Based on the method tested in China and in a global framework (Liu et al., 2020, Liu et al 2020), this paper developed a global, spatially continuous cropping intensity map at a 30-m resolution (GCI30) using multi-resource satellite data from 2016 to 2018. Accuracy assessments were conducted with visually interpreted validation samples from Geowiki and in situ observations from the PhenoCam network, and they showed reasonably good agreement. The authors further carried out both statistical and spatial comparisons of GCI30 with 6 existing global CI estimates. They also explored the spatial heterogeneity of cropping intensity across countries, continents and Agroecological zones. Indeed cropping intensity is a critical parameter in agricultural system and sustainable intensification in particular. Undergoing a global study like this is a huge project. The global coverage, very fine-resolution (30 m) and the latest time period (2016-18) indeed fills the data gap for achieving SDGs. However, I do have a few major concerns and I hope the authors could address them to make this paper not only publishable but also even more solid.

**Response:** We would like to thank the Referee for the constructive suggestions that help significantly improve the research and the quality of this work. We revised the manuscript according to these comments, and below we provided our detailed responses to the points raised in the supplement.

**Major comments:**

*1 My biggest concern (I guess most readers too) is on the method of estimating cropping intensity (Section 2.3). This is obviously the core of this paper. The authors seem to take for granted that they could simply adopt Liu et al (2020) method and apply it to produce the global CI. (BTW, there are two Liu et al (2020), you should specify exactly which one you are referring in the paper). While I acknowledge the good quality of a peer-reviewed paper (or papers if you refer to both papers), there are at least two concerns: one is that what is the major contribution of this paper, or putting it more bluntly how to justify your publishing another paper if you already published two papers: one on China case study, another one on a global CI framework. You need to justify that. The other concern is that global cropping system has much more spatial heterogeneity than your China, or a few regional (in your global paper) cases. For example, subsistence agriculture in Africa (e.g. slash and burn) may include quite a few crops/vegetables within a year, or have fallow period extending multiple years. For many smallholder farmers, your 30m resolution is also too coarse This would not eliminate the mixed pixel problem you cited as one of the big advantage of a fine resolution. In addition, I don’t know how Nfc(False crop cycle) is estimated in your method (Page 6, Line 6-9).

**Response:** Thank you for raising the point which encourages us to clarify our main methodology and emphasize the contribution of this manuscript. The paper we refer our methodological framework to is the one titled "A new framework to map fine resolution cropping intensity across the globe: Algorithm, validation, and implication" published in Remote Sensing of Environment by C. Liu et al. (2020). In this cited paper, eight 10 by 10-degree regions across the terrestrial world were selected to test the performance of the main algorithm for mapping cropping intensity. Estimated cropping intensity was validated also for the eight regions. Thus, C. Liu et al. (2020) paper as a pilot study focused on justifying the robustness and solidness of the algorithms within the designed framework.

Moving a step forward, in this manuscript, the contributions are to substantially improve the algorithm of mapping cropping intensity, practically applying the framework for the entire world (i.e., all cropland over the terrestrial surface), and publicizing the global product to serve the research and education community. We generated the layer of cropping intensity at 30m resolution for all cropland during 2016-2018, and packaged the global product and publicized it to the public (non-commercial and main purposes for research, education, and policy evaluation). To our best knowledge, this is so far the most updated and latest product on cropland-specific intensity at 30m for the globe, which can be beneficial for a variety of research and practical uses key to sustainable development.

For the cropping system diversity issue, we agree that accounting for the spatial heterogeneity is challenging, and what we are doing is to develop a simple but effective approach for global CI mapping at fine resolution. In fact, our pilot study did include an Africa region as a part for method validation (C. Liu et al. 2020). As expected, this region exhibited reasonable yet relatively low accuracy compared to other regions. As the first version GCI30, we accepted the tradeoff between accuracy and efficiency, and we will continue improve our technical framework to update later GCI30 versions and expand the temporal coverages in the future. Spectral mixture is a common uncertainty source when applying satellite image mapping, and its influence is related to the raster pixel size. A major advantage of GCI30 lies in its 30-m spatial resolution, which is much higher than previous dataset. Though the spectral mixture issue still exists at 30m, we would argue that the mixture effects is lower than the existing research on cropping intensity mapping and the previously available products. We added some description of the mixed pixels in the result and discussion part according in **Section 3.1**.

For the Nfc exclusion, we added sentences in the revised manuscript explaining our procedure in **Section 2.3.1**.

*2 The authors divide the croplands into two categories by different mapping method, i.e. non-flooded cropland and flooded rice paddy. Due to the transplanting, flooded rice paddy is treated differently. Again the cropping system is quite diverse, there may have other cropping patterns or farming practices which also need special treatments. For example, the inter-cropping/mixed cropping of a staple crop with a pulse crop (e.g. millet and cowpea) in South Asia, and Sub-Sahara Africa is widely present. I suspect their vegetation indices would also be hard to distinguish and also need special treatment?

**Response:** Thanks for raising the issue on clarification. We agree with the comment that global cropping systems are highly diverse due to factors including climate, policy, and socioeconomic conditions. 1) Instead of pursuing algorithmic consideration for each cropping type, this study aims to use a general scheme for creating GCI30 that is efficient and representative of the major cropping types worldwide. 2) We treated flooded paddy rice differently because of two reasons. The first reason is that rice is a major crop, especially for many developing countries. The second reason is that there are successful applications of paddy rice transplanting characteristics (Xiao et al. 2005; Dong et al. 2015; 2016), which can guide our CI mapping in this study. 3) Identification of inter/mixed cropping using satellite remote sensing is extremely challenging. Since the proposed approach is pixel-based, it reflects the composition of all cropping system within that pixel. Unfortunately, we did not have *in situ* samples of inter/mixed cropping in South Asia or Sub-Sahara Africa as mentioned by the Referee. Here we provide a typical example among others in Northeast China to test this intercropping issue, as shown in the following figure. Fig. R1 shows a cropland pixel located in northeast of China where maize and soybean are intercropped. Although maize and soybean are simultaneously planted in alternating rows of the same pixel, satellite NDVI time series is still able to reflect the greening/browning cycles of the entire 30×30 m extent. In spite of these promising results, it should be recognized that for some extreme cases, in which two or more crops have totally different phenological features, our method may be less reliable. We added this information in the revised manuscript.

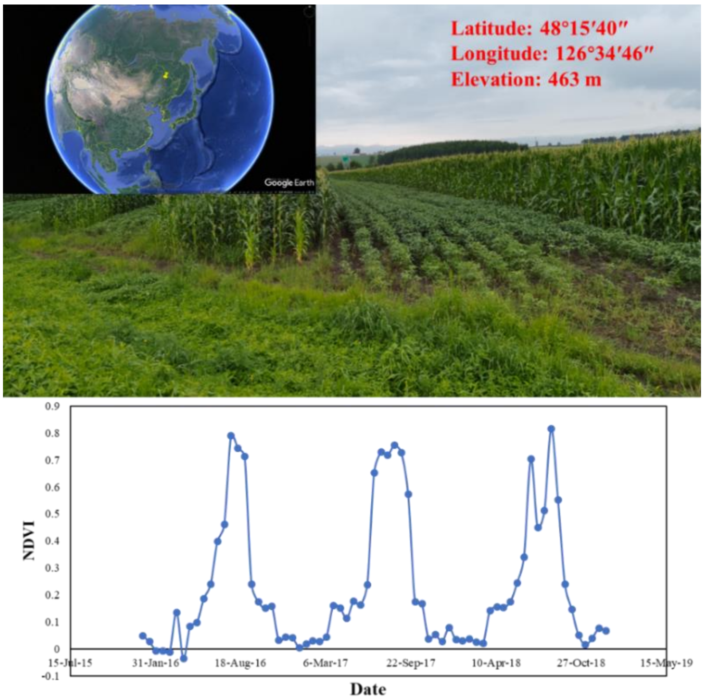


Figure R1 a demo showing NDVI time series of a inter/mixed cropping system

*Reference 1: Xiao, Xiangming, Stephen Boles, Jiyuan Liu, Dafang Zhuang, Steve Frolking, Changsheng Li, William Salas, and Berrien Moore III. 2005. "Mapping Paddy Rice Agriculture in Southern China Using Multi-Temporal MODIS Images." Remote Sensing of Environment 95 (4): 480–92.*

*Reference 2: Dong, Jinwei, and Xiangming Xiao. 2016. "Evolution of Regional to Global Paddy Rice Mapping Methods: A Review." ISPRS Journal of Photogrammetry and Remote Sensing 119: 214–27.*

*Reference 3: Dong, Jinwei, Xiangming Xiao, Michael A Menarguez, Geli Zhang, Yuanwei Qin, David Thau, Chandrashekhar Biradar, and Berrien Moore III. 2016. "Mapping Paddy Rice Planting Area in Northeastern Asia with Landsat 8 Images, Phenology-Based Algorithm and Google Earth Engine." Remote Sensing of Environment 185: 142–54.*

*3 One of the important inputs is cropland extent. The authors integrated an ensemble of multiple land cover/cropland layer products. While I applaud the authors' effort of mix and match to try to get the best available cropland extent globally, such an approach would create another problem of data consistency (e.g. different products even define cropland differently. Orchards are cropland? Plantain or coffee trees?). I suggest the authors look into Dr. Steffen Fritz work on global cropland. (You used Dr. Fritz' Geowiki datasets and I assumed you are familiar with his work).

**Response:** Thanks for this valuable comment on the integration of different existing products. The cropland definition adopted in our research is based on the concept presented by the Joint Experiment of Crop Assessment and Monitoring (JECAM) network which was created by the Group on Earth Observation Global Agriculture Monitoring Community of Practice. The JECAM network has adopted a shared definition of the cropland that matches the Food and Agriculture Organization's (FAO) Land Cover Meta Language. The general definition of annual cropland (including area affected by crop failure) is a piece of arable land that is sowed or planted at least once within a 12-month period. The annual cropland produces an herbaceous cover and is sometimes combined with some tree or woody vegetation. One exception is the sugarcane plantation and cassava crop, which are included in the cropland class although they have a longer vegetation cycle and are not yearly planted.

In our research, we integrated 10 existing global, regional, and national land-cover maps, or cropland dataset (listed in the table S1 in the supplementary document) to delimit the global cropland extent while masking out irrelevant non-cropland pixels for the period of 2016–2018 (Figure 1). Although variations of classification systems among different products exist, a subset classes of those land cover/cropland layer products were selected to best fit into the cropland definition. We revised the manuscript in **Section 2.1.1** accordingly.

In our case, there are two known exceptions in the integration. The first is greenhouse farming which is included in the cropland class in the FROM-GLC by the definition. However, the GCI30 product excluded the greenhouse pixels as CI of greenhouse crops are detected as zero cropping monitored by remote sensing. The second is the perennial woody crops such as orchards and vineyards from NLCD. As the NLCD data was only used for Alaska region, it will have very limited impact on the integrated global cropland layer and accordingly minor effect on GCI30. On the other hand, as no single product has yet been shown to be consistently accurate in representing cropland distribution, our approach by integrating different dataset is still better than relying on a single source of land cover or cropland layer which already pointed out by Fritz et al. (2015). We added those descriptions in section 3.4 to further discussion the uncertainty resulted from the integration of different dataset.

As suggested, we also revised the table S1 in the supplementary document to include subclasses selected for the integration from each dataset and the corresponding definitions.

*Reference*:

*Fritz, S., See, L., McCallum, I., You, L., Bun, A., Moltchanova, E., Duerauer, M., Albrecht, F., Schill, C., Perger, C. and Havlik, P., 2015. Mapping global cropland and field size. Global change biology, 21(5), 1980-1992.*

*4 Limited reference samples. The authors constructed two independent reference datasets, namely RDsat and RDsite, to evaluate the GCI30 performance. RDsat has 3744 sample records and RDsite has only 40. I understand the difficulty of obtaining the reference samples, particularly in a global study. And yet less than 4000 observations in a hugely diverse cropping system in the world is still quite limited.

**Response:** Thank you for this comment. As you mentioned, it is a challenging task to construct a reliable reference dataset for GCI30 evaluation. This is because 1) there is still no product can be directly used for global CI mapping assessment; 2) the identification of CI value by visual interpretation requires not only the location information, but also precisely judging the number of growing seasons, which is time consuming and laborious; 3) the reference dataset should represent the diversity of global cropping systems. For the first issue, it is the primary reason for us to build new reference sets. For the second issue, we have seven remote sensing experts (listed as coauthors) checked all collected points, and only well-interpreted points with high-level confidence were kept. For the third issue, we adopted a stratified sampling approach to ensure that RDsat was geographically representative across the globe. Moreover, we utilized all available PhenoCam cropland in-situ data although its spatial representative is somehow limited. In summary, multiple efforts were made to make our evaluation as solid as possible, and we agree with the comment that the current RDsat and RDsite data are far away from perfect, which needs further cooperation and study in the future.

**Minor comments:**

*1 Page 4 line 16-17: is there any reference to explain the gap-filling method?

**Response:** We added sentences in **the last paragraph in Section 2.1** explaining the adopted gap-filling method: "In particular, the coarse MODIS datasets were resized to 30-m using the bicubic interpolation method. Then an empirical linear function was built for each pixel to bridge the data records of MODIS and Landsat/Sentinel-2, and missing data gaps were filled with the resampled, transformed MODIS data (labelled as MODIS modelled) (Liu et al. 2020). If there is no valid data from either Landsat/Sentinel-2 or MODIS, temporally adjacent (within 48-day) cloud free LANDSAT/Sentinel-2 observations were used to determine the filling value (labelled as interpolated)."

*Reference: Liu, Chong, Qi Zhang, Shiqi Tao, Jiaguo Qi, Mingjun Ding, Qihui Guan, Bingfang Wu, et al. 2020. "A New Framework to Map Fine Resolution Cropping Intensity across the Globe: Algorithm, Validation, and Implication." Remote Sensing of Environment 251: 112095. https://doi.org/10.1016/j.rse.2020.112095.*

*2 Page 4 line 17: there are four reasons for invalid observation mentioned above (Page 4 line6), but here, authors just list one reason (i.e. clouds) for data gaps. In addition, "vacancy of cloud-free Landsat/Sentinel-2 observation", such expression may cause misunderstanding, whether “cloud-free” means satellite images without clouds or satellite images which were masked by mask algorithm?

**Response:** Thank you for this comment! We modified the sentence to “We also used the MOD13Q1 NDVI/EVI product and MOD09A1-derived LSWI in our study to fill data gaps caused by the vacancy of Landsat/Sentinel-2 observations that were removed by the Fmask algorithm”.

*3 Page 5 line 18: add references for GCC

**Response:** Reference (Richardson et al., 2018) added.

*Reference: Richardson, Andrew D., Koen Hufkens, Tom Milliman, Donald M. Aubrecht, Min Chen, Josh M. Gray, Miriam R. Johnston, et al. 2018. “Tracking Vegetation Phenology across Diverse North American Biomes Using PhenoCam Imagery.” Scientific Data 5 (1): 180028. https://doi.org/10.1038/sdata.2018.28.*

*4 Page 6 line 19: in reference Ding et al. 2020, it is more than 12% instead of 12%.

**Response:** Corrected in the revised manuscript.

*5 Fig. 2:

A. Please modify the font size of the horizontal axis label of Fig.2(a) or Fig.2(b) to ensure that the two graphs have the same font size.

B. Please modify the vertical axis scale interval of Fig.2(a) or Fig.2(b) to ensure that the two graphs are tidier.

C. “original phase” in Fig2(a), “flooding signal” in (b), “final phase” in (c), these three dashed polylines are all trapezoidal. But I think rectangular polylines can better represent different phases and transition points.

**Response:** Agreed and we modified Figure 2 in the revised manuscript.

*6 Fig. 5: please indicate the unit for the Area in the bar charts.

**Response:** Modified in the revised manuscript.

*7 Page 11, Line 14: I don't see this (Wu et al., 2021) in your reference list

**Response:** Thanks for this comment. As Wu et al., 2021 is an unpublished citation, we now replace this citation by (Zohaib and Choi, 2020) and rewrite the sentence as follows: "These regions are commonly characterized by warm and humid climates, except for the Nile River basin, in which irrigation has been commonly used to support intensive farming practices (Zohaib and Choi, 2020)."

*8 Page 12 line 16: shouldn't it be "top 9 countries"?

**Response:** We appreciate this comment. Sri Lanka was lost in the list and we fixed this mistake in the revised manuscript.

*9 Page 13 line 7: shouldn't it be "South America"?

**Response:** Thanks and we corrected this bug in the revised manuscript.

*10 Page 14 line 14: change "to" to "two"?

**Response:** Corrected.

*11 Page 14 line 17: title of table 2. Shouldn't it be "four different studies"?

**Response:** Corrected. This table is now moving to methodology part in **section 2.5 Comparison with other global products** to demonstrate which studies and existing products are used for inter-comparison.

*12 Page 15 line 15: according to Fig.8(B), shouldn't it be 32% (10%+22%)?

**Response:** Agreed and corrected.

*13 There are many mistakes in reference section and in-text citations (almost all citation formats are incorrect), please check and modify according to the journal reference format requirements.

https://www.earth-system-science-data.net/submission.html#references

**Response:** Agreed and modified. We have gone through the manuscript and made sure all citations (including the Reference section and in-text citations) correct according to ESSD's requirement.