Dear Dr. Hanqin Tian,

We would like to thank you and the reviewers for the time and effort spent on reviewing. All the comments are fully considered during the revision. Below you could find our responses, structured as: **[Comment]** from referees, [Response] from authors, and [Change] made in the manuscript (clean mode and track mode).

Kind regards,

Han Su, on behalf of all co-authors

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Multidisciplinary Water Management group, University of Twente

Referee #1 (RC1, RC2, and RC3)

- **RC1**

General comment:

[Comment] I respect the authors' challenge in compiling farm-size- and crop-specific harvested area datasets like one presented in this study. Although there might be much room for further validation of the developed dataset, I would not request it since it is in realty difficult to objectively assess the uncertainties of the dataset when no similar dataset is available. My comments are mostly from editorial point of view, and to improve the manuscript further.

[Response] We would like to thank you for the time and effort spent on reviewing. We appreciate your comments which enable us to improve our manuscript. We provide our responses below.

Relatively major comments:

[Comment] 1. I did not find any list of the 56 countries covered in this dataset. Probably, Table S6 is close to the list, but it might be incomplete in the case that Meharabi's dataset and your dataset are not overlapped. Related to this, why don't you present your dataset as the map in main text for demonstration purpose? Showing a map of main variable of your dataset is help readers understand your dataset.

[Response] We agree that the complete list of the 56 countries, taken from Ricciardi's dataset, is missing in the manuscript, and will add it as supplementary materials. We will also add maps on the harvested area of rainfed maize belonging to two farm sizes (2-5 ha and 500-1000 ha) in the next revision to illustrate some of the multiple dimensions of the dataset in a limited number of maps.

The list of 56 countries:

Table. The list of 56 countries and country code

No.	Country code	Country	No.	Country code	Country
1	ALB	Albania	29	LUX	Luxembourg
2	AUT	Austria	30	LVA	Latvia
3	BEL	Belgium	31	MEX	Mexico
4	BFA	Burkina Faso	32	MLI	Mali
5	BGR	Bulgaria	33	MLT	Malta
6	BIH	Bosnia and Herzegovina	34	MNG	Mongolia
7	BRA	Brazil	35	MWI	Malawi
8	COL	Colombia	36	NER	Niger
9	COS	Costa Rica	37	NGA	Nigeria
10	CYP	Cyprus	38	NLD	Netherlands
11	CZE	Czechia	39	NOR	Norway
12	DEU	Germany	40	PAN	Panama
13	DNK	Denmark	41	PER	Peru
14	ESP	Spain	42	POL	Poland
15	EST	Estonia	43	PRT	Portugal
16	ETH	Ethiopia	44	PRY	Paraguay
17	FIN	Finland	45	ROM	Romania
18	FRA	France	46	RUS	Russian Federation
19	GBR	United Kingdom	47	SVK	Slovakia
20	GHA	Ghana	48	SVN	Slovenia
21	GRC	Greece	49	SWE	Sweden
22	HRV	Croatia	50	TJK	Tajikistan
23	HUN	Hungary	51	TLS	Timor-Leste
24	IND	India	52	TZA	United Republic of Tanzania
25	IRL	Ireland	53	UGA	Uganda
26	ITA	Italy	54	URY	Uruguay
27	KHM	Cambodia	55	USA	United States of America
28	LTU	Lithuania	56	ZAF	South Africa

The maps for demonstration purposes:

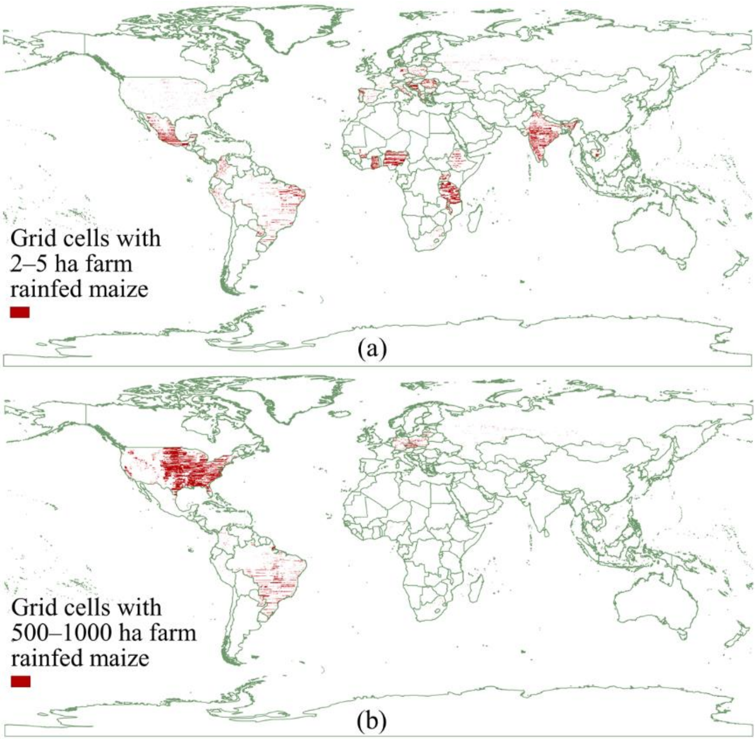

Fig. The gird cells with a harvested area of rainfed maize belonging to the farm size 2–5 ha (a) and farm size 500–1000 ha (b), according to the GAEZ based downscaled map.

[Change] The complete list of the 56 countries was add in the supplementary material, [S1]. The figure for illustration was added as Fig. 2, in section 3.1, and lines 251-253 (lines 257-259 in track mode).

[Comment] 2. Since some farming types (e.g., the rainfed subsistence in SPAM2010) are assumed to be an indicator of small-scale farmers in literature (e.g., Iizumi et al. (2021)), it would be great if you could show how the individual farming type considered here correlate with field size or not, using your dataset.

[Response] We agree that the combined data on farm size and farming type is valuable in providing insights into agriculture structure and is worthwhile to be illustrated in the paper. We will add the distribution of farming systems within each farm size in the next revision.

Our dataset indicates the subsistence and low-input rainfed farming system is mainly operated at smaller farms, but the smaller farms do not exclusively consist of subsistence and low-input rainfed farming system: they also operate a significant portion of the irrigated and high-input rainfed area. Similarly, the main type of farming system of larger farms is high-input rainfed, but the high-input rainfed is far from being limited to larger farms.

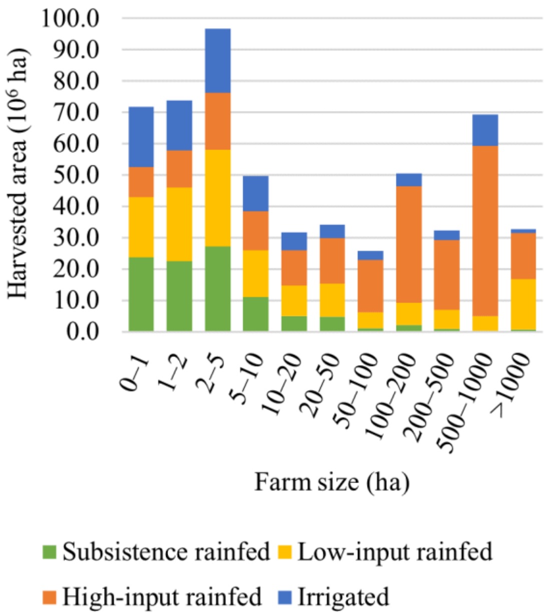

Fig. The distribution of irrigated, low- and high-input rainfed, and subsistence rainfed farming systems within each farm size according to the SPAM based downscaled map

[Change] Illustration on farming systems was added as Fig. 4, in section 3.2, and lines 299-303 (lines 310-314 in track mode).

[Comment] 3. I would encourage the authors to add a brief discussion towards next step – specifically, compiling a farm-size and crop-specific production or yield dataset. Increasing productivity of small-scale farmers is a main goal in SDG 2 (zero hanger). Once farm-size harvested area datasets like one presented hare become available, then people expect farm-size- and crop-specific yield dataset to calculate the production share of small-scale farmers. But it is elusive how yield differ by farm size (e.g., Muyanga and Jayne (2019) and Supplementary Text of Iizumi et al. (2021)). What is your though on the current feasibility and limitations to develop such dataset?

[Response] One of the underlying aims of constructing the current dataset is to compile the best-available empirical farm-size specific dataset. Compared to harvested area, an empirical farm-size specific dataset on yield or production is even more scarce. The data on yield or production of farm sizes is available for limited countries, but those countries are not always the most vulnerable in terms of food insecurity. Developing farm-size specific maps on yield or production may be the goal of further research and may be one of the applications of our dataset that directly benefit from the additional dimensionality achieved. Such datasets would require estimating the yield based on additional datasets or models.

As pointed out by the reviewer, correlations between farm size and yield are still under debate. Many factors contribute to this relationship, including but not limited to crop types, fertilizer input, climate, and soil conditions. The farm size itself does not directly affect yield, but farm size often correlates with factors that affect yield.

So, estimating crop yield for different farm sizes requires first unpacking the factors that directly impact yield and correlate with farm sizes. For environmental factors like soil conditions and climate, this could be achieved by overlapping our dataset with the soil and climate database. Agricultural management and input factors, like fertilizer input, could be inferred from the agricultural production system data. Specifying agricultural management and input factors according to farming systems could help to first evaluate crop yield for different farming systems, and then allocate the yield back to farm sizes according to their proportion in each farming system. Such an approach would rely on the assumption that agricultural management practices of different farming systems do not depend on farm size. Reliable estimations of yield for different farming systems could be either derived from SPAM2010 and GAEZ v4 data or based on crop modeling when the data on the factors are available.

We will add the above discussion in the next revision.

[Change] The above discussion on farm-size-specific production was added as section 4.3, lines 434-451 (lines 446-463 in track mode).

Specific comments:
[Comment] 4. Table1. The units of spatial resolution are mixed (arcmin and km). Using a consistent unit or showing an indication for conversion (for instance, approximately 10 km for 5 arcmin) increase readability.

[Response] We agree with your suggestion. We will add indications for unit conversion.

[Change] The unit conversion was added in Table 1, lines 125-126 (lines 129-130 in track mode).

[Comment] 5. L129. Can you add a brief definition of crop area, planted area, harvested area and cultivated area? Especially, are crop area and cultivated area used here crop-specific?

[Response] The crop area, planted area, harvested area, and cultivated area is crop-specific. These variables were identified by Ricciardi's dataset from the local agriculture census. There is no worldwide standard definition for these items (FAO, 2015). Local agriculture censuses have their preference to use one of them for specific crops. Generally speaking, planted area is used for temporary crops; cultivated area for temporary crops and permanent crops; crop area for temporary crops, permanent crops, fallow, meadows, and pastures; harvested area is the cultivated area excluding the area destroyed by natural disasters or other reasons (FAO, 2015, 2020). We will clarify them in the next revision.

[Change] We clarified these items in section 2.2, lines 130-135 (135-140).

[Comment] 6. L164. "the total harvested" -> "the total area harvested"

[Response] We agree with your suggestion. This phrase will be corrected.

[Change] We fixed this phrase, section 2.3, line 170 (line 175 in track mode).

[Comment] 7. L216. "access" -> "assess"

[Response] We agree with your suggestion. This word will be corrected.

[Change] We fixed this phrase, section 2.5, line 222 (line 227 in track mode).

[Comment] 8. Fig. 3. How did you associate farm size with the water scarcity levels of Hoekstra et al. (2012)? Since the water scarcity level data are on monthly resolution, did you calculate an average for cropping season?

[Response] We are sorry that there is a mistake in the reference here. We used the updated water scarcity map of Hoekstra et al. (2012), Mekonnen and Hoekstra (2016). In the updated dataset, there are monthly water scarcities and also an annual average of monthly blue water scarcity. We used the latter one. We will correct the reference and clarify the data source in the next revision.

[Change] We corrected the reference and clarified the data source, section 3.2, line 275 (line 281 in track mode).

[Comment] 9. L308-309. This is rather speculative. At least, relevant citations are needed to support this statement on change in farm size for ten-year period. And for your reference, in their Fig. 2, Yu et al. (2013) reports based on farmer interview that change in farmland area per household increase from 1.3 ha in the early 1980s to 2.6 he in the early 2010s for some villages in North China. Although you have talked here about Bulgaria, which could be largely different with China, it seems that the difference (78.5% and 5% of harvested area is under the farm size 50-100 ha in Lowder's dataset and your dataset, respectively) is too large to be explain by the difference in the reported time.

[Response] Thanks for pointing it out. Here, we want to emphasize both our results and other datasets indicate large farms are the major farm size in the country, but you are right, we also need to explain the difference better. How datasets process the farm size class may contribute to the differences besides the reported time. The farm size classes collected from the local agriculture census usually need to be harmonized into a classification system. Different datasets may have their own choice during this process. This may lead to the differences shown in the comparison, especially when the major farm sizes are similar but not the same.

We will add some explanations in the next revision.

[Change] We added the above explanation in the section 3.5, lines 350-354 (lines 363-365 in track mode).

[Comment] 10. L364. I think the social-ecological factors mentioned here indicate the use of GAEZ. Although this reasoning may be true, there is no result to show what social-ecological factors lead to the difference in the two crop maps.

[Response] Indeed, the social-ecological factors were considered in both GAEZ and SPAM. Quantifying how the use of different social-ecological factors may lead to differences in the two crop maps however is beyond the scope of this manuscript. Instead, we will weaken this statement in the next revision.

[Change] We weakened this statement in section 4.1, line 409 (line 421 in track mode).

- **RC2**

[Comment] In relation to the author's response to [Comment] 2, I'm very much impressed by the figure (Fig. The distribution of irrigated, low- and high-input rainfed,

and subsistence rainfed farming systems within each farm size according to the SPAM based downscaled map) that the portion of the subsistence rainfed and low-input rainfed farming systems account for more in the smaller farm sizes than in the larger farm sizes. The figure also shows that the portion of the irrigated farming system is more in the smaller farm sizes. Why is the irrigation-equipped area share relatively high in small size farmers? I would be appreciate it if the authors could explain this point. I suspect that this is due to the large number of small size farmers in Asia (in particular India) where water resources are abundant thanks to monsoon rainfalls.

[Response] Thank you for your comment. Indeed, a higher portion of irrigated farming system in smaller farms is shown in the figure you refer to, as well as in Fig. 3 in our manuscript this is supported by previous evidence (FAO, 2021; Ricciardi et al., 2020). The inclusion of the 56 countries and exclusion of other countries affect this estimation, but for the 56 countries, the overall higher portion of irrigated area in smaller farms correlates with the level of water scarcity: Fig. 3 in the manuscript indicates that higher portions of smaller farms are located in water-scarce regions as compared to larger farms. In the water-scarce regions, the percentage of the irrigated area could reach on average 40% for small farms. For India, the water scarcity map of Mekonnen and Hoekstra (2016) indicates a large part of India is under water scarcity from January to June, and thus under water scarcity on an annual average. The India agriculture input survey (DAFW, 2022) indicates 47.8% of the crop area belonging to farm size 0-2 ha was irrigated in India during 2011-2012. Thus, water scarcity may partly contribute to the high portion of irrigated areas in Indian small farms. Asian smaller farms also contribute to the higher irrigation portion in another way. In Asian countries including India, previous studies show that independent of regional water scarcity, on average the percentage of irrigated area in small farms is high: over 50% when water is scarce and over 20% when water is not scarce (Ricciardi et al., 2020). This percentage is much higher than that in Europe, Central Asia, Latin America, and Sub-Saharan Africa (Ricciardi et al., 2020). Since a large number of small farms are from Asia, the overall portion of irrigated areas in small farms is high. We will add the above analysis in the next revision.

[Change] We added the above additional explanation on the overall higher irrigation of smaller farms in section 3.2, lines 272-281 (lines 278-291 in track mode).

- **RC3**

[Comment] Thank you very much for your clarifications that is convincing. I look forward to see a revised manuscript.

[Response] Thank you very much.

Referee #2 (RC4)

- **RC4**

[Comment] This study tries to map the global distribution of farm size using data harmonization approach. This is an interesting topic, but there are a few major issues that need to be solved.

[Response] Thank you for your comments. These comments enable us to improve our manuscript. We appreciate the time and effort you spent on reviewing. Below are our responses and how we will address them in the next revision.

[Comment] First, there is a large gap in China, causing an unpleasant blank area in the entire East Asia. I believe China's data can be easily obtained from the annual yearbook or other statistical records, and I would suggest the authors fill this gap.

[Response] The inclusion of China is our ambition since designing the research, however, data access remains unsolved so far. To include any extra country or region, we need farm-size specific and crop-specific data at the regional level from statistical records. This information for China is not publicly available, which is confirmed by the *Statistics Information Service* from the *National Bureau of Statistics of China* after consulting. According to our best knowledge, two databases may provide such data: the microdata of the *Third National Agricultural Census in China* (NBS, 2022) and the *China Rural Household Panel Survey* (CRHPS) (SSECZU, 2019). We submitted our data request and discussed with the database manager of the two databases in August 2021 and February 2022 respectively, however, we could not be granted access according to the corresponding current data policy. The data policy might change in the future, and we are prepared to include more countries including China once additional data is available. We would also like to invite scholars, users, and policymakers to update our database together in the future.

[Change] We added a note on updating our database when additional data is available in section 4.2, lines 432-433 (lines 444-445 in track mode).

[Comment] Second, I have concerns about the validation in Lines 220-224. The comparisons are actually a compromise of data inconsistency. What if a different threshold value was used? Do the conclusions change if a different threshold was used? A sensitivity analysis maybe helpful here.

[Response] We agree that a sensitivity analysis would be helpful to understand the comparison here. Besides the current threshold of 25 ha, we also tried 10 ha and 50 ha as thresholds and conducted the same comparison with observations from satellite images. We found the conclusions in Section 3.3 are not sensitive to the choice of threshold. We will add the sensitivity analysis in the next revision.

[Change] We added the sensitivity analysis in section 3.3, lines 311-313 (lines 322-324 in track mode).

[Comment] Third, language editing is also needed.

[Response] The next revision will receive proofreading from a native speaker.

[Change] The manuscript was polished to improve the readability.

Other minor suggestions:
[Comment] 1. Line 119, an extra "and"?

[Response] Yes, this word is redundant and will be removed in the next revision.

[Change] The redundant word was deleted, section 2.2, line 120 (line 124 in track mode).

[Comment] 2. The claims in Lines 263-264 were actually not supported by the figure. There is a large drop in the >1000 category in Fig. 3a for the orange and red lines. Please also explain.

[Response] Thanks for pointing it out; we agree that more precise formulation is due. The more appropriate claim will be that large farms irrigate to a larger extent than small farms when water is scarce.

The reason for the drop is that the water scarce area of the >1000 ha farm size is mainly contributed by limited crops from a few regions, at least in our dataset. In this case, the characteristics of these crops and regions have more impact on the overall relationship between water scarcity and irrigation. For example, one of the main contributors to the significant and severe water scarce area of >1000 ha farm size (the orange and red lines) is sugarcane from São Paulo in Brazil. Brazil is the world's largest sugarcane producer and São Paulo account for around 60% of sugarcane production in Brazil (Bordonal et al., 2018; Palludeto et al., 2018). Sugarcane in this area is dominated by >1000 ha farm size (Ricciardi et al., 2018), mainly rainfed (OECD-FAO, 2015; Yu et al., 2020), and under water scarcity (Mekonnen and Hoekstra, 2016). However, water scarcity is not present all year round. The level of water scarcity is low from January to June, which is the tillering phase for sugarcane. During the dry season, sugarcane is usually harvested, during which moisture in sugarcane is relatively low and the sugar is highly concentrated (Kavats et al., 2020). This may help to explain why the large farms in this area are rainfed even though under a certain level of water scarcity.

In Fig. 3, we do not aim to draw conclusions on irrigation levels for specific farm sizes in absence of further investigation on influencing factors and uncertainties. The reason we have Fig. 3 is to compare it with previous observations. Ricciardi et al. (2020) show that large farms irrigate to a larger extent than small farms when water is scarce. In their study, farms are divided into either small or large farms without further classification, and the status of water scarcity is only classified as the water is scarce (moderate, significant, and severe) or not (low). Plausible thresholds to differentiate small and large farms could be country specific, and range from 1-42 ha for most countries (FAO, 2017, 2019; Khalil et al., 2017). With any threshold within this range, our dataset supports previous observations given that the farm size >1000 ha only contributes to less than 4.5% of water scarce area of large farms, so specific observations for the largest farm size may be spurious and are not emphasized in the paper.

In the next revision, we will improve the claim, clarify the intention of this analysis, and explain Fig. 3 with more details based on the above response.

[Change] We improved the claim, clarified the intention of the analysis, and added explanations on the >1000 ha farm size in section 3.2, lines 267-271, 282-295 (lines 273-277, 293-306 in track mode).

[Comment] 3. In line273, I don't know why the author made this claim: "This means the spatial distributions of oil palm production in our downscaled maps and Descals et al. (2020) are similar." The comparisons were about the harvested area, and why and how did the production involved here?

[Response] Thanks for pointing it out. The statement indeed is about the harvested area instead of production. We will formulate it unambiguously in the next revision.

[Change] We clarified the claim in section 3.3, line 310 (lines 321-322 in track mode).

[Comment] 4. Line 328, separately?

[Response] Yes, this word will be corrected in the next revision.

[Change] The word was corrected in section 4.1, line 373 (line 384 in track mode).

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