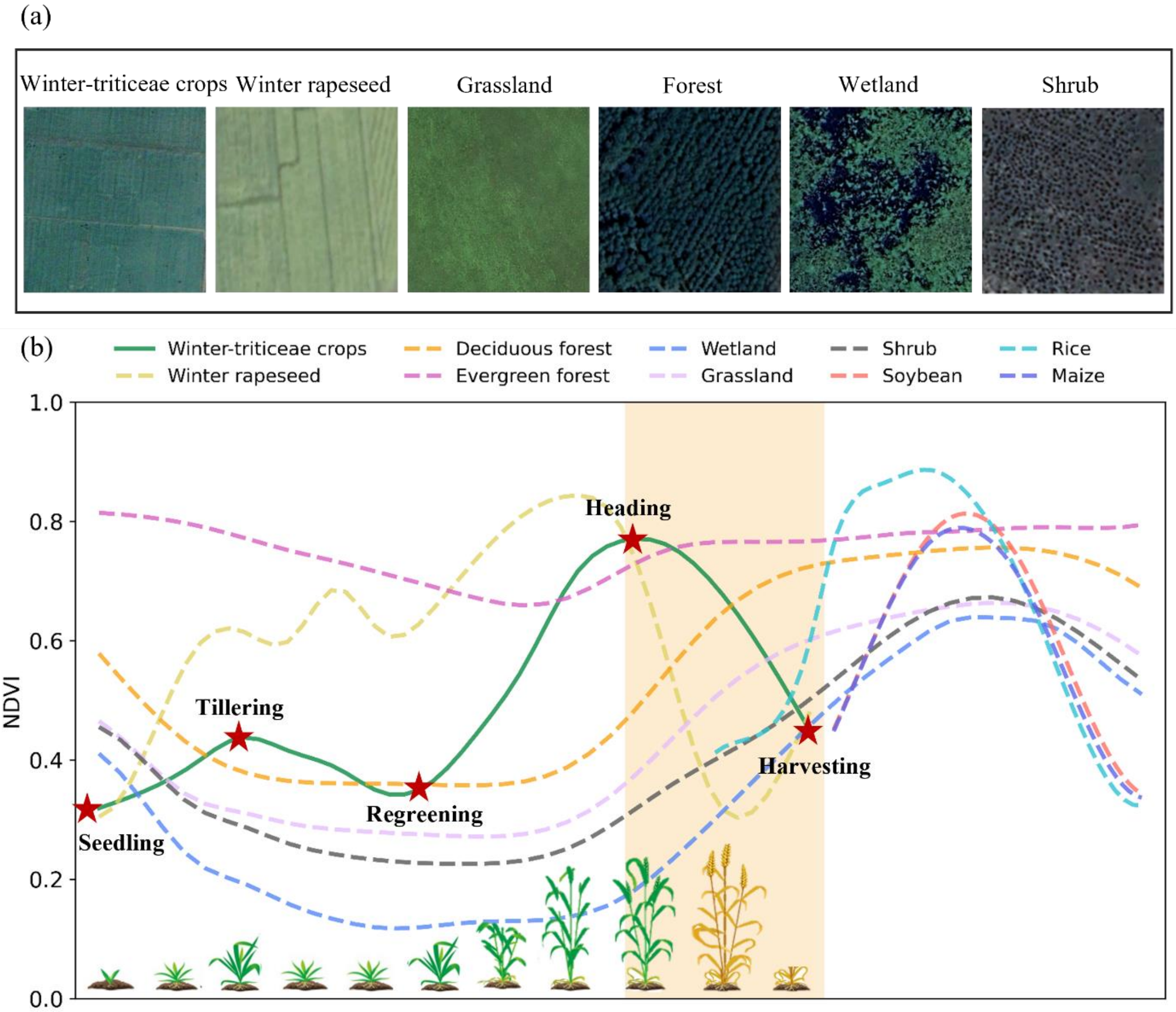


Figure 3: Example of the (a) textures and colours on the high-resolution images from © Google Earth and (b) NDVI time series characteristics of different land cover types. The red five-pointed stars represent the different phenological stages of winter-triticeae crops.

5). The WTCI is the key variable to identify the winter-triticeae crops, a comparison statistical analysis (e.g., a box plot of WTCI values for different vegetation type or frequence distribution map) in WTCI between winter-triticeae crops and non-winter-

triticeae crops should be provided in the manuscript.

Response: Thank you for your suggestion. We have plotted a figure to compare the WTCI values between winter-triticeae crops and non-winter-triticeae crops. Except for winter rapeseed, there are significant differences in WTCI values between other land cover types and winter-triticeae crops, and this study used VH to exclude winter rapeseed when identifying winter-triticeae crops. Due to the fact that the calculation of WTCI values requires the use of phenological period of winter-triticeae crops, and the phenological period of summer crops is obviously different from that of winter-triticeae crops, they do not participate in the calculation of WTCI. Therefore, the figure only displays the WTCI values of some land cover types that overlap with the phenological period of winter-triticeae crops, and does not show the WTCI values of summer crops.

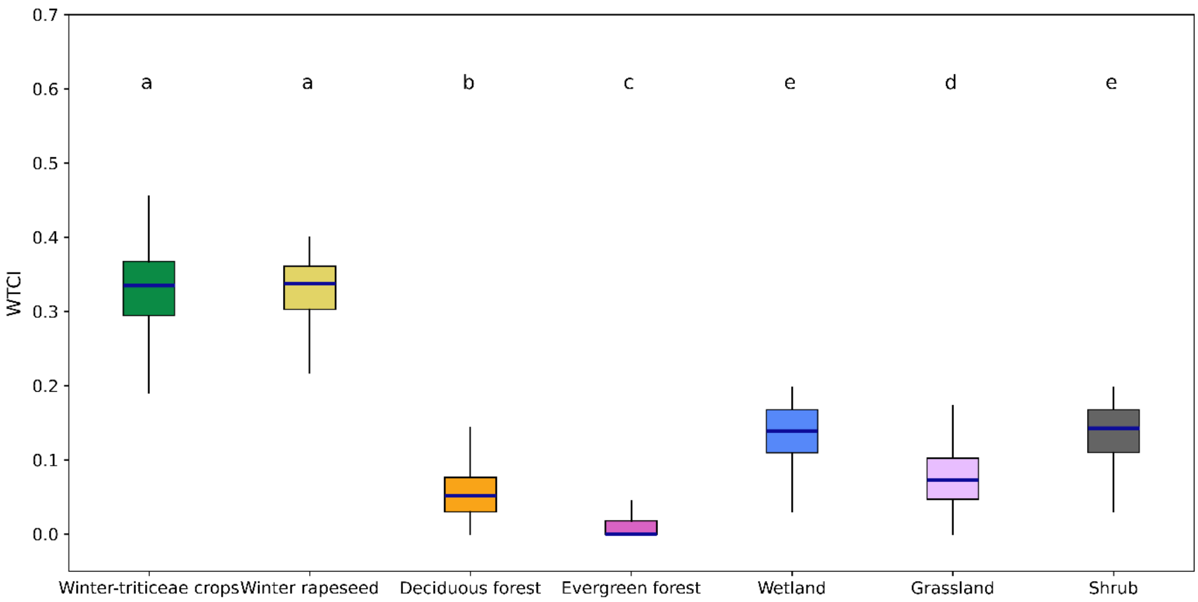


Figure S1: WTCI values of different land cover types. Letters represent statistically significant differences in WTCI values for different land cover types (Tukey's Test, $P < 0.05$).

6). Section 3.4. The title should be "Harvest time of global winter-triticeae crops" rather than "Harvest dynamics of global winter-triticeae crops", because there is no temporal analysis.

Response: Thank you for your reminder. We have revised the title of section 3.4.

7). The winter-triticeae crops dataset refers planted area rather than harvested area. While, Section 4.3 emphasized too much on the harvested area rather than the spatial variations of harvested time.

Response: Thank you for your reminder. In fact, the winter-triticeae crops dataset refers to harvested area, as we used NDVI during the harvest period when identifying winter-triticeae crops. In addition, we speculate that you are referring to section 3.4. We described the harvested area in this section to show and compare the proportion of winter-triticeae crops harvested area at different harvest times to the global winter-triticeae crops harvested area. Here, we have added some contents to describe the spatial variations of harvested time, and the details are as follows:

"Overall, the harvest time of winter-triticeae crops is delayed with increasing latitude (Fig. 14). In the Northern Hemisphere, winter-triticeae crops in East and South Asia were harvested in May and June (Fig. 14c), and the harvested area accounted for about 35.64% of the total harvested area in the study area (Fig. 15). The harvest time in Central Asia, Europe, North Africa and North America was concentrated between July and August (Fig. 14b, 14c 14d and 14f), and the proportion of harvested area to the total area was around 47.05% (Fig. 15). The regions with harvest time in September were mainly distributed in high latitude areas of Russia (Fig. 14b). In the Southern Hemisphere, the harvest time of winter-triticeae crops was mainly from November to January of the following year (Fig. 14e and 14g), with the harvested area accounting for 13.7% of the total harvested area (Fig. 15). These areas with the harvest time occurring from November to January were mainly located in high latitude regions of Australia and South America (Fig. 14e and 14g), and the harvest time in October only occurred in some areas of low latitude regions of South America (Fig. 14g)." (Line 393-402)

Specific comments:

8). Line 74-75: 278.87 and 209.15 refer planting area, harvested area, or physical area?

Response: Thank you for your reminder. 278.87 and 209.15 refer harvested area. Here, we have revised these contents that:

"The harvested 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 harvested area (Zhao et al., 2018). According to the statistics of the winter-triticeae crops area provided on official websites of various countries (Table S1), the total harvested area of winter-triticeae crops in our study area in 2020 is 207.45 million ha, occupying 99.19% of the global winter-triticeae crops harvested area." (Line 73-78)

9). Line 77: 207.45 million ha. Dot not comma.

Response: Thank you for your meticulous discovery. We have revised this punctuation, and the details can be found in the response to Q8.

10). Line 349-351: How do you get this conclusion? Delete this sentence or give some examples.

Line 349-351: Similar to the results of 2020, the regions with a higher error are concentrated in areas with small planting areas of winter-triticeae crops and diverse planting types of winter crops.

Response: Thank you for your suggestion. We have deleted this sentence.

11). Line 360: I didn't find the R^2 of any state was 1.

Line 360: At state scale, the R^2 varied between 0.52 to 1, and the RMAE was in 9.01%-57.84% (Fig. 12b-12w).

Response: Thanks for pointing this out. We have modified this sentence as follows:

"At state scale, the R^2 varied between 0.52 to 0.96, and the RMAE was in 9.01%-57.84% (Fig. 12b-12w)." (Line 369-370)

12). Line 410: Why does the US winter-triticeae crops data not include year of 2017-2019 and 2021-2022? The reason should be explained in manuscript.

Response: Thank you for your comments. The United States already has high-accuracy and annually updated Cropland Data Layer (CDL) product, while other countries where winter-triticeae crops are planted widely still lack high-accuracy distribution maps of winter-triticeae crops. To avoid duplication of work, this study focuses on producing distribution maps of winter-triticeae crops for other countries. On the other hand, this study developed the WTCI method based on 2020, therefore only the winter-triticeae crops data in 2020 in the US was produced and compared with CDL product to validate the performance of the WTCI method. In fact, we have explained the reason on Line 47-52 and Line 135-142 of the original manuscript.

13). Line 450: Revise "Sichuan (SC)" as "Sichuan (SC) province of China".

Line 450: First, the commission error is higher in regions where winter-triticeae crops are not dominant crops, such as in Sichuan (SC), West Bengal (WB), Bihar (BR), Karnataka (KA) and few countries in Mediterranean Sea region indicating that here non-winter-triticeae crops are misclassified as winter-triticeae crops.

Response: Thank you for your advice. We have revised this sentence, and the details are as follows:

"First, the commission error is higher in regions where winter-triticeae crops are not dominant crops, such as Sichuan (SC) province of China, West Bengal (WB), Bihar (BR), Karnataka (KA) and few countries in Mediterranean Sea region, indicating that here non-winter-triticeae crops are misclassified as winter-triticeae crops." (Line 458-461)

14). Line 453: What does "…large differences in the available images…" mean? quantity or quality of satellite images?

Line 453: 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.

Response: Thanks for pointing this out. We have revised this sentence:

"Although we used synthetized images from Landsat and Sentinel productions to increase the amount of effective data and conducted linear interpolation and the Savitzky-Golay filter to further improve data quality, there are still differences in the quantity and quality of satellite data among the study area." (Line 461-464)

15). Line 457: The cloud pixels in satellite images have been removed as the descriptions in the methods, why the cloud and rain contaminations still introduce noise in the NDVI?

Line 457: 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).

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

16). Line 476: "Google Earth samples" is weird. Revise it as "visual interpretation samples from Google Earth images".

Line 476: The new method exhibits high accuracy and strong spatiotemporal transferability by comparing the produced maps with field survey and Google Earth samples, the CDL and LPIS datasets, and agricultural statistical data.

Response: Thank you for your suggestion. We have revised this sentence, and the details are as follows:

"The new method exhibits high accuracy and strong spatiotemporal transferability by comparing the produced maps with field survey samples and visual interpretation samples from Google Earth images, the CDL and EuroCrops datasets, and agricultural statistical data." (Line 485-487)

References:

Huang, X. J., Fu, Y. Y., Wang, J. J., Dong, J., Zheng, Y., Pan, B. H., Skakun, S., Yuan, W. P.: High–resolution mapping of winter cereals in Europe by time series Landsat and Sentinel images for 2016–2020, Remote Sens., 14(9), 2120, https://doi.org/10.3390/rs14092120, 2022.

Xu, X. M., Conrad, C., Doktor, D.: Optimising phenological metrics extraction for different crop types in Germany using the moderate resolution imaging Spectrometer (MODIS). Remote Sens., 9(3), 254, https://doi.org/10.3390/rs9030254, 2017.

Reviewer #2

The paper presents significant contributions to the field and demonstrates substantial effort. However, there are still a few areas for improvement in the methodology and accuracy evaluation sections.

Response: Thank you for your comments and suggestions. Your suggestions are very valuable for us to improve our research. Here, we have revised our manuscript based on your suggestions, and we also attached a point by point letter to you. The detailed responses are listed below.

1). Methodology: **While the paper provides additional explanations on the calculation and application of the WTCI, the threshold calculation for the index remains unclear. The authors mention relying on provincial or state-level statistics to set the threshold but fail to detail how these statistics are used. It is unclear how the consistency between statistical data and threshold products is determined, whether a single year's data is used to set thresholds for other years, or if yearly statistical data is directly used for threshold determination. Detailed explanations are needed for the index threshold determination. Additionally, the paper uses NDVI>0.4 to identify potential crop areas, based on a study from a small region in Sichuan, China. It is questionable if this threshold can be globally applicable. The authors should provide more references or experiments to validate the reliability of this threshold.**

Response: Thank you for your suggestions. We have added some contents to explain the calculation of WTCI threshold, and the details are as follows:

"<u>The potential pixels (*N*th) with high WTCI values are considered winter-triticeae crops in a given identification unit, and the total area of all *N* potential pixels should be equal to the agricultural statistical area of the identification unit.</u>" (Line 234-236)

"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. <u>The annual statistical area was used to determine the threshold of WTCI for each</u>

identification unit in the current year." (Line 245-248)

In addition, we have added some references to support the reliability of the threshold (NDVI>0.4), and the details are as follows:

"Some regional and global scale studies have reported that NDVI greater than 0.4 usually indicates vegetation cover (Ma et al., 2022; Peng et al., 2019; Xu et al., 2023; Yang et al., 2024; Yang et al., 2024)." (Line 175-176)

2). Accuracy assessment: The paper dedicates significant space to demonstrating high agreement between the product and statistical data. However, since the methodology relies on statistical areas to set thresholds, the evaluation does not convincingly reflect the product's accuracy. The authors should elaborate on the index threshold determination method and consider using crop reference layers in regions with such data to further verify the product's accuracy through consistent area distribution.

Response: Thank you for your suggestion. In fact, 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 province (or state) scale statistical area to determine the thresholds for China, Brazil, India, Australia and the United States, and evaluated the accuracy of each province (or state) using the statistical area of low-level administrative regions, such as, municipal or county scale. A province (or state) 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. The method of accuracy assessment using agricultural statistical area was described in the section 2.4 of the original manuscript. Here, we randomly selected some regions to verify the relationship between national scale statistical area and province scale identification area (Fig. 1a), as well as province scale statistical area and municipal scale identification area (Fig. 1b). It can be seen that there is almost no correlation between the two variables, indicating that our method of setting thresholds using statistical area is reliable.

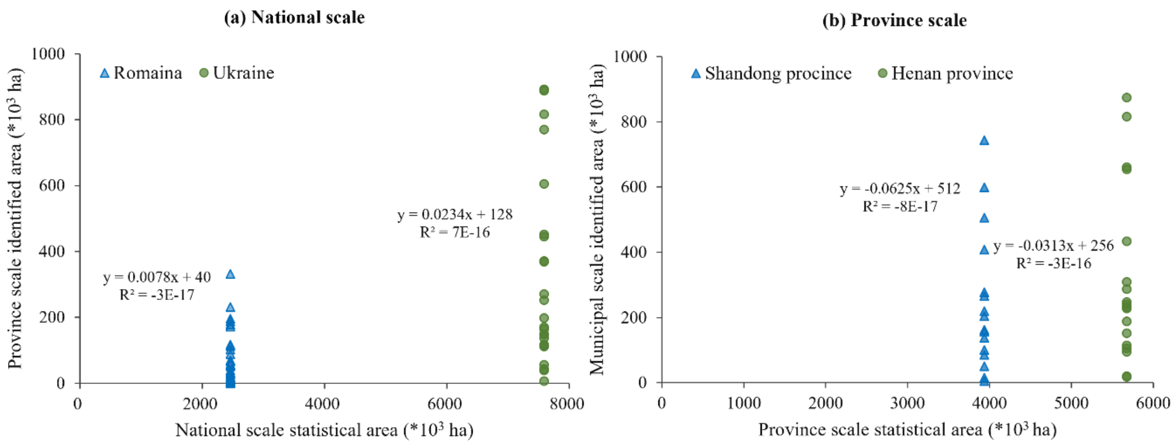


Figure 1: Comparison between (a) national scale statistical area and province scale identification area of winter-triticeae crops in Romania and Ukraine and (b) province scale statistical area and municipal scale identification area of winter-triticeae crops in Shandong and Henan provinces of China.

In addition, we have added some contents to explain the process of determining the WTCI threshold, and the details can be found in the response to Q1. Moreover, we validated the product's accuracy using CDL and EuroCrops datasets in section 3.3 of the original manuscript, which have high recognition and are widely used for accuracy assessment of data products.

3). Figures and Tables: The design of figures and tables requires improvement. For instance, Fig. 3(a) shows texture features of different land types, which is not mentioned anywhere in the paper. The authors should reconsider the necessity of this figure. In Fig. 6, adding results from crop reference layers could provide a clearer and more intuitive presentation of data quality to the readers.

Response: Thank you for your suggestions. Fig 3(a) is to explain how to select validation samples based on the features of Google Earth images. In fact, we have described the Fig 3(a) in section 2.2.2 of the original manuscript. According to the suggestion of another reviewer, we have further improved the content and Figure 3. The details are as follows:

"We first chose regions with available images during the growing season of winter-triticeae crops (section 2.3.3), and selected samples from these regions based on the texture features and colours. Winter-triticeae crops have deeper colour or stronger texture than winter rapeseed and grassland, and their roughness is lower than that of forest, which can be used to distinguish winter-triticeae crops from other land cover types (Fig .3a). The images of wetland and shrub show obvious differences from those of winter-triticeae crops. Wetland have dual characteristics of water and vegetation, and without regular texture features. Shrub have lower vegetation coverage and stronger graininess. These features make them easy to distinguish from winter-triticeae crops (Fig .3a). Crops with different growing season (such as maize, rice, and soybean) will not affect the visual interpretation." (Line 125-132)

In addition, we have added comparisons with crop reference layers produced by other studies, and the details are as follows:

"In addition, we compared the spatial distribution map of winter-triticeae crops in this study with some existing products in Europe (Huang et al., 2022) and China (Dong et al., 2020), which also have a spatial resolution of 30 m. The spatial distribution of winter-triticeae crops fields in the maps produced in this study was similar to other studies, and the maps generated by WTCI method had less noise and clearer boundaries of roads and rivers (Fig. S3)." (Line 304-308)

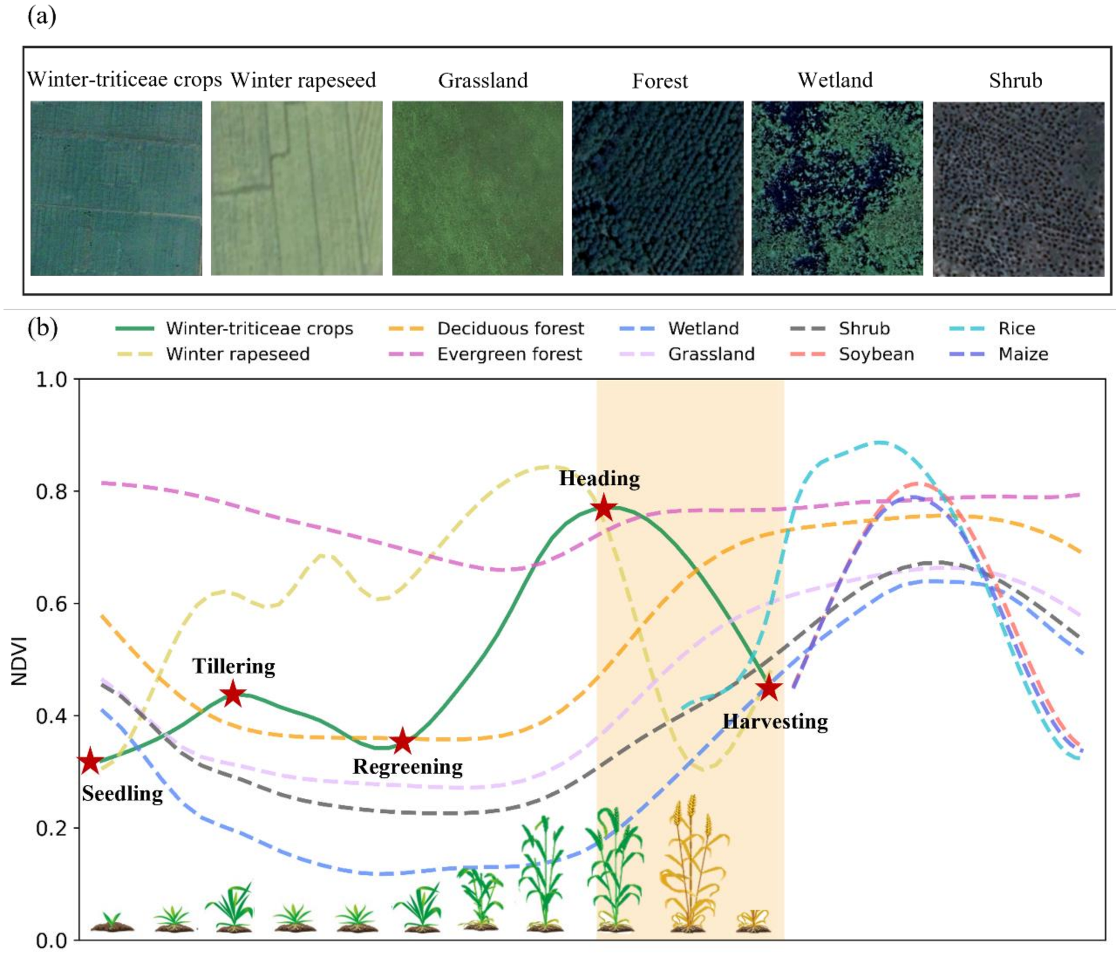


Figure 3: Example of the (a) textures and colours on the high-resolution images from © Google Earth and (b) NDVI time series characteristics of different land cover types. The red five-pointed stars represent the different phenological stages of winter-triticeae crops.

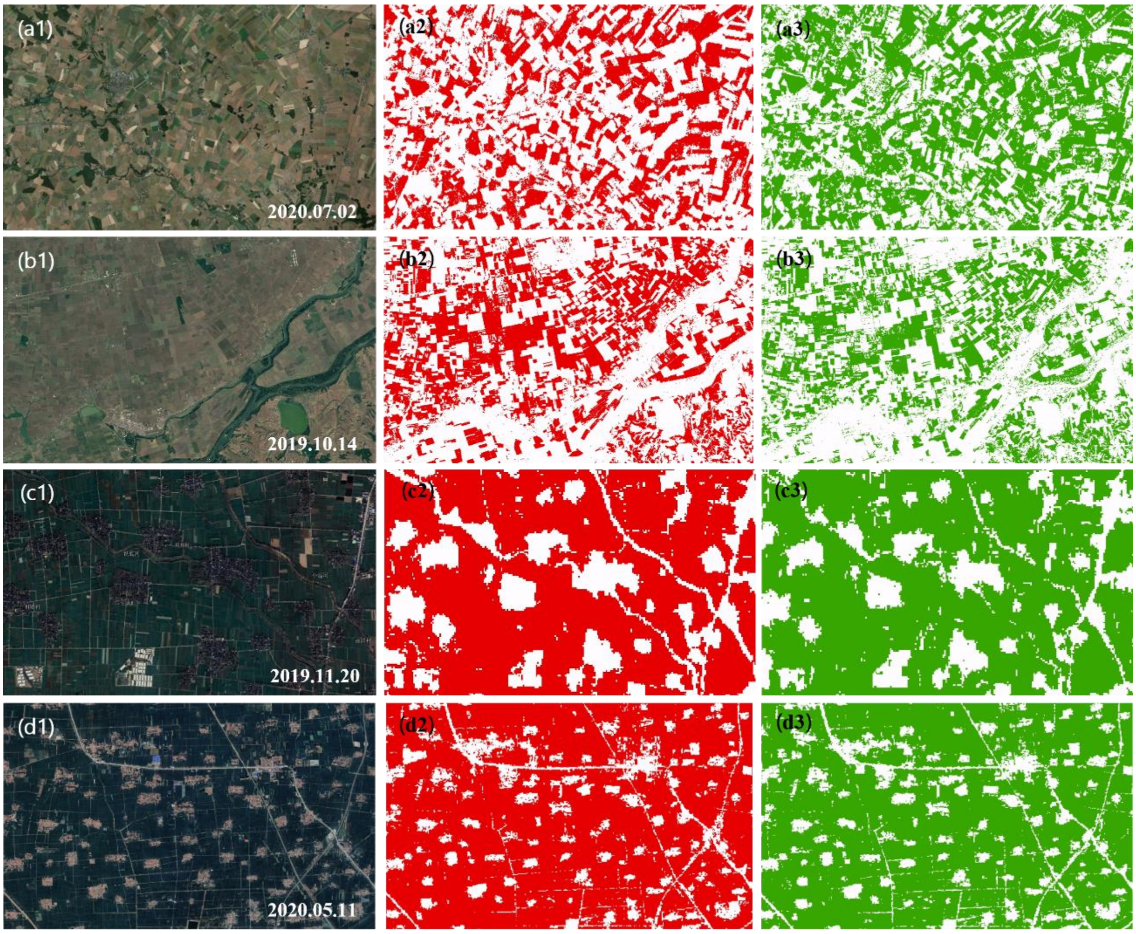


Figure S3: Comparison between the identification maps of this study and other studies. (a1-d1) represent the high-resolution images from © Google Earth in the study area; (a2-d2) represent the zoomed-in maps of the identification results based on WTCI method; (a3-d3) represent the zoomed-in maps of the identification results of other studies. Area a-d can be found in Figure 5.

References:

Ma, Z., Dong, C., Lin, K., Yan, Y., Luo, J., Jiang, D., Chen, X.: A Global 250-m Downscaled NDVI Product from 1982 to 2018, Remote Sens., 14(15), 3639, https://doi.org/10.3390/rs14153639, 2022.

Xu, S., Zhu, X. L., Chen, J., Zhu, X. L., Duan, M. J., Qiu, B. W., Wang, L. M., Tan, X. Y., Xu, Y. N., Cao, R. C.: A robust index to extract paddy fields in cloudy regions from SAR time series, Remote Sens. Environ., 285, 113374, https://doi.org/10.1016/j.rse.2022.113374, 2023.

Yang, J. Y., Wu, T. X., Sun, X. Y., Liu, K., Farhan, M., Zhao, X., Gao, Q. S., Yang, Y. Y., Shao,

Y. H., Wang, S. D.: Global 24 solar terms phenological MODIS normalized difference vegetation index dataset in 2001–2022, Geosci. Data J., 00, 1–12, https://doi.org/10.1002/gdj3.268, 2024.

Yang, J., Yan, D. M., Yu, Z. L., Wu, Z. N., Wang, H. L., Liu, W. M., Liu, S. M., Yuan, Z.: NDVI variations of different terrestrial ecosystems and their response to major driving factors on two side regions of the Hu-Line, Ecol Indic., 159, 111667, https://doi.org/10.1016/j.ecolind.2024.111667, 2024.

Reviewer #3

Summary

I have performed an earlier review of the initial manuscript, and will therefore limit myself to remaining questions based on author feedback and additional comments based on the latest version of the manuscript.

Overall, the current version of the manuscript has improved from a content point of view, even though I still have some remaining questions listed below. However, from a data point of view, I still see the same issues I raised before. I will give some examples below which for me still hamper the use of the published data.

Therefore, I recommend (major) revisions, especially to the data provision.

Response: Thank you for your comments and affirmation of our revised manuscript. We also appreciate your clear and detailed feedback. Here, we have revised our manuscript based on your comments this time and attached a point by point letter to you. The detailed responses are listed below.

Manuscript comments:

1). L23: terminology of these datasets has changed. LPIS only contains the parcel geometries. GSAA contains the crop type declarations which is what was used here (ref: https://wikis.ec.europa.eu/download/attachments/86968605/JRC133145_lpisgsa_v05_finalb.pdf?version=1&modificationDate=1691571477191&api=v2). I suggest to update throughout the manuscript to be in line with official terminology.

Line 23: Moreover, compared with the Cropland Data Layer (CDL) and the Land Parcel Identification System (LPIS) datasets, the overall accuracy and F1 score in most regions of the United States and Europe were more than 80% and 75%.

Response: Thank you for your suggestion. In fact, the LPIS dataset we use comes from a publicly available EuroCrops dataset that includes detailed crop types. Specifically, the EuroCrops project manually collected all publicly available self-declared crop reporting datasets from countries of the European Union, with the LPIS dataset being an important component. Then they developed a new version of the Hierarchical Crop and Agriculture

Taxonomy (HCAT) in order to organize all crops that are cultivated within the EU into a common hierarchical representation scheme. The detailed information can be found in https://doi.org/10.1038/s41597-023-02517-0. In this study, we have chosen EuroCrops data that winter-triticeae crops were clearly labelled as validation data. We believe that the EuroCrops dataset is reliable for accuracy assessment. Here, we have refined some content, and the details are as follows:

"The EuroCrops dataset, supported by the German Space Agency at DLR on behalf of the Federal Ministry for Economic Affairs and Climate Action (BMWK), is combines all publicly available self-declared crop reporting datasets from countries of the European Union. Importantly, this dataset utilizes a new version of Hierarchical Crop and Agriculture Taxonomy (HCAT) to provide a unified hierarchical representation scheme for all crops within the European Union (Schneider et al., 2023). We collected 10 countries (Austria, Belgium, Germany, Denmark, Estonia, France, Netherlands, Slovakia, Slovenia and Sweden) with winter-triticeae crops clearly labelled in EuroCrops dataset, 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), and these data cover the period from 2018 to 2021." (Line 144-151)

2). L104-105: please explain why the nearest neighbor method is preferred over another resampling method that would be closer to the aggregated effect of several Sentinel-2 pixels embedded in one Landsat pixel.

Line 104-105: 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.

Response: Thank you for your deep thought. We randomly selected two groups pixels of 10 m × 10 m (9 pixels per group) from the 10 m resolution image of Sentinel-2, and extracted the NDVI curves of each pixel during the winter-triticeae crops growing season. Furthermore, we used the nearest neighbor method to resample Sentinel-2 image to 30 m, and searched the corresponding 30m × 30m pixels in the resampled image, and extracted their NDVI curves separately. There are slight differences in NDVI values between pixels with 30 m resolution and pixels with 10 m resolution, pixels with 30 m resolution can still accurately reflect the trend of NDVI changes over time (Fig. 2). The WTCI method also focuses on the trend of NDVI changes. In addition, even if the nearest neighbor method may have some impact on data quality, this study used linear interpolation and the Savitzky-Golay filter to further improve the data quality. Some studies have demonstrated the available and valuable of the nearest neighbor method, and indicated that this seemingly simple method remains competitive in some cases against the state-of-the-art techniques (Boiman et al., 2008; Chen and Shah, 2018; Weinberger and Saul, 2009).

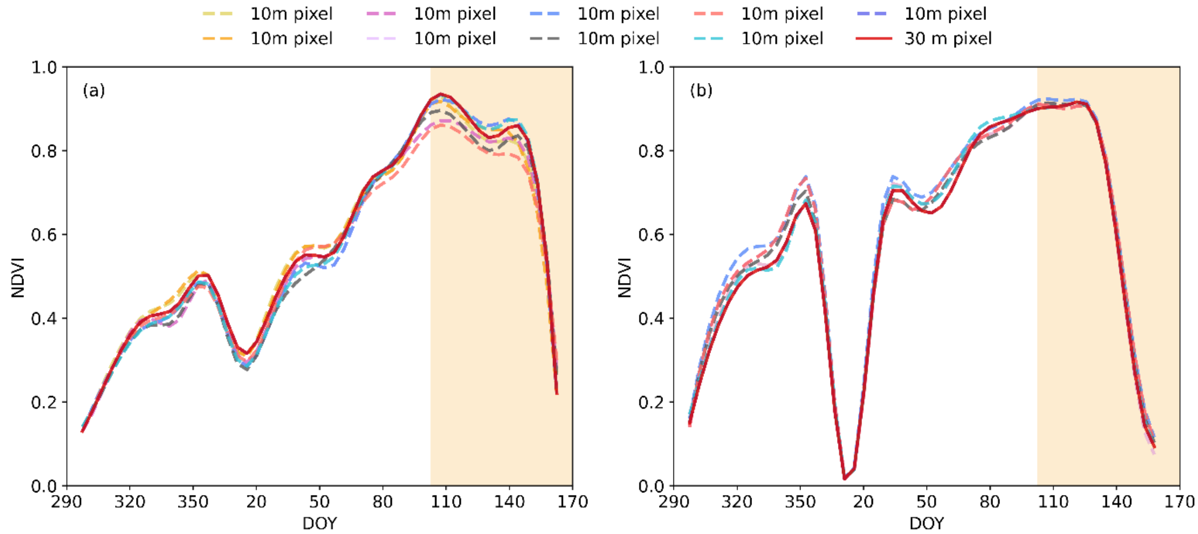


Figure 2: Comparison of NDVI time series between 10 m and 30 m pixels.

3). L114: similar question: why nearest neighbor resampling?

Line 114: and finally obtained the monthly maximum composite values of VH from 2016 to 2022 and resampled them to 30 m using the nearest neighbour method to keep consistency with NDVI.

Response: The reason can be found in response to Q2.

4). L135-151: sampling from CDL and LPIS/GSAA is only done for cropland. How can the method be validated for commission errors in other non-crop land covers?

Response: Thank you for your suggestion. In fact, we conducted sampling both in cropland and non-cropland based on CDL and EuroCrops datasets, and the details can be found in lines 140 and 148-149 of the original manuscript. Here, we have added some details information about sampling from CDL and EuroCrops datasets:

"Non-winter-triticeae crops samples were randomly generated in the remaining pixels, including other crops pixels in cultivated land and non-cultivated land pixels." (Line 141-142)

"We first convert the polygon file into point file using Acrmap 10.2, then randomly extracted winter-triticeae crops samples from the point file labelled with winter-triticeae crops in each country, and selected non-winter-triticeae crops samples from other land cover types, such as forest, grassland or other crops." (Line 151-154)

In addition, we have added tables in the supplement to display the validation results of commission errors for non-winter triticeae crops (or other non-crop land covers), and the details are as follows:

Table S4: The confusion matrix of the identification maps of winter-triticeae crops based on CDL dataset.

Country	CDL samples	Map		Producer's accuracy (%)	User's accuracy (%)	Overall accuracy (%)	F1 score (%)
		Winter-triticeae crops	Non-Winter-triticeae crops				
Alabama (AL)	Winter-triticeae crops	99	38	72.26	88.39	88.54	79.52
	Non-Winter-triticeae crops	13	295	95.78	88.59		
Arkansas (AR)	Winter-triticeae crops	101	18	84.87	90.18	90.76	87.45
	Non-Winter-triticeae crops	11	184	94.36	91.09		
California (CA)	Winter-triticeae crops	34	20	62.96	79.07	75.21	70.10
	Non-Winter-triticeae crops	9	54	85.71	72.97		
Colorado (CO)	Winter-triticeae crops	204	31	86.81	90.67	93.59	88.70
	Non-Winter-triticeae crops	21	555	96.35	94.71		
Delaware	Winter-triticeae	308	62	83.24	90.59	90.12	86.76

(DE)	crops						
	Non-Winter-triticeae crops	32	549	94.49	89.85		
Georgia (GA)	Winter-triticeae crops	64	31	67.37	84.21	81.47	74.85
	Non-Winter-triticeae crops	12	125	91.24	80.13		
Idaho (ID)	Winter-triticeae crops	174	66	72.50	80.18	82.36	76.15
	Non-Winter-triticeae crops	43	335	88.62	83.54		
Illinois (IL)	Winter-triticeae crops	247	49	83.45	92.51	91.68	87.74
	Non-Winter-triticeae crops	20	513	96.25	91.28		
Indiana (IN)	Winter-triticeae crops	287	95	75.13	96.31	89.21	84.41
	Non-Winter-triticeae crops	11	589	98.17	86.11		
Kansas (KS)	Winter-triticeae crops	344	46	88.21	93.99	93.13	91.01
	Non-Winter-triticeae crops	22	578	96.33	92.63		
Kentucky (KY)	Winter-triticeae crops	130	25	83.87	90.28	90.30	86.96
	Non-Winter-triticeae crops	14	233	94.33	90.31		
Maryland (MD)	Winter-triticeae crops	216	78	73.47	85.04	87.14	78.83
	Non-Winter-triticeae crops	38	570	93.75	87.96		
Michigan (MI)	Winter-triticeae crops	345	80	81.18	97.46	91.32	88.58
	Non-Winter-triticeae crops	9	591	98.50	88.08		

Missouri (MO)	Winter-triticeae crops	148	50	74.75	85.06	88.74	79.57
	Non-Winter-triticeae crops	26	451	94.55	90.02		
Mississippi (MS)	Winter-triticeae crops	73	30	70.87	83.91	82.26	76.84
	Non-Winter-triticeae crops	14	131	90.34	81.37		
Montana (MT)	Winter-triticeae crops	122	51	70.52	81.88	84.46	75.78
	Non-Winter-triticeae crops	27	302	91.79	85.55		
North Carolina (NC)	Winter-triticeae crops	108	30	78.26	89.26	86.73	83.40
	Non-Winter-triticeae crops	13	173	93.01	85.22		
North Dakota (ND)	Winter-triticeae crops	63	45	58.33	77.78	70.42	66.67
	Non-Winter-triticeae crops	18	87	82.86	65.91		
Nebraska (NE)	Winter-triticeae crops	263	51	83.76	88.55	89.68	86.09
	Non-Winter-triticeae crops	34	476	93.33	90.32		
New Jersey (NJ)	Winter-triticeae crops	203	70	74.36	91.44	85.02	82.02
	Non-Winter-triticeae crops	19	302	94.08	81.18		
New Mexico (NM)	Winter-triticeae crops	79	32	71.17	84.95	79.46	77.45
	Non-Winter-triticeae crops	14	99	87.61	75.57		
New York (NY)	Winter-triticeae crops	167	70	70.46	84.77	77.43	76.96
	Non-Winter-	30	176	85.44	71.54		

	triticeae crops						
Ohio (OH)	Winter-triticeae crops	315	49	86.54	94.59	92.49	90.39
	Non-Winter-triticeae crops	18	510	96.59	91.23		
Oklahoma (OK)	Winter-triticeae crops	159	27	85.48	90.34	94.24	87.85
	Non-Winter-triticeae crops	17	561	97.06	95.41		
Oregon (OR)	Winter-triticeae crops	244	36	87.14	91.73	92.67	89.38
	Non-Winter-triticeae crops	22	489	95.69	93.14		
Pennsylvania (PA)	Winter-triticeae crops	162	34	82.65	90.00	91.23	86.17
	Non-Winter-triticeae crops	18	379	95.47	91.77		
South Carolina (SC)	Winter-triticeae crops	91	28	76.47	89.22	86.17	82.35
	Non-Winter-triticeae crops	11	152	93.25	84.44		
South Dakota (SD)	Winter-triticeae crops	147	61	70.67	84.00	83.79	76.76
	Non-Winter-triticeae crops	28	313	91.79	83.69		
Tennessee (TN)	Winter-triticeae crops	99	33	75.00	90.83	88.56	82.16
	Non-Winter-triticeae crops	10	234	95.90	87.64		
Texas (TX)	Winter-triticeae crops	113	24	82.48	89.68	92.64	85.93
	Non-Winter-triticeae crops	13	353	96.45	93.63		
Utah (UT)	Winter-triticeae crops	76	29	72.38	83.52	81.12	77.55

	Non-Winter-triticeae crops	15	113	88.28	79.58		
Virginia (VA)	Winter-triticeae crops	124	27	82.12	90.51	90.85	86.11
	Non-Winter-triticeae crops	13	273	95.45	91.00		
Washington (WA)	Winter-triticeae crops	275	80	77.46	84.88	86.28	81.00
	Non-Winter-triticeae crops	49	536	91.62	87.01		
Wisconsin (WI)	Winter-triticeae crops	214	64	76.98	89.54	85.71	82.79
	Non-Winter-triticeae crops	25	320	92.75	83.33		
Wyoming (WY)	Winter-triticeae crops	100	42	70.42	89.29	84.66	78.74
	Non-Winter-triticeae crops	12	198	94.29	82.50		

Table S5: The confusion matrix of the identification maps of winter-triticeae crops based on EuroCrops dataset.

Country	EuroCrops samples	Map		Producer's accuracy (%)	User's accuracy (%)	Overall accuracy (%)	F1 score (%)
		Winter-triticeae crops	Non-Winter-triticeae crops				
Austria (AUT)	Winter-triticeae crops	240	96	71.43	89.22	85.05	79.34
	Non-Winter-triticeae crops	29	471	94.20	83.07		
Belgium (BEL)	Winter-triticeae crops	139	50	73.54	76.37	86.50	74.93
	Non-Winter-triticeae crops	43	457	91.40	90.14		
Denmark (DNK)	Winter-triticeae crops	185	60	75.51	84.09	83.76	79.57
	Non-Winter-	35	305	89.71	83.56		

	triticeae crops						
Estonia (EST)	Winter-triticeae crops	128	73	63.68	92.75	82.96	75.52
	Non-Winter-triticeae crops	10	276	96.50	79.08		
France (FRA)	Winter-triticeae crops	285	57	83.33	89.34	87.53	86.23
	Non-Winter-triticeae crops	34	354	91.24	86.13		
German (DEU)	Winter-triticeae crops	128	23	84.77	96.24	94.79	90.14
	Non-Winter-triticeae crops	5	381	98.70	94.31		
Netherlands (NLD)	Winter-triticeae crops	62	27	69.66	93.94	87.98	80.00
	Non-Winter-triticeae crops	4	165	97.63	85.94		
Slovakia (SVK)	Winter-triticeae crops	161	78	67.36	80.90	71.22	73.52
	Non-Winter-triticeae crops	38	126	76.83	61.76		
Slovenia (SVN)	Winter-triticeae crops	108	30	78.26	85.71	84.26	81.82
	Non-Winter-triticeae crops	18	149	89.22	83.24		
Sweden (SWE)	Winter-triticeae crops	45	25	64.29	71.43	74.71	67.67
	Non-Winter-triticeae crops	18	82	82.00	76.64		

5). L171-172: why not shrubland or wetland?

Line 171-172: After applying these steps, the main remaining land cover types in the potential pixels were forest, grassland, and cultivated land.

Response: Thank you for your reminder. We have modified Figure 3 and added NDVI time series of shrub and wetland for comparison with winter-triticeae crops. Meanwhile, we have also made modifications to the corresponding content. The details are as follows:

"After applying these steps, the main remaining land cover types in the potential pixels were forest, grassland, cultivated land, wetland and shrub." (Line 178-179)

"There are significant differences in the temporal variations of NDVI between winter-triticeae crops and natural vegetation types (i.e., deciduous forest, evergreen forest, shrub and grassland) as well as wetland during the growing season of winter-triticeae crops (Fig. 3b). 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, and wetland also exhibit the similar characteristics (Fig. 3b). From the regreening to the heading stages, the NDVI of winter-triticeae crops rapidly increases and reaches its maximum value, while the increase of NDVI of natural vegetation types and wetland tends to lag behind that of winter-triticeae crops (Fig. 3b). Furthermore, the NDVI of winter-triticeae crops show a downward trend and reach their lowest value during the harvesting stage. However, the NDVI values of natural vegetations and wetland rapidly increase at this time (Fig. 3b)." (Line 180-188)

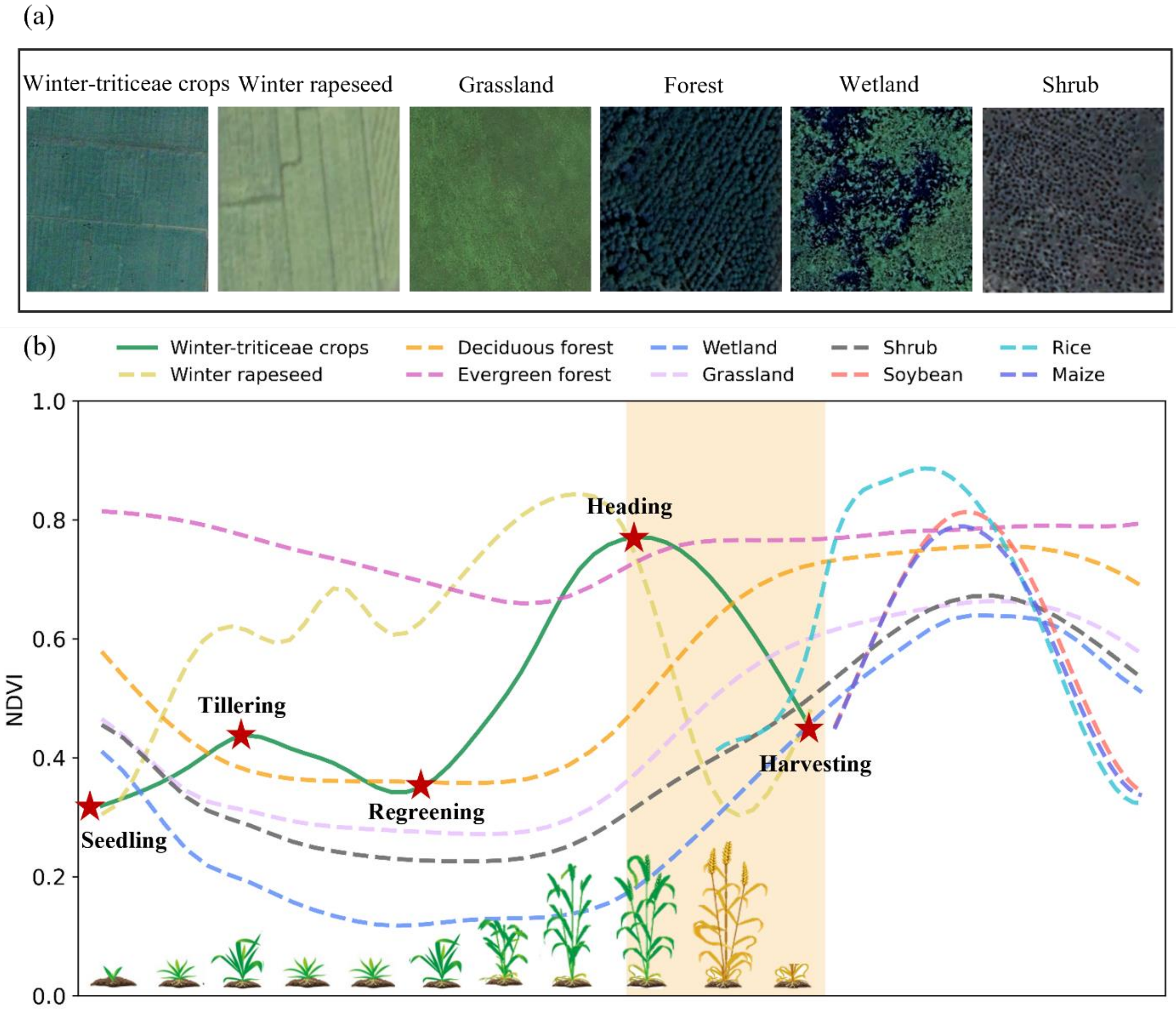


Figure 3: Example of the (a) textures and colours on the high-resolution images from © Google Earth and (b) NDVI time series characteristics of different land cover types. The red five-pointed stars represent the different phenological stages of winter-triticeae crops.

6). L324: coming back to my earlier comment in the first review, I remain reluctant to accept that computing area statistics from pixel counting is a good approach here. Such area statistics are biased (see Olofsson et al., 2014). Please comment on this.

Line 324: In addition, compared to the agricultural statistical area in different administrative units in 2020, the WTCI method can effectively estimate the planting area of winter-triticeae crops.

Response: Thank you for your deep thought. We have carefully read the paper you suggested. The "good practices" recommendations mentioned in the paper can be used to obtain more accurate areas by using sample-based approach to calculate the area to compensate for the bias introduced by area estimation based on map (e.g., pixel counting). In this study, our main goal is to develop the identification method of winter-triticeae crops and produce the high-resolution distribution maps of winter-triticeae crops, and the area estimation is only a part of accuracy assessment. Even if we adjusted the area using sample-based approach estimation, we could not change the mapping results on the pixel scale. More importantly, the distribution map produced in our study is a simple binary (1 represents winter-triticeae crops and 0 represents non-winter-triticeae crops), and each pixel has a regular shape of 30 m × 30 m. Therefore, we tend to believe that the method of calculating area in the study is applicable for this situation. Previous studies (Shen et al., 2023; Zheng et al., 2022) have also used the same method for area validation. Of course, we highly appreciate the comprehensiveness and rigor of "good practice" methodology in area estimation, and we are willing to use this method in our further studies.

Data comments:

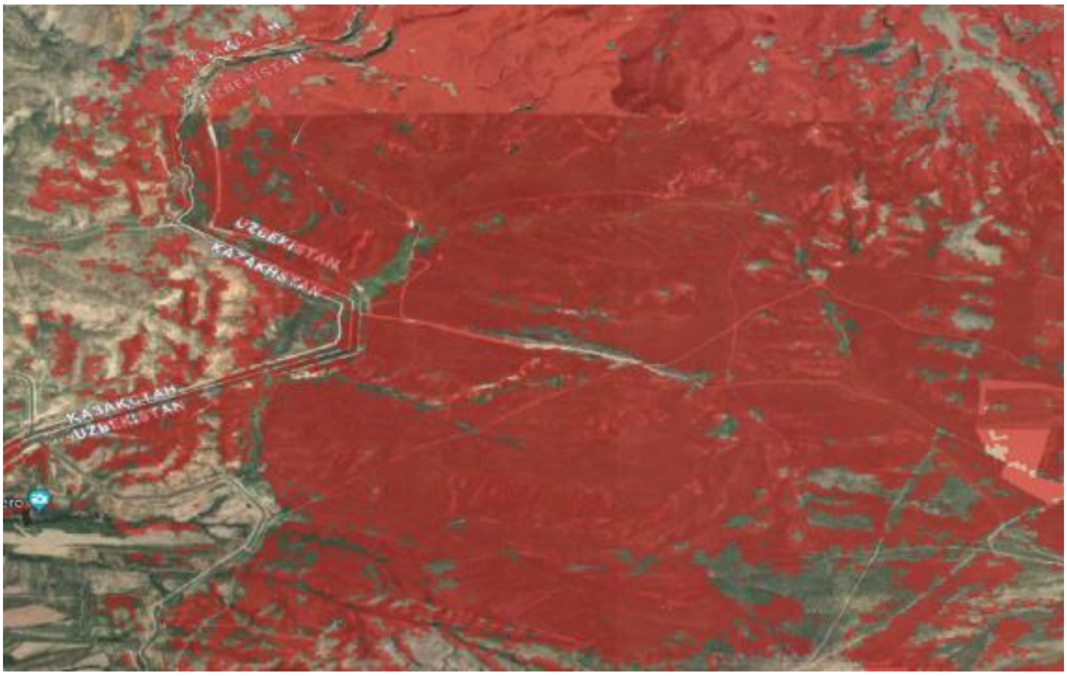
7). In general, I still have issues with understanding the projection of the individual files. In case standardized projection information is encoded in the files, visualizing them in software such as QGIS should be straightforward. However, for some files I checked this is still not the case. Files like the Belgian and France ones are still offsetting by default when being imported in QGIS. How does a user correctly visualize these?

Response: Sorry for any confusion caused. Maybe we didn't explain it clearly in our last reply. Although we have added a documentation with the dataset to introduce the spatial projection, users still need to convert the projection according to own needs to match the reference layer data. For the convenience of users, we have unified the spatial reference of all maps as WGS84 (EPSG:4326), a commonly used coordinate system, and update the dataset (https://doi.org/10.57760/sciencedb.12361).

Some other comments after checking some files:

8). Uzbekistan_2017

The method seems to be triggered in certain plantations (first picture) and also larger regions that seem not to be related to winter triticeae. What is causing this?

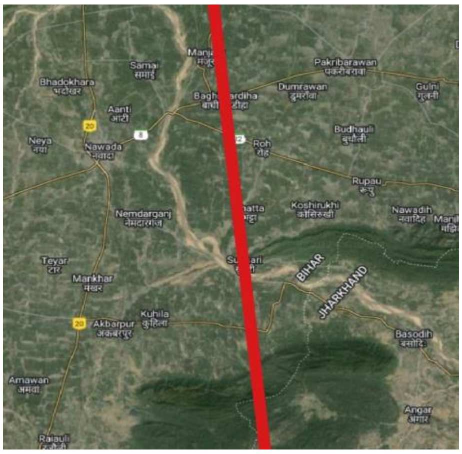


Response: Thank you for your carefully check. First, we cannot confirm whether the year between the image and distribution map of winter-triticeae crops matches, and whether the time of the image is during the winter-triticeae growing season. In addition, although the distribution maps of winter-triticeae crops have achieved good results in most regions, the global mapping accuracy has not yet reached 100%. Therefore, as shown in the pictures you presented, there may be errors in some areas. We have discussed the reasons for errors caused by the WTCI method in the Discussion section of the original manuscript and added some new contents, and the details as below. These discussions on errors will promote us to improve the WTCI method in future work or provide references for other researchers.

"Besides, this study ignored the internal differences between winter wheat, winter barley, winter rye and triticale due to their similar NDVI time series and phenological characteristics (Huang et al., 2022; Xu et al., 2017), which may affect the identification accuracy. We referred to previous studies (Dong et al., 2020; Huang et al., 2022) on winter crop mapping and only distinguished winter rapeseed to reduce its impact on the identification of winter-triticeae crops. Other winter crops with smaller planting area that have not been discovered or overlooked may also interfere with the identification and lead to errors in the identification map. In the future, identifying useful bands or vegetation indexes that eliminate interferences from other land covers, further subdividing each winter-triticeae crop, as well as increasing the availability and quality of satellite data, will further promote the performance of the WTCI method." (Line 471-478)

9). India_West_Bengal_2021

When checking this file, I stumbled upon an artefact on the west side of the product which contains a stripe of 1 (winter triticeae) values which is clearly an artefact.



Response: Thank you very much for your meticulous inspection. We have investigated the reason of the above issue and suspect that there may be an error in the output of winter-triticeae crops identification map and we have re-output the identification map for this state (Fig. 3).

Meanwhile, the dataset has been checked and updated.

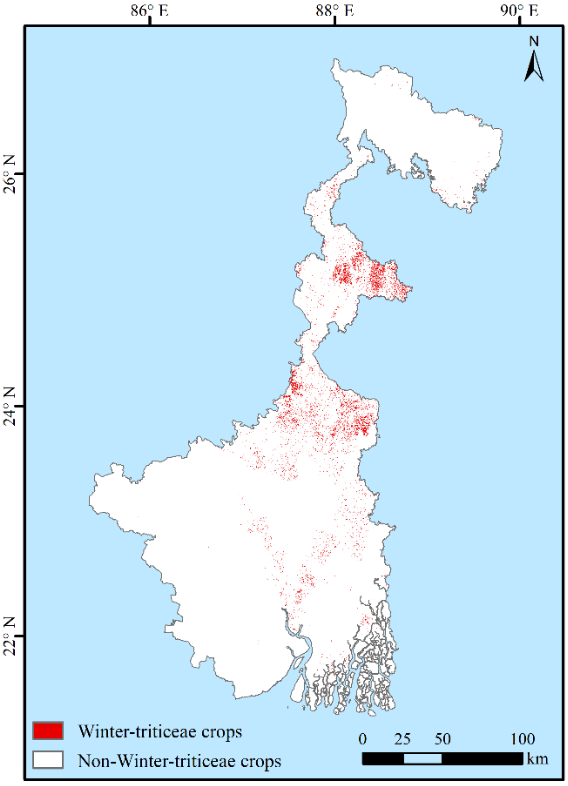
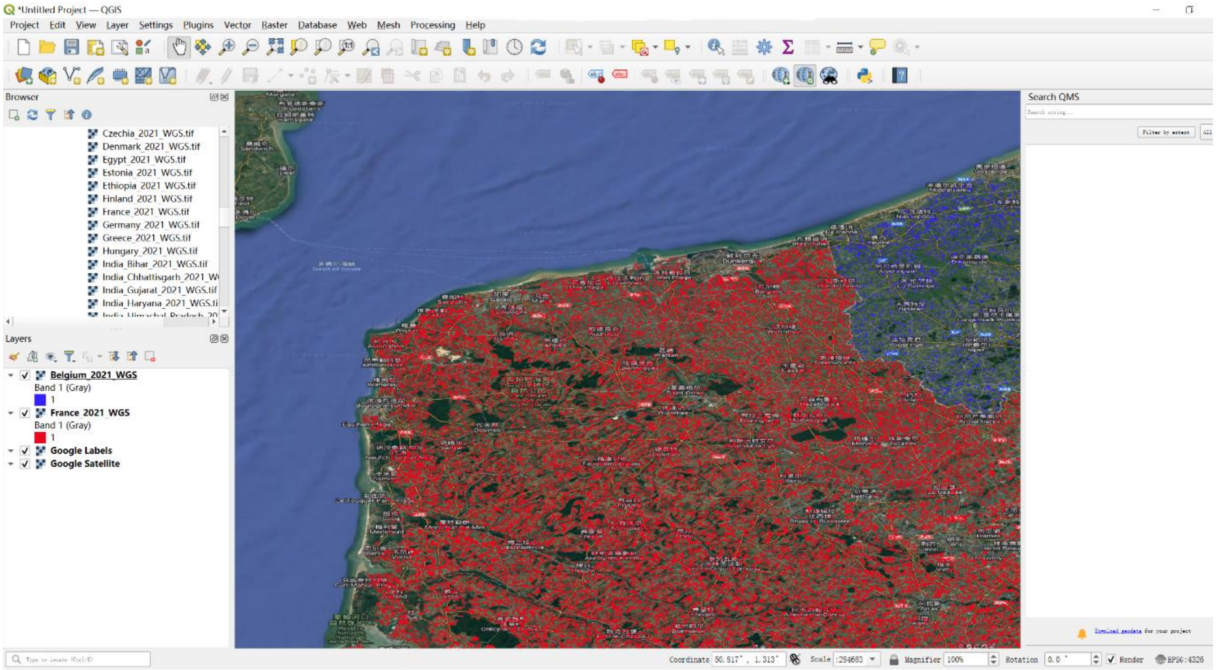


Figure 3: The distribution map of winter-trirticeae crops in the West Bengal state of India in 2021.

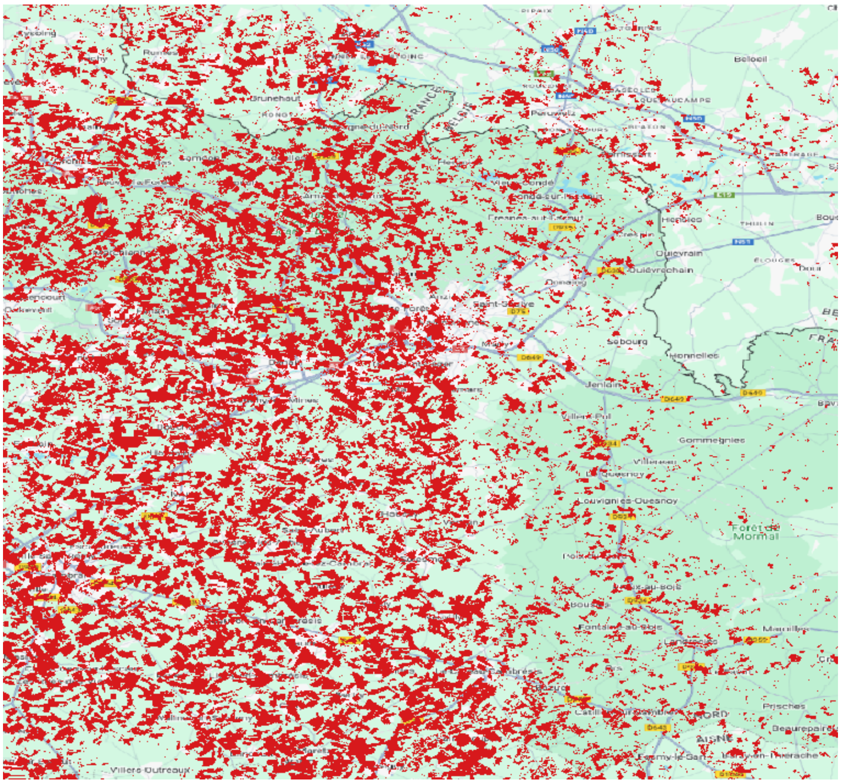
10). France_2021

Example of the projection issue that I still encounter:

Response: Sorry for the inconvenience caused to you. We have unified the spatial references of all identification maps to WGS84 (EPSG:4326) for user convenience. We have carefully checked to ensure that these data can be displayed correctly on QGIS, for example:



11). In previous review round I mentioned a strong artefact which the authors replied to be related to the projection issue I was facing. I'm not convinced by this however. There seems to be another reason which really causes this difference and artefact. Please investigate and explain.



Response: Thank you for your reminder. We have rechecked this data and compared it with the distribution maps of winter-triticeae crops in other years (in the figure below), and found that the reason for the above phenomenon is the striping issues of the satellite data. This issue has been discussed in the Discussion section of the original manuscript.

Technical corrections:

12). L120: great -> greater

Line 120: In the fieldwork, we only selected large winter-triticeae crops fields with an area great than 900 m^2, and used GPS (G120, UniStrong, Beijing, China) (Fu et al., 2023b) to mark the locations inside the fields.

Response: Thank you for pointing this out. We have revised this word:

"In the fieldwork, we only selected large winter-triticeae crops fields with an area greater than 900 m^2, and used GPS (G120, UniStrong, Beijing, China) (Fu et al., 2023b) to mark the locations inside the fields." (Line 118-119)

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