

Supplementary Materials

GlobalWheatYield4km: a global wheat yield dataset at 4-km resolution during 1982-2020 based on deep learning approach

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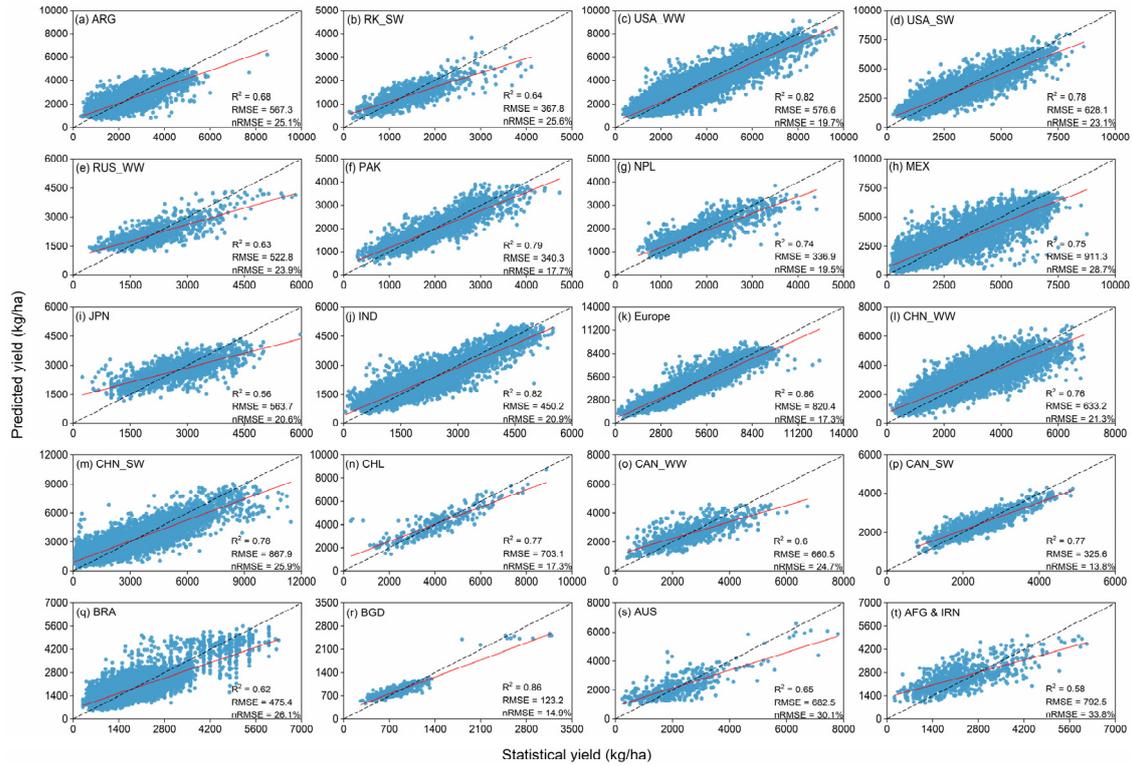


Figure S1: Comparisons between the predicted yields of GlobalWheatYield4km and observed yields. RK_SW: spring wheat in RUS and KAZ; USA_WW: winter wheat in USA; USA_SW: spring wheat in USA; RUS_WW: winter wheat in RUS; CHN_WW: winter wheat in China; CHN_SW: spring wheat in China; CAN_WW: winter wheat in Canada; CAN_SW: spring wheat in Canada;

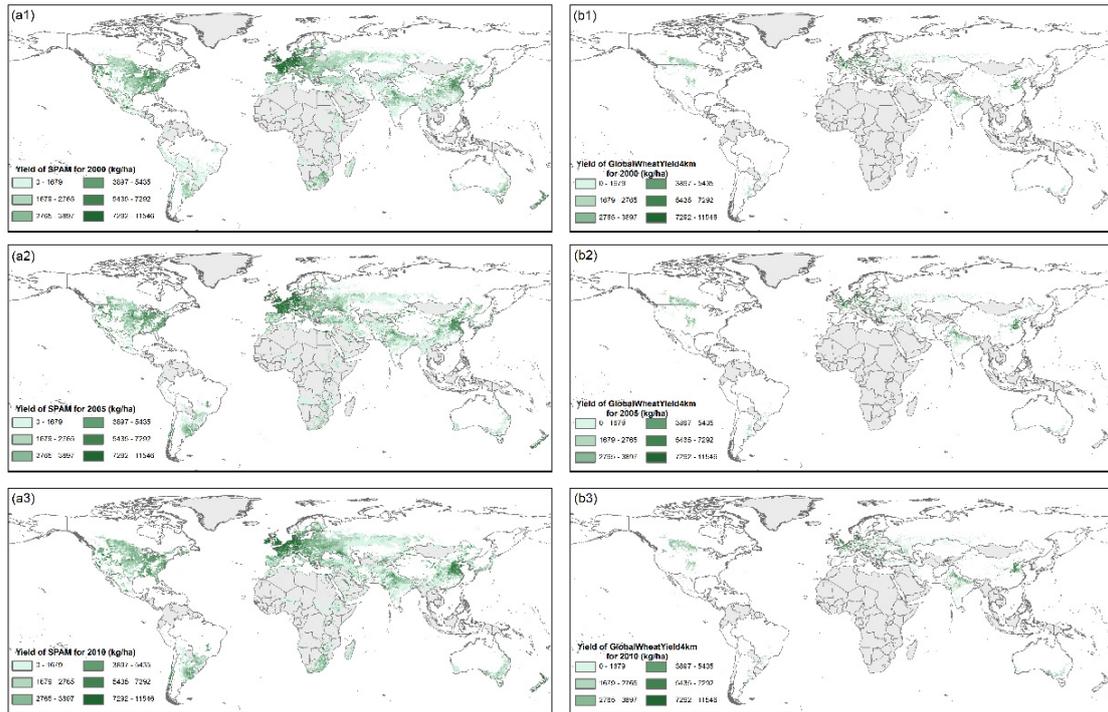


Figure S2: Spatial distributions of the yields from SPAM (a1-a3) and GlobalWheatYield4km (b1-b3) for 2000 (a1, b1), 2005 (a2, b2) and 2010 (a3, b3).

Table S1: Summarization for information on each country across the study area.

Country	Wheat type	Political unit of statistical data (Number)	Time frame	Source
Afghanistan	Winter wheat	ADM1 (34)	2011-2017	CountrySTAT, http://afghanistan.countrystat.org/
Albania	Winter wheat	ADM0 (1)	1987-2017	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Argentina	Winter wheat	ADM2 (503)	1981-2019	Ministerio de Agroindustria, http://www.siiia.gov.ar/
Australia	Winter wheat	Natural Resource Management Region (50) + ADM1 (9)	2005-2018 1981-2018	Australian Bureau of Statistics, http://www.abs.gov.au/
Austria	Winter wheat	ADM1 (9)	1981-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Azerbaijan	Winter wheat	ADM2 (79)	2000-2018	CountrySTAT, http://azerbaijan.countrystat.org/home/en/
Bangladesh	Winter wheat	ADM2 (65)	1981-2014	Bangladesh Bureau of Statistics, https://bbs.portal.gov.bd
Belgium	Winter wheat	ADM1 (11)	1981-2017	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Bolivia	Winter wheat	ADM1 (9)	1984-2019	Instituto Nacional de Estadística, https://www.ine.gob.bo/
Brazil	Winter wheat	ADM2 (5504)	1981-2017	Companhia Nacional de Abastecimento, www.conab.gov.br/index.php
Bulgaria	Winter wheat	ADM1 (6)	1985-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Canada	Winter wheat Spring wheat	ADM2 (82)	1981-2019	Statistics Canada, https://www.statcan.gc.ca/eng/start
Chile	Winter wheat	ADM1 (13)	1981-2019	Oficina de Estudios y Políticas Agrarias, https://www.odepa.gob.cl/
China	Winter wheat Spring wheat	County (2008)	1981-2015	National Bureau of Statistics of China, http://www.stats.gov.cn
Croatia	Winter wheat	ADM0 (1)	2006-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Czechia	Winter wheat	ADM1 (8)	1981-2017	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Denmark	Winter wheat Spring wheat	ADM1 (5)	1981-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Estonia	Winter wheat Spring wheat	ADM0 (1)	1987-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Finland	Spring wheat	ADM1 (5)	1981-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
France	Winter wheat	ADM1 (27)	1981-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Germany	Winter wheat	ADM1 (38)	1981-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Greece	Winter wheat	ADM1 (13)	1981-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Hungary	Winter wheat	ADM1 (19)	1981-2017	EUROSTAT, https://ec.europa.eu/eurostat/web/main
India	Winter wheat	ADM2 (506)	1997-2015	Department of Planning, Economics & Statistics, https://data.gov.in/
Iran	Winter wheat	ADM1 (31)	2004-2020	Iran's Agricultural Ministry, www.maj.ir
Ireland	Winter wheat	ADM1 (3)	2017-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Italy	Winter wheat	ADM1 (21)	1981-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Japan	Winter wheat	ADM1 (47)	1981-2018	Statistics of Japan, https://www.e-stat.go.jp/
Kazakhstan	Spring wheat	ADM1 (14)	2014-2020	Ministry of National economy of the Republic of Kazakhstan Committee on Statistics, https://stat.gov.kz/
Latvia	Winter wheat Spring wheat	ADM0 (1)	1987-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Lithuania	Winter wheat Spring wheat	ADM1 (2)	2017-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Luxembourg	Winter wheat	ADM0 (1)	1981-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Macedonia	Winter wheat	ADM0 (1)	2005-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main

Mexico	Winter wheat	ADM2 (2442)	2003-2018	Servicio de Informacion Agroalimentaria y Pesquera, http://infosiap.siap.gob.mx/
Nepal	Winter wheat	ADM2 (75)	1981-2018	NEPAL IN DATA, https://nepalindata.com/
Netherlands	Winter wheat	ADM1 (12)	1981-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Norway	Spring wheat	ADM1 (7)	2015-2017	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Pakistan	Winter wheat	ADM3 (113)	1981-2014	Directorate of Agriculture Punjab, http://www.amis.pk/
Peru	Winter wheat	ADM1 (26)	1981-2018	Ministerio de Agricultura, https://www.gob.pe/
Poland	Winter wheat	ADM1 (17)	1995-2016	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Portugal	Winter wheat	ADM1 (7)	1999-2015	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Republic of Moldova	Winter wheat	ADM1 (37)	2007-2018	National Bureau of Statistics of the Republic of Moldova, https://statbank.statistica.md/PxWeb/pxweb/en/
Romania	Winter wheat	ADM1 (7)	1995-2017	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Russia Federation	Winter wheat Spring wheat	ADM1 (62)	1990-2016	Федеральная служба государственной статистики, https://data.gov.ru/?language=en
Slovakia	Winter wheat	ADM1 (4)	1995-2017	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Slovenia	Winter wheat	ADM1 (2)	2007-2017	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Spain	Winter wheat	ADM1 (18)	1981-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Sweden	Spring wheat	ADM1 (8)	1992-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Turkey	Winter wheat	ADM1 (26)	1995-2016	EUROSTAT, https://ec.europa.eu/eurostat/web/main
Ukraine	Winter wheat	ADM1 (27)	2004-2017	EUROSTAT, https://ec.europa.eu/eurostat/web/main
United Kingdom	Winter wheat	ADM1 (40)	1987-2018	EUROSTAT, https://ec.europa.eu/eurostat/web/main
United States	Winter wheat Spring wheat	ADM2 (2846)	1981-2016	USDA, https://quickstats.nass.usda.gov/

Table S2: Comparisons of harvested areas between the GWPMS-based estimates and subnational-level data.

Region/ Crop type	2006		2007		2008		2009		2010		2011		2012		2013		2014	
	R ²	nRMSE (%)																
SEA	0.81	38.6	0.76	41.5	0.8	38.2	0.85	43.3	0.78	46.9	0.82	42.3	0.83	42.5	0.81	41.6	0.77	44.6
CA	0.82	34.5	0.77	38.8	0.71	44.9	0.85	32.4	0.69	35.8	0.83	40.9	0.84	37.9	0.75	36.4	0.8	35.4
Europe	0.78	36.8	0.81	35.4	0.86	38.8	0.77	40.6	0.78	33.2	0.83	34.5	0.81	31.4	0.8	36.6	0.82	34.7
RK_SW	0.85	38.2	0.84	43.7	0.82	45.6	0.8	54.7	0.84	50.8	0.81	46.6	0.79	48.2	0.86	37.3	0.76	41.4
RUS_WW	0.75	46.2	0.82	44.2	0.86	38.5	0.79	36.4	0.77	41.3	0.81	34.2	0.83	41.8	0.78	34.8	0.84	43.1
AUS	0.87	42.7	0.84	33.7	0.88	40.7	0.86	36.8	0.89	49.5	0.88	44.7	0.86	37.2	0.82	41.6	0.87	38.9
SA	0.75	45.6	0.8	43.5	0.82	43.9	0.77	43.8	0.72	45.9	0.79	45.1	0.76	42.3	0.65	45.1	0.74	45.9
NA_SW	0.79	45.4	0.85	44.2	0.82	45.9	0.84	46.6	0.82	45.8	0.87	45.9	0.8	44.8	0.75	46.2	0.76	44.9
NA_WW	0.78	43.9	0.84	34.4	0.81	31.5	0.85	32.5	0.84	43.8	0.85	31.6	0.77	39.4	0.79	42.5	0.8	44.3

Note: SEA, South and East Asia; CA, Central Asia; RK_SW, spring wheat in Russian Federation and Kazakhstan; RUS_WW: winter wheat in Russian Federation; SA, South America; NA_SW, spring wheat in North America; NA_WW, winter wheat in North America.

Table S3: Comparisons of yields between the GlobalWheatYield4km- or SPAM-based estimates and observed data.

Country/ Crop type	2000				2005				2010			
	Our dataset		SPAM		Our dataset		SPAM		Our dataset		SPAM	
	R ²	RMSE (kg/ha)										
ARG	0.65	424.5	0.01	879.9	0.74	497.3	0.77	506.7	0.72	748.7	0.57	786.4
AUS					0.7	480.2	0.41	1190.1	0.65	522	0.24	868.8
BGD	0.73	99.8	0.17	968.5	0.77	146.5	0.4	877.7	0.74	141.2	0.6	1389.7
BOL	0.41	144.7	0.01	235.9	0.66	373.2	0.5	314.7	0.78	365	0.91	166.7
BRA	0.49	479.8	0.08	606.1	0.6	479	0.68	545.5	0.62	480.2	0.62	545.5
CAN	0.64	324.3	0.68	454.1	0.8	522.8	0.66	515.4	0.66	487.4	0.27	616.7
CHL	0.65	621.2	0.29	1011.1	0.74	434	0.31	1748.4	0.89	509	0.6	1906.7
CHN_WW	0.79	718.6	0.59	1008.7	0.84	684.1	0.88	694.9	0.84	742.9	0.82	945.6
CHN_SW	0.81	983	0.51	1297.7	0.7	1097.6	0.71	1138.9	0.77	990.2	0.75	1083
Europe	0.86	834.9	0.84	921.8	0.91	703.1	0.94	583	0.88	671.1	0.8	1058.9
IND	0.83	448.2	0.55	769.9	0.87	396.2	0.69	611.2	0.83	461.7	0.83	534.6
IRN					0.75	547.9	0.37	1076.7	0.74	553	0.73	535.5
JPN	0.71	617	0.01	1193.4	0.68	558.7	0.77	419.2	0.66	412.1	0.81	374.6
MEX					0.82	800.1	0.65	1237.6	0.7	1033.4	0.7	1224.9
NPL	0.4	263.6	0.09	373.8	0.57	314.1	0.05	786.1	0.72	395.5	0.01	969.8
PAK	0.77	447.7	0.1	949.5	0.84	278.3	0.32	896.8	0.81	388.9	0.64	743
PER	0.57	749.1	0.11	868.9	0.27	1035.1	0.09	1271.1	0.54	932.3	0.05	1229.3
RUS	0.69	366	0.02	713.5	0.73	416.5	0.96	166.1	0.79	460.5	0.93	208.6
UKR					0.4	316	0.02	335.8	0.55	437.9	0.56	354.7
USA_WW	0.86	555.8	0.72	739.5	0.77	693.2	0.6	1065.4	0.8	579.1	0.62	937.7
USA_SW	0.77	645.9	0.67	1337.8	0.7	725.4	0.61	1361.1	0.82	512.1	0.75	1150.4
Mean	0.68	513.2	0.32	842.9	0.71	547.6	0.54	825.8	0.74	563.1	0.61	839.6