Supplement Information

Mapping Complex Cropping Patterns in China (2018–2021) at 10 m Resolution: A Data-Driven Framework based on Multi-Product Integration and Google Satellite Embedding

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S1. Data and method

S1.1 Agro-Natural Regionalization

The Agro-Natural Regionalization of China was proposed by Mr. Qiu Baojian and Mr. Huang Bingwei, who divided China into 38 agricultural natural regions based on temperature zones and moisture conditions (Fig S1, Table S1).

Based on thermal conditions, China is divided into 14 temperature zones defined by multiple indices, including accumulated temperature, mean temperature of the coldest month, and mean temperature of the warmest month (Table S2). These zones reflect the country's thermal resources and growing season length, and they differ significantly in cropping systems and dominant agricultural products. In addition, according to moisture conditions, the whole country is further divided into four regions of different humidity regimes: humid, semi-humid, semi-arid, and arid zones (Table S3). These reflect the balance between precipitation and evapotranspiration, which directly affects vegetation patterns, land use, and agricultural practices. By overlaying the classification of temperature zones with that of moisture conditions, the framework of agricultural natural regionalization was established. This systematic division highlights how both heat (temperature) and water (moisture) jointly determine the spatial differentiation of China's agriculture, leading to distinct regional cropping systems, land-use patterns, and dominant agricultural products.
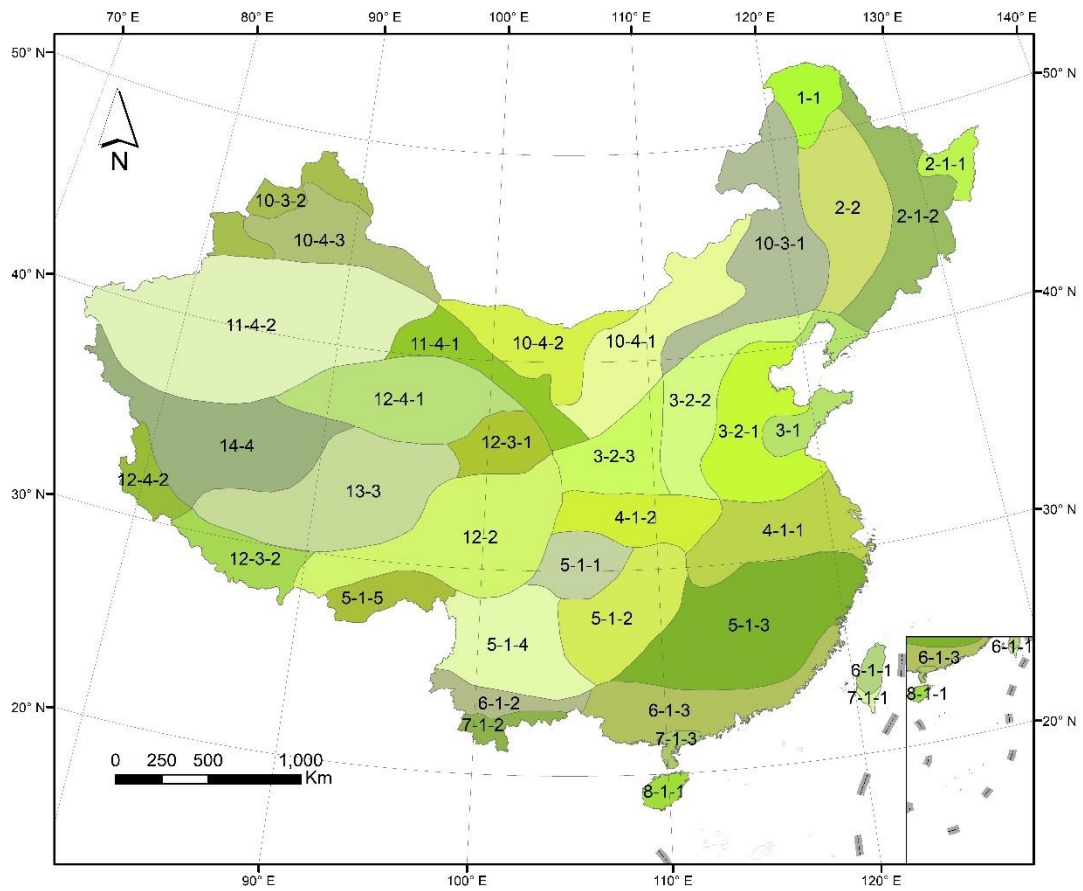
Fig S1 Agro-Natural Regionalization of China.

S1.2 Multi-Product coverage

We synthesize multiple publicly available crop mapping products in China (Table 1). These products include seven major crop types: maize, rice, wheat, soybean, rapeseed, sugarcane, and cotton. These products differ in spatial coverage (Table S4). Some focus on key production regions, for example, winter wheat mapping in the Huang–Huai–Hai Plain, which accounts for about 90% of China's total output, and cotton mapping in Xinjiang, which contributes more than 80% of national production. Others, such as maize and rapeseed, extend to almost all provinces nationwide. Importantly, the spatial extent of existing crop distribution products is not temporally continuous or consistent but varies across years. To address this limitation, we generate crop distribution products with continuous temporal coverage and consistent spatial extent by applying spatiotemporal transfer of classifiers to fill gaps in specific years

and regions.

Some special treatments were applied to specific crops. For rice, outside the three northeastern provinces there is essentially only one dataset available, namely the double- and single-cropping rice maps developed by Yuan's research lab (Pan et al., 2021; Shen et al., 2023). In these regions, areas where two maps overlap reflect inconsistencies instead of agreement and were therefore treated separately. In addition, the soybean area in eastern Inner Mongolia, adjacent to the three northeastern provinces, was excluded from the provincial coverage since it did not represent the whole province and was treated separately as a special case.

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Table S1. Agro-Natural Regionalization of China

ID	Name	Temperature Zone	Moisture Zone
1-1	Northern Greater Khingan Range Area	Cold Temperate	Humid Zone
2-1-1	Sanjiang Plain	Middle Temperate	Humid Zone
2-1-2	Lesser Khingan–Changbai Mountain Area	Middle Temperate	Humid Zone
2-2	Songliao Plain	Middle Temperate	Semi-Humid Zone
3-1	Liaodong–Shandong Peninsula	Warm Temperate	Humid Zone
3-2-1	North China Plain	Warm Temperate	Semi-Humid Zone
3-2-2	North China Mountain Area	Warm Temperate	Semi-Humid Zone
3-2-3	Loess Plateau	Warm Temperate	Semi-Humid Zone
4-1-1	Middle–Lower Yangtze River Area	Northern Subtropical	Humid Zone
4-1-2	Upper–Middle Han River Area	Northern Subtropical	Humid Zone
5-1-1	Sichuan Basin	Central Subtropical	Humid Zone
5-1-2	Guizhou Plateau	Central Subtropical	Humid Zone
5-1-3	Jiangnan Hilly Area	Central Subtropical	Humid Zone
5-1-4	Yunnan Plateau	Central Subtropical	Humid Zone
5-1-5	Southern Slope of the Himalayas Area	Central Subtropical	Humid Zone
6-1-1	Taipei Area	Southern Subtropical	Humid Zone
6-1-2	Southern Yunnan Mountain Area	Southern Subtropical	Humid Zone
6-1-3	Fujian–Guangdong Hilly Area	Southern Subtropical	Humid Zone
7-1-1	Tainan Area	Marginal Tropical	Humid Zone
7-1-2	Valleys and Basins of Southern Yunnan	Marginal Tropical	Humid Zone
7-1-3	Qiong–Le Area (Hainan & Leizhou)	Marginal Tropical	Humid Zone
8-1-1	Southern Hainan Island Area	Mid-Tropical	Humid Zone
8-1-2	Dongsha, Zhongsha, and Xisha Islands Area	Mid-Tropical	Humid Zone

ID	Name	Temperature Zone	Moisture Zone
9-1	Nansha Islands Area	Equatorial Tropical	Humid Zone
10-3-1	Eastern Inner Mongolia Area	Arid Middle Temperate	Semi-Arid Zone
10-3-2	Northwestern Mountain Area of Northern Xinjiang	Arid Middle Temperate	Semi-Arid Zone
10-4-1	Central Inner Mongolia Area	Arid Middle Temperate	Arid Zone
10-4-2	Western Inner Mongolia Area	Arid Middle Temperate	Arid Zone
10-4-3	Northern Xinjiang Area	Arid Middle Temperate	Arid Zone
11-4-1	Hexi Corridor Area	Arid Warm Temperate	Arid Zone
11-4-2	Southern Xinjiang Area	Arid Warm Temperate	Arid Zone
12-2	Western Sichuan–Eastern Tibet Area	Plateau Temperate	Semi-Humid Zone
12-3-1	Qinghai Area	Plateau Temperate	Semi-Arid Zone
12-3-2	Southern Tibet Area	Plateau Temperate	Semi-Arid Zone
12-4-1	Qaidam Basin	Plateau Temperate	Arid Zone
12-4-2	Western Tibet Area	Plateau Temperate	Arid Zone
13-3	Southern Qiangtang Area	Plateau Sub-Frigid Zone	Semi-Arid Zone
14-4	Northern Qiangtang Area	Plateau Frigid Zone	Arid Zone

Table S2 Regional Division of Temperature Zones and Associated Cropping Systems in China

Zone Type	Zone	Accum. Temp. ≥10℃ (°C)	Coldest Month Temp. (°C)	Annual Extreme Low Mean (°C)
Monsoon	1 Cold Temperate Zone	<1700	<-30	<-45
	2 Middle Temperate Zone	1700–3500	-30 ~ -10	-45 – -25
	3 Warm Temperate Zone	3500–4500	-10 – 0	-25 – -10
	4 Northern Subtropical Zone	4500–5300	0 – 5	-10 – -5
	5 Central Subtropical Zone	5300–6500	5 – 10	-5 – 0
	6 Southern Subtropical Zone	6500–8000	10 – 15	0 – 5
	7 Marginal Tropical Zone	8000–8500	15 – 18	5 – 8
	8 Central Tropical Zone	>8500	>18	>8
	9 Equatorial Tropical Zone	>9000	>25	>20
Arid	10 Arid Middle Temperate Zone	<4000	<-10	<-20
	11 Arid Warm Temperate Zone	>4000	>-10	>-20
		Accum. Temp. ≥0℃ (°C)	Warmest Month Temp. (°C)	
High-cold	12 Plateau Frigid Zone	≤500	<6	
	13 Plateau Sub-Frigid Zone	500–1500	6 – 10	
	14 Plateau Temperate Zone	1500–3500	10 – 18	

Table S3 Regional Division of Humid and Arid Zones in China

Region	Annual Precipitation (mm)	Humidity Condition	Distribution Area	Vegetation	Land Use
Humid Zone	>800	Precipitation > Evaporation	South of the Qinling Mountains–Huaihe River line, southern Qinghai–Tibet Plateau, northeastern Inner Mongolia, eastern Northeast China	Forest	Agriculture dominated by paddy fields
Semi-Humid Zone	>400	Precipitation > Evaporation	Northeast Plain, North China Plain, most of the Loess Plateau, southeastern Qinghai–Tibet Plateau	Forest–Grassland	Agriculture dominated by dry farming
Semi-Arid Zone	<400	Precipitation < Evaporation	Inner Mongolia Plateau, part of the Loess Plateau, most of the Qinghai–Tibet Plateau	Grassland	Grassland livestock grazing, irrigated farming
Arid Zone	<200	Precipitation < Evaporation	Xinjiang, western Inner Mongolia Plateau, northwestern Qinghai–Tibet Plateau	Desert	Alpine livestock grazing, oasis irrigation farming

Table S4 Province coverage of crop type maps collected by this study

	c1	m1	m2	m3	m4	m5	m6	m7	ra1	ra2	ra3	ri1	ri2	ri3	ri4	so1	so2	so3	so4	so5	su1	su2	w1	w2	w3	w4
Anhui	0	0	0	1	0	1	1	1	1	1	1	0	0	1	1	0	0	1	1	1	0	1	1	1	1	1
Macau	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Beijing	0	0	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
Fujian	0	0	0	0	0	1	0	1	1	0	1	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0
Gansu	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Guangdong	0	0	0	0	0	1	0	1	1	0	1	0	0	1	0	0	0	1	0	0	1	1	0	0	0	0
Guangxi	0	0	0	1	0	1	1	1	1	0	1	0	0	1	1	0	0	1	0	0	1	1	0	0	0	0
Guizhou	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0
Hainan	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	1	0	0	1	1	0	0	0	0
Hebei	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1
Henan	0	0	0	1	0	1	1	1	1	0	1	0	0	0	1	0	0	1	1	1	0	1	1	1	1	1
Heilongjiang	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0
Hubei	0	0	0	1	0	1	1	1	1	1	1	0	0	1	1	0	0	1	1	1	0	1	1	1	1	1
Hunan	0	0	0	1	0	1	1	1	1	1	1	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0
Jilin	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0
Jiangsu	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1	0	0	1	1	1	0	1	1	1	1	1
Jiangxi	0	0	0	0	0	1	0	1	1	1	1	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0
Liaoning	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	0
Inner Mongolia	0	0	0	1	1	1	1	1	1	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Ningxia	0	0	0	1	1	1	1	1	1	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Qinghai	0	0	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Shandong	0	0	0	1	0	1	1	1	1	0	1	0	0	0	1	0	0	1	1	1	0	1	1	1	1	1

	c1	m1	m2	m3	m4	m5	m6	m7	ra1	ra2	ra3	ri1	ri2	ri3	ri4	so1	so2	so3	so4	so5	su1	su2	w1	w2	w3	w4
Shanxi	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	1	0	0	1	1	1	1	1
Shaanxi	0	0	0	1	1	1	1	1	1	0	1	0	0	0	1	0	0	1	1	0	0	0	1	1	1	1
Shanghai	0	0	0	0	0	1	0	1	1	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Sichuan	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1	0	0	1	0	1	0	1	1	0	0	0
Taiwan	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Tianjin	0	0	0	1	0	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
Tibet	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hong Kong	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Xinjiang	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Yunnan	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1	0	0	1	1	0	1	1	0	0	0	0
Zhejiang	0	0	0	0	0	1	0	1	1	1	1	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0
Chongqing	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0

c:cotton; m:maize; ra:rapeseed; ri:rice; so:soybean; su:sugarcane; w:wheat.

Products with partial rather than full provincial coverage were excluded from this table, but were given special treatment during mapping process (as described above).

S2. Results validation and comparison
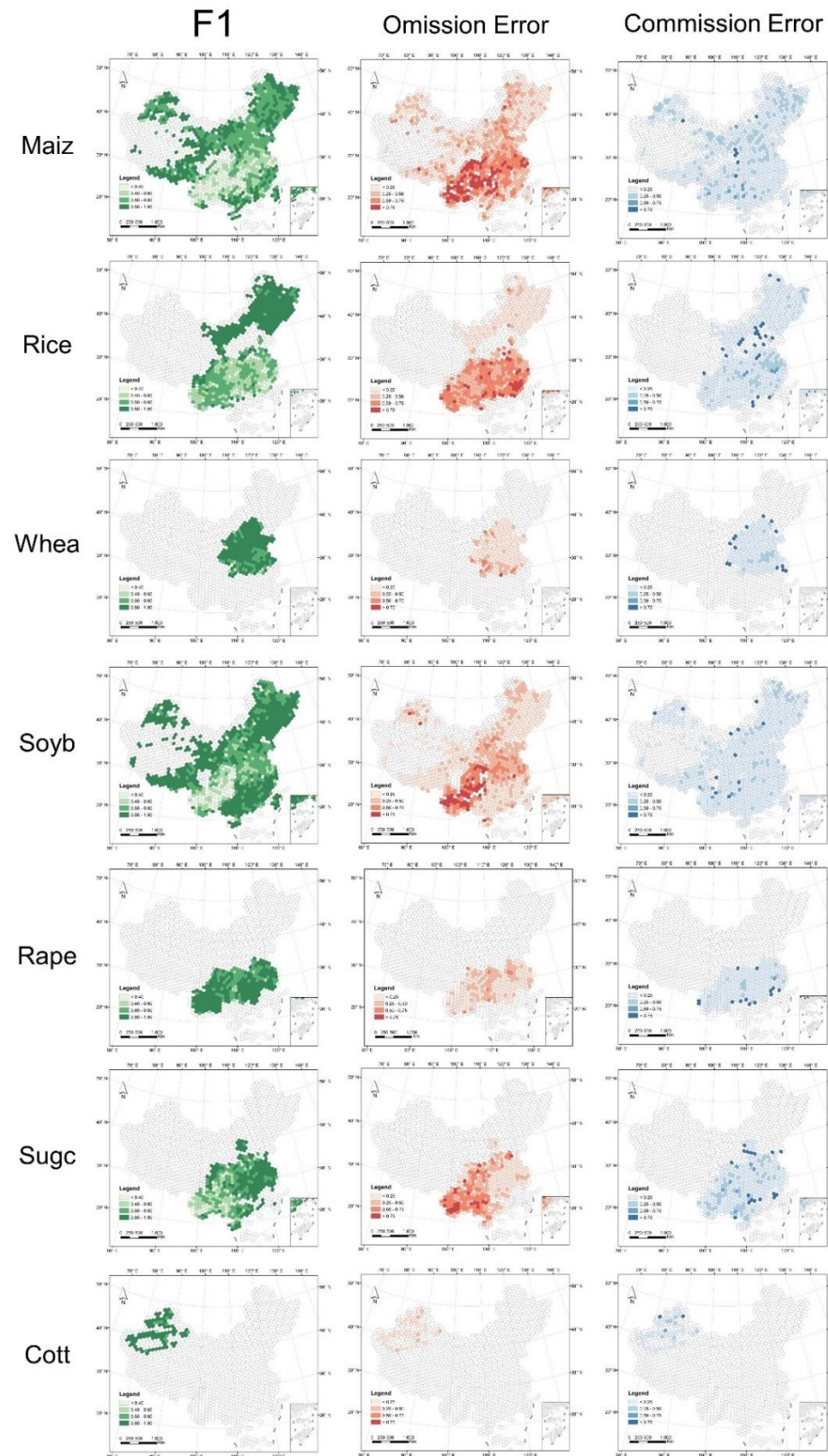
Figure S2 Spatial variation of mean accuracy of classifiers for year periods from 2018 to 2021 per crop type.

Reference:

Pan, B., Zheng, Y., Shen, R., Ye, T., Zhao, W., Dong, J., . . . Yuan, W. (2021). High Resolution Distribution Dataset of Double-Season Paddy Rice in China. *Remote Sensing, 13*(22).   doi:10.3390/rs13224609

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