MS No.: essd-2020-69

MS Type: Data description paper

Title: Early season mapping of winter wheat in China based on Landsat and Sentinel images

Journal: Earth System Science Data

Dear Editor and reviewer:

We are very grateful to you and reviewers for your constructive comments and suggested amendments on our manuscript “Early season mapping of winter wheat in China based on Landsat and Sentinel images” (MS No.: essd-2020-69). The comments have helped improve the paper quite tremendously. We have carefully studied the comments, and revised our manuscript accordingly. Consequently, our manuscript has been considerably improved.

Here are our detailed responses to reviewer’s comments. Please note that the comments from the reviewers are in **bold** followed by our responses in regular text. The contents we revised in the manuscript are underlined and highlighted in yellow.

Please contact us if further materials or information are required. We deeply appreciate your consideration of our manuscript.

Sincerely,

Jie Dong, Wenping Yuan, on behalf of all co-authors

Email: yuanwpcn@126.com

Reviewer #2 Sergii Skakun

The ms presents the method and data for winter wheat mapping in China at 30 m spatial resolution for 2016-2018. Authors use Landsat, Sentinel-1 and Sentinel-2 data for mapping and phenological metrics to do it in-season. I think overall it is an interesting study and having those maps for China is of paramount importance for global Ag monitoring, and though it's a data-description paper, I'd like to see more analysis on how certain selection of method components can influence the resulting performance and accuracy of the product.

We appreciate your positive comments on our manuscript and the insightful questions for us to further consider. Please find below the point-by-point responses to your comments.

Major issues:

1. **I'm curious if monthly composites are enough for discrimination. Can you show some analysis how the accuracy depends on the composite period?**

Response 1:

We understand your concern. Taking Henan province, which has the largest planting area of winter wheat in China, as an example, we explored the effect of monthly composite and 16-day composite period on the identification accuracy. Specifically, NDVI data were composited into 16-day maximum images for the period between October 1, 2017 and June 30, 2018. Then, linear interpolation and Savitzky-Golay filter were used to fill the missing observations and enhance the signals (Verger et al., 2011). Figure 1 shows that seasonal change curves of 16-day and monthly maximum composite NDVI are very similar, except that the former is smoother. Based on the method described in the manuscript, we identified winter wheat planting area of Henan province with 16-day composite images as an input, and then calculated the producer's accuracy and user's accuracy.

Table 1 and Table 2 exhibit the confusion matrixes for the winter wheat maps identified by these two different composite periods, respectively. In addition, the estimated planting area obtained from two composite periods are also compared with municipality and county levels statistical area (Figure 2 and Figure 3), respectively. The results show that there is almost no difference in accuracy between these two composite periods, and the monthly composite is slightly more accurate. Therefore, we think that the monthly composites are enough for identifying the planting area of winter wheat.

Table 1 Confusion matrix for the identification map of planting areas of winter wheat in Henan provinces with 16-day composite period.

Class	Non-Wheat	Wheat	Row Total	Producer's Accuracy (%)
Non-Wheat	2438	672	3110	78.39
Wheat	177	6170	6347	97.21
Col Total	2615	6842	9457	
User's Accuracy (%)	93.23	90.18		

Table 2 Confusion matrix for the identification map of planting areas of winter wheat in Henan provinces with monthly composite period.

Class	Non-Wheat	Wheat	Row Total	Producer's Accuracy (%)
Non-Wheat	2495	615	3110	80.23
Wheat	156	6191	6347	97.54
Col Total	2651	6806	9457	
User's Accuracy (%)	94.12	90.96		

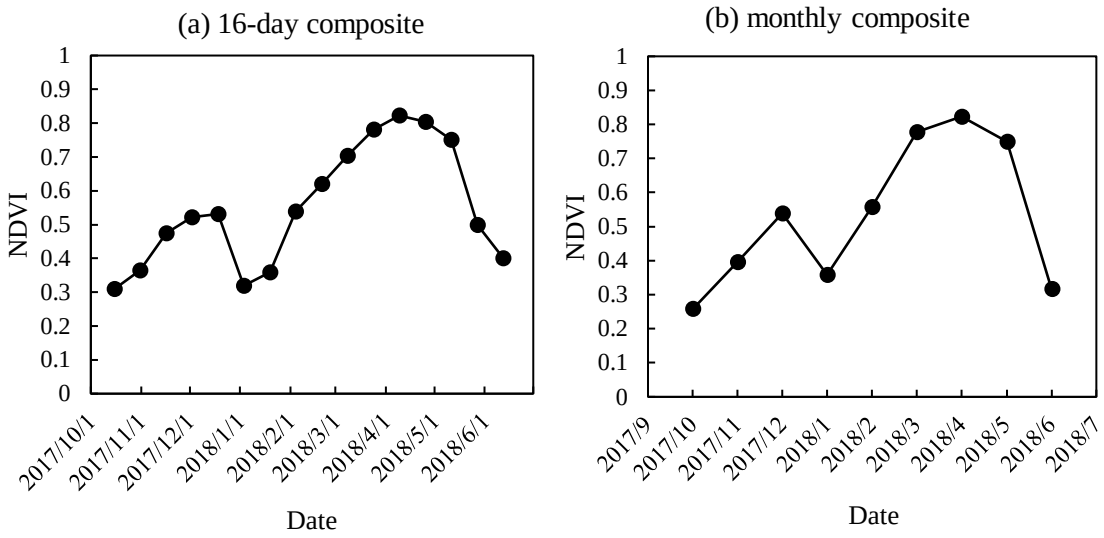


Figure 1. NDVI seasonal change curves of 16-day composite and monthly composite.

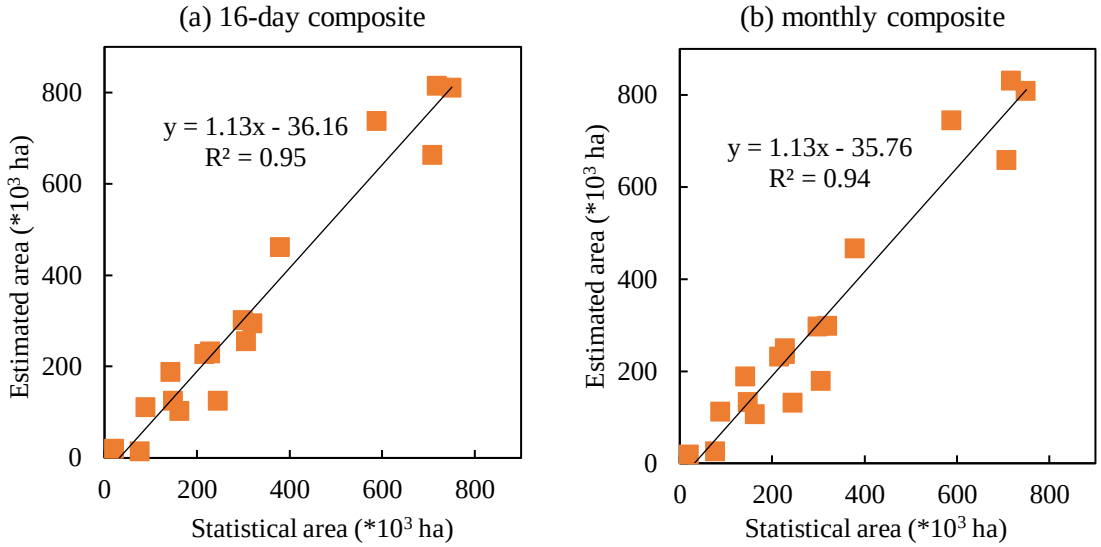


Figure 2. Comparison between the estimated planting area of winter wheat and agricultural statistical area at the municipal level with two composite periods.

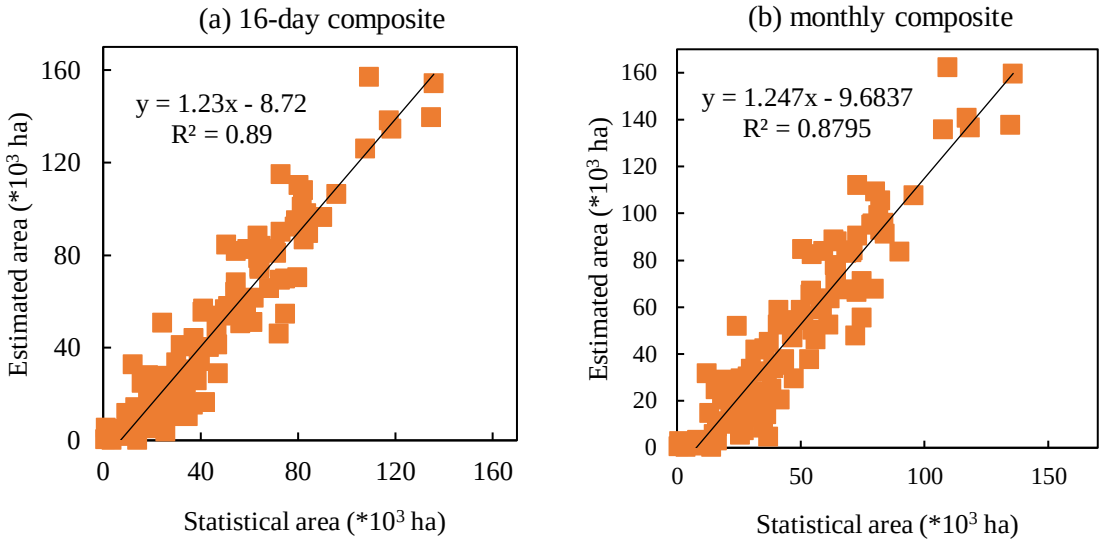


Figure 3. Comparison between the estimated planting area of winter wheat and agricultural statistical area at the county level with two composite periods.

2. **Line 124-125: how accurate and reliable census data? It's well known that official statistics is adjusted and it takes time for that to be released. Which census are you taking? Please provide a strong justification why it's appropriate to take census data as part of the method. Overall, matching to official stats, in my mind, is not a good practice, since your method is influenced by accuracy and reliability of census, which for most countries is not available and unknown (in terms of uncertainties).**

Line 124-125: In this research, we employ the area census data of winter wheat at the province level to determine the thresholds of dissimilarity.

Response 2:

In this study, census data is the official statistical data, which come from agriculture department of each province. In the revised manuscript, we changed all "census data" to "statistical data" to avoid confusion.

Statistical data at the county level collected by agro-technicians in each township, were the first-hand information from the basic-level, and then reported to a higher-level department, and summarized into county and municipality levels statistical data by each municipal Agriculture Department. It is indeed that the official statistics may be adjusted, but it is still the most important reference data for comparing and evaluating the accuracy over the regional scales. Actually, the statistical data has been widely used by a large number of studies to compare and evaluate the performance of identifying methods (Johnson et al., 2019; Luo et al., 2020; Wang et al., 2020; Zhong et al., 2019). In addition, we used statistics data to evaluate the method performance for identifying spatial variations of planting areas of winter wheat, not temporal changes. The statistics even sometimes was adjusted, and it still can indicate the differences through the counties or cities. In the process of establishing the method, we only used statistics at the province level to determine the thresholds of dissimilarity since the province-level statistics are always available, and used the statistics at county or city levels to evaluate the performance. Moreover, the proposed method proved to be robust in China based on the validation of a larger number of field samples.

3. **Line 129: why 20%? Actually looking at Fig. 4 – there's a lot of variability. For example, there are provinces having NDVI 0.3 in March, and other having 0.8 at the same time.**

Line 129-130: The standard seasonal curve of winter wheat was generated by averaging the NDVI with 20% of the winter wheat pixels randomly selected from field surveys in each province (see Section 2.3).

Line 122-123: The dissimilarity values can then be calculated by comparing the seasonal change in NDVI at each investigated pixel with the standard seasonal curve of winter wheat.

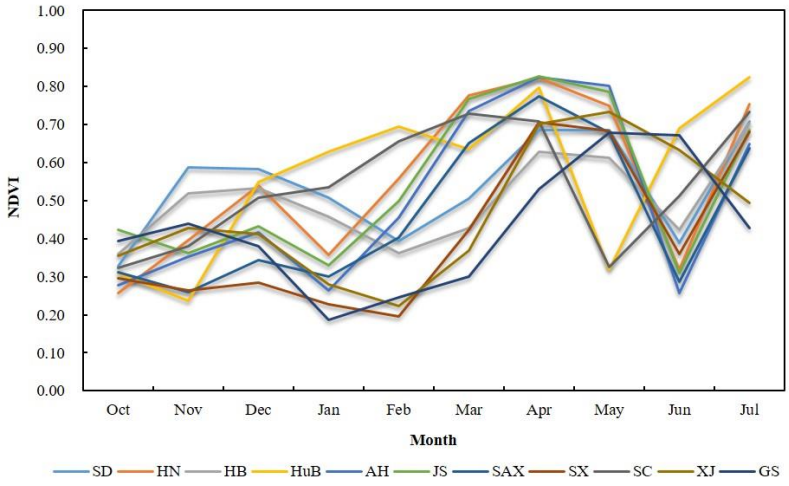


Figure 4: Seasonal changes of NDVI for winter wheat over 11 provinces in the study area.

Response 3:

Yes, there are variabilities in seasonal change curves of winter wheat in different provinces. Therefore, when calculating dissimilarity values, we take each province as a unit to compare the unknown seasonal change in NDVI with the standard seasonal curve of winter wheat. To make the expressions clearer, we modified the corresponding contents to that

"Taken each province as a unit, the dissimilarity values can then be calculated by comparing the seasonal change in NDVI of each investigated pixel with the standard seasonal curve of winter wheat in a given province." (Line 124-126 in the revised manuscript)

In each province, we take 20% of the winter wheat pixels to acquire the standard seasonal curve, and the remaining 80% to validate the identification accuracy, which we have described in the section 2.2.3 that

"Eighty percent of the winter wheat samples and all non-winter wheat samples were selected to obtain the confusion matrix of the winter wheat map for each province (see Section 3 for more details)." (Line 164-166 in the original manuscript)

4. Line 132-133: please prove this assumption/claim. I would suspect that profiles would vary depending on the temperature.

Line 132-133: We assumed that the seasonal change of winter wheat for each province does not vary from year to year.

Response 4:

Taking Shandong province as an example, we went through all pixels and selected pixels identified as winter wheat for three consecutive years, and extracted seasonal changes of NDVI of these pixels. Figure 5 shows the average seasonal changes of all winter wheat pixels for three years. It is found that the seasonal changes are very similar over three years, all capturing NDVI peak in April to May, although there were some differences in winter. It may be caused by poor data quality.

Overall, the migration of the standard seasonal change curve is feasible in the short term, such as within 3-4 years, but in the long term, the influence of temperature on the seasonal change of winter wheat should be considered. That's exactly what we're going to do next.

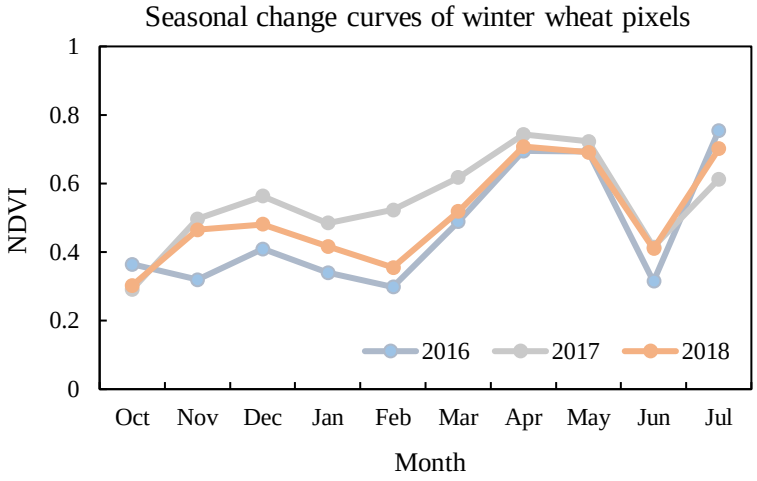


Figure 5. Seasonal changes of NDVI for winter wheat over 2016-2018 in Shandong province.

5. **Line 144-145: Can rapeseed be identified during the flowering stage? Obviously just NDVI will not help, you shall employ red band, since during the flowering it's yellowish (a combination of green and red).**

Line 144-145: Relying solely on optical imagery to discriminate them would be a challenge because of their similar spectral characteristics and phenological stages.

Response 5:

Thank you very much for your advice. You provide a good idea. In Hubei province, rapeseed has a flowering period of two months, namely March and April. We extracted the time series of the red spectral band of rapeseed and winter wheat from October, 2017 to June, 2018 (Figure 6). It can be seen that there are some differences between rapeseed and winter wheat in March, however, the differences are not as large as VH backscatter values in April (Figure 5b in the original manuscript). One possibility is that the red band is affected by the soil background, and reflectance itself is small, so there is no obvious difference in the remote sensing data.

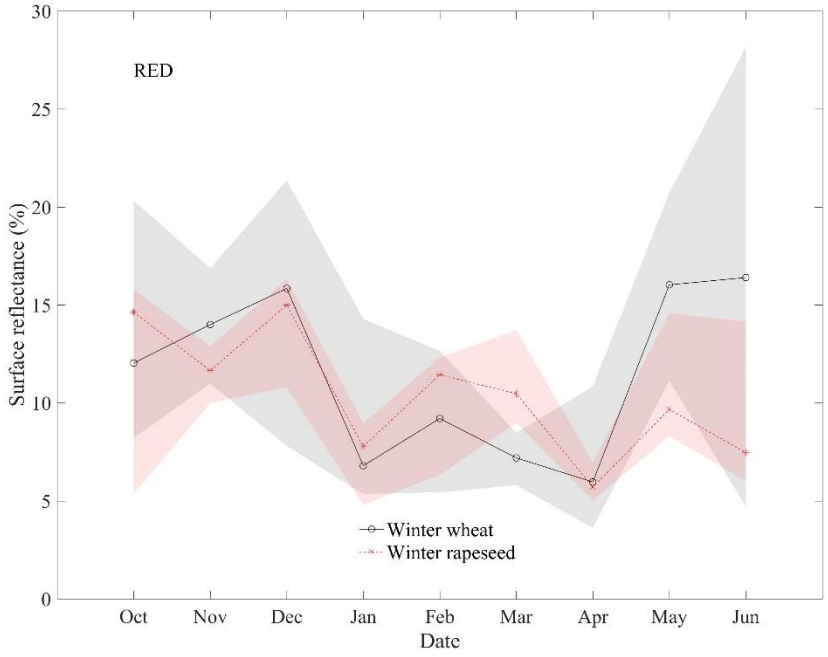
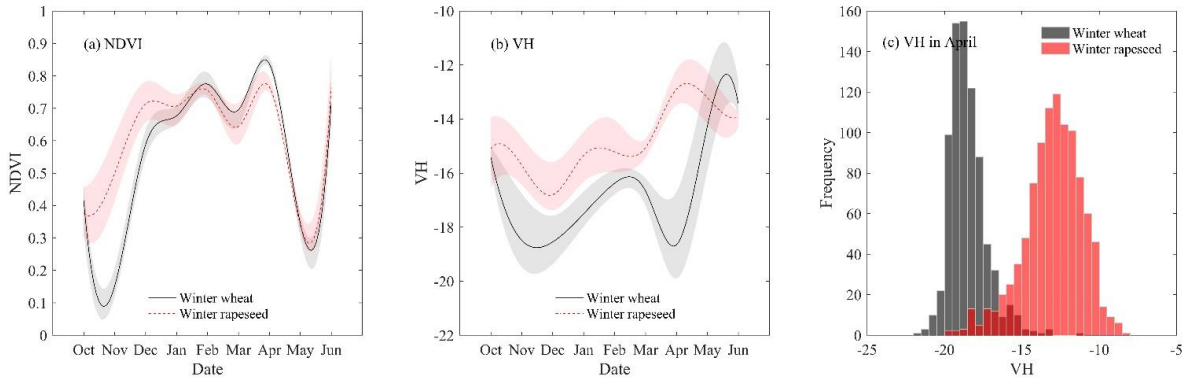


Figure 6. The seasonal change in monthly maximum composite red band of winter wheat and winter rapeseed at HuB province.



(Original manuscript) Figure 5. The seasonal change in monthly maximum composite NDVI (a) and VH

(b) of winter wheat and winter rapeseed at HuB province; (c) Frequency histograms of winter wheat and winter rapeseed in terms of VH in April.

6. **How is your method for rapeseed different from the one described in d'Andrimont, R., Taymans, M., Lemoine, G., Ceglar, A., Yordanov, M., & van der Velde, M. (2020). Detecting flowering phenology in oil seed rape parcels with Sentinel-1 and- 2 time series. Remote sensing of environment, 239, 111660.?**

Response 6:

The way we distinguished winter rapeseed and winter wheat is completely different from d' Andrimont's method. In d' Andrimont's study, a random forest classifier was used to extract rapeseed parcel. The input data included a large number of training data and Sentinel-2 multispectral composite of cloud-free images. The bands including B2, B3, B4, B5, B6, B7, B8, B11 and B12, were used to create the composite.

Our study was aimed at identifying winter wheat planting area, not winter rapeseed. Therefore, we captured the time period when winter wheat and rapeseed have the most differences in the plant structure, and distinguished between these two crops based on the differences of VH backscatter values. Actually, we have introduced the method in the original manuscript that

"Fortunately, the difference in the plant structure between winter wheat and winter rapeseed makes it possible to differentiate them based on radar data (Veloso et al., 2017). Therefore, we used radar data to exclude the interference from winter rapeseed in this study. By investigating the survey samples in HuB province, we found that the VH backscatter values in April are a good indicator to differentiate winter wheat from winter rapeseed. The VH backscatter values in April for winter wheat were lower than −15.5 whereas they were higher for winter rapeseed (Figure 5), which meant the pixels (with VH values greater than −15.5) had less possibility to plant winter wheat. Accordingly, by assigning a higher dissimilarity to these pixels, this study distinguished winter wheat and rapeseed in HuB, JS, and AH provinces." (Line 155-161)

7. **Line 169: kappa is discouraged to be use – see Foody, G. M. (2020). Explaining the unsuitability of the kappa coefficient in the assessment and comparison of the accuracy of thematic maps obtained by image classification. Remote Sensing of Environment, 239, 111630. Kappa is correlated with Oa, and for this study the most important metrics PA and UA.**

Line 169: The kappa coefficient (Kappa) was employed to assess the classification accuracy; it is between −1 and 1, and the closer the value is to 1, the higher the accuracy.

Response 7:

Thanks for your suggestion. We have studied this paper carefully and found the unsuitability of the Kappa coefficient. Therefore, we deleted the contents about Kappa coefficient in this study. Please refer to the revised manuscript.

8. **Line 164: you used census in your method (line 126). I don't think you can use census**

for validation.

Line 162-164: The identification accuracy of winter wheat was evaluated based on two methods: 1) validation using the ground truth samples at the field level, including ground surveys and visual interpretation of very high-resolution images from Google Earth, and 2) comparisons with agricultural census data at administrative units.

Response 8:

First, in the process of establishing the method, we only used statistics **at the province level** to determine the thresholds of dissimilarity. Second, the data used for validation is mainly ground truth samples from different sources, including thirty-eight field sites, covering a total of 29754 pixels, 291 field survey samples, and 3759 samples from the very high-resolution images derived from Google Earth. These have been introduced in detail in the section 2.3.2 Field data. Another data used for comparison and validation is the statistics **at the municipality and county levels**.

9. Table 3 – can you present comparison to official stats through plots – it's not clear what areas are and how RMSE is related to it.

Response 9:

Yes, that is a good point. We replaced Table 3 (original manuscript) with a graph to present more details about the comparison with official statistics in the revised manuscript. Please refer to Figure 7 (i.e., Figure 9 in the revised manuscript).

In addition, we added the descriptive sentences for the new graph that

"In addition, this method accurately estimates the areas of winter wheat compared to the available agricultural statistical data at the municipal and county levels (Figure 9). The correlation coefficient (R^2 values) between the identified and agricultural statistical areas ranges from 0.85 to 0.99 at the municipal level (Figure 9Ⅰ,a-h), indicating a strong correlation. At the county level, the method performs a little worse, with correlation coefficient (R^2 values) ranging from 0.7 to 0.88 (Figure 9Ⅱ, a-h). Considering the MAE and the RMSE, JS, HN, and AH show higher error at the municipal and county levels." (Line 242-246 in the revised manuscript)

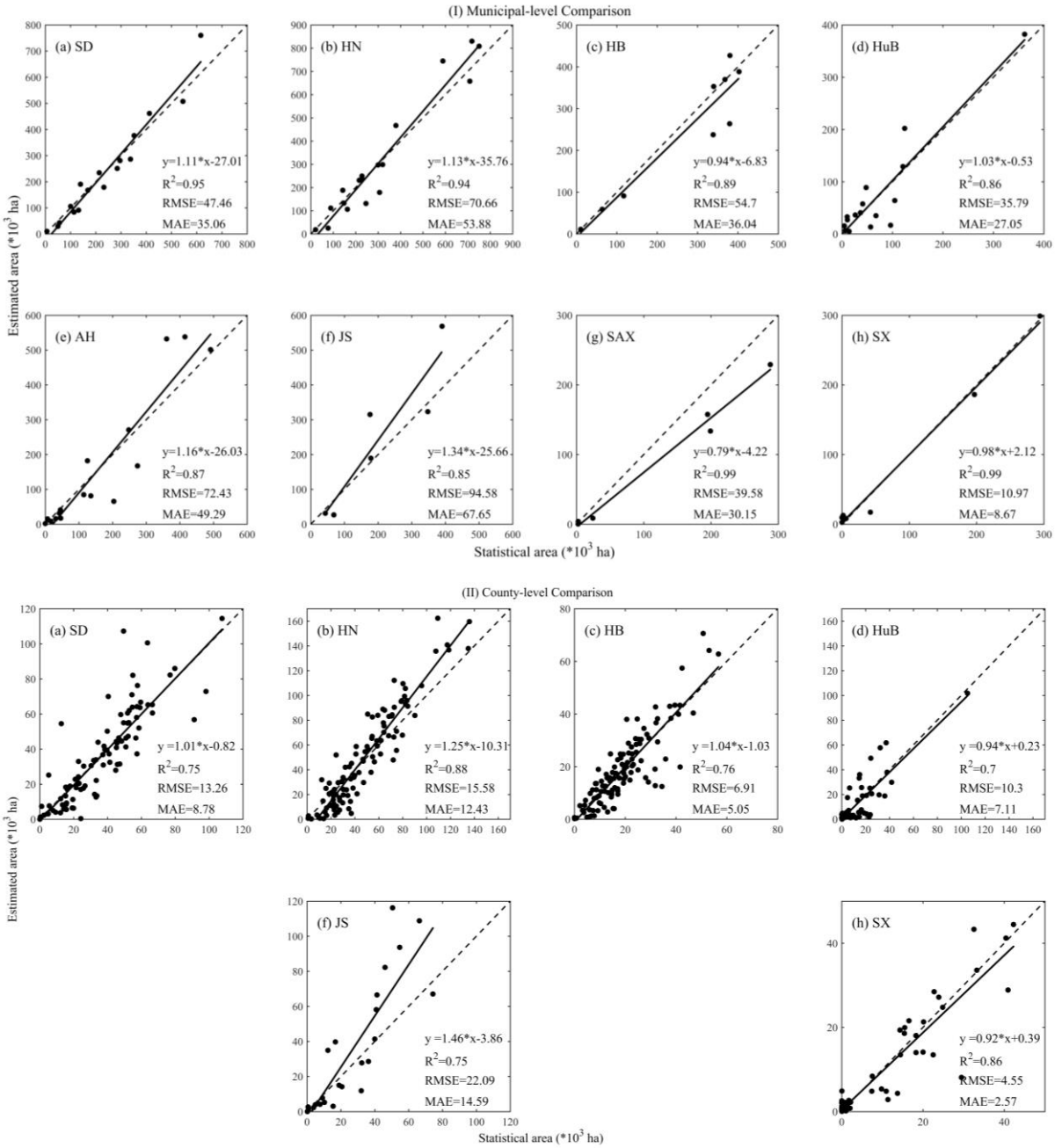


Figure 7. Comparison between the estimated planting area of winter wheat and agricultural statistical area at the municipal (I) and county levels (II) for 2018. The dotted line denotes the 1:1 line. The agricultural statistical area at county level for AH and SAX provinces are not available. The units of RMSE and MAE are 1000 ha.

Minor:

10. Introduction line 33 – add Russia and Ukraine and Argentina to the list of countries. Line 32-34: As a major type of wheat, winter wheat dominates the wheat production in many countries including China, United States, France, and Australia (National Bureau of Statistics of China, 2018; USDA-ERS, 2018).

Response 10:

Thanks for your suggestion. We added these countries in the revised manuscript that "As a major type of wheat, winter wheat dominates the wheat production in many countries including China, United States, France, Russia, Ukraine, Argentina, and Australia (National Bureau of Statistics of China, 2018; USDA-ERS, 2018)." (Line 32-34)

11. Paragraphs 55 and 60: In addition to DTW, please add accumulated GDD which is a more physical way accounting for difference in wheat emergence, see Franch, B., Vermote, E. F., Becker-Reshef, I., Claverie, M., Huang, J., Zhang, J., ... & Sobrino, J. A. (2015). Improving the timeliness of winter wheat production forecast in the United States of America, Ukraine and China using MODIS data and NCAR Growing Degree Day information. Remote Sensing of Environment, 161, 131-148.

Response 11:

Thanks for your advice. In the revised manuscript, we added the contents about the accumulated GDD in the Introduction section that

"Some studies integrate accumulated Growing Degree Day (GDD) to consider the phenology difference to reduce phenology variability due to different climatic conditions (Franch et al., 2015; Skakun et al., 2017; Zhong et al., 2014)." (Line 56-58)

12. English shall be edited and improved, e.g.: o Line 103: "involves produces" -> rewrite Line 103: (2) data processing, which involves produces standard seasonal change of NDVI for winter wheat for each province based on the winter wheat samples.

Response 12:

The manuscript has been polished by a professional company called "Editage" and has been greatly improved. In the revised manuscript, we modified this sentence to that

"(2) data processing, which produces standard seasonal change of NDVI for winter wheat for each province based on the winter wheat samples." (Line 106-107)

Reference:

Franch, B., Vermote, E.F., Becker-Reshef, I., Claverie, M., Huang, J., Zhang, J., Justice, C., Sobrino, J.A., 2015. Improving the timeliness of winter wheat production forecast in the United States of America, Ukraine and China using MODIS data and NCAR Growing Degree Day information. Remote Sensing of Environment 161, 131–148.

Johnson, D.M., 2019. Using the Landsat archive to map crop cover history across the United States. Remote Sensing of Environment 232, 111286.

Luo, Y., Zhang, Z., Li, Z., Chen, Y., Zhang, L., Cao, J., Tao, F., 2020. Identifying the spatiotemporal changes of annual harvesting areas for three staple crops in China by integrating multi-data sources. Environ. Res. Lett.

Skakun, S., Vermote, E., Becker-Reshef, I., Justice, C., Kussul, N., Franch, 2017. Early season large-area winter crop mapping using MODIS NDVI data, growing degree days information and a Gaussian mixture model. Remote Sensing of Environment 195, 244–258.

Verger, A., Baret, F., Weiss, M., 2011. A multisensor fusion approach to improve LAI time series. Remote Sensing of Environment 115, 2460–2470.

Wang, J., Xiao, X., Liu, L., Wu, X., Qin, Y., Steiner, J.L., Dong, J., 2020. Mapping sugarcane plantation dynamics in Guangxi, China, by time series Sentinel-1, Sentinel-2 and Landsat images. Remote Sensing of Environment 247, 111951.

Zhong, L., Gong, P., Biging, G.S., 2014. Efficient corn and soybean mapping with temporal extendability: A multi-year experiment using Landsat imagery. Remote Sensing of Environment 140, 1–13.

Zhong, L., Hu, L., Zhou, H., Tao, X., 2019. Deep learning based winter wheat mapping using statistical data as ground references in Kansas and northern Texas, US. Remote Sensing of Environment 233, 111411.