Annex B. Quick reference to CropWatch indicators, spatial units and methodologies

The following sections give a brief overview of CropWatch indicators and spatial units, along with a description of the CropWatch production estimation methodology. For more information about CropWatch methodologies, visit CropWatch online at www.cropwatch.com.cn.

CropWatch indicators

The CropWatch indicators are designed to assess the condition of crops and the environment in which they grow and develop; the indicators—RAIN (for rainfall), TEMP (temperature), and RADPAR (photosynthetically active radiation, PAR)—are not identical to the weather variables, but instead are value-added indicators computed only over crop growing areas (thus for example excluding deserts and rangelands) and spatially weighted according to the agricultural production potential, with marginal areas receiving less weight than productive ones. The indicators are expressed using the usual physical units (e.g., mm for rainfall) and were thoroughly tested for their coherence over space and time. CWSU are the CropWatch Spatial Units, including MRUs, MPZ, and countries (including first-level administrative districts in select large countries). For all indicators, high values indicate "good" or "positive."

INDICATOR			
BIOMSS			
Biomass accumulation potential			
Crop/ Ground and satellite	Grams dry matter/m^2, pixel or CWSU	An estimate of biomass that could potentially be accumulated over the reference period given the prevailing rainfall and temperature conditions.	Biomass is presented as maps by pixels, maps showing average pixels values over CropWatch spatial units (CWSU), or tables giving average values for the CWSU. Values are compared to the average value for the last five years (2012-2016), with departures expressed in percentage.
CALF			
Cropped arable land and cropped arable land fraction			
Crop/ Satellite	[0,1] number, pixel or CWSU average	The area of cropped arable land as fraction of total (cropped and uncropped) arable land. Whether a pixel is cropped or not is decided based on NDVI twice a month. (For each four-month reporting period, each pixel thus has 8 cropped/ uncropped values).	The value shown in tables is the maximum value of the 8 values available for each pixel; maps show an area as cropped if at least one of the 8 observations is categorized as "cropped." Uncropped means that no crops were detected over the whole reporting period. Values are compared to the average value for the last five years (2012-2016), with departures expressed in percentage.
CROPPING INTENSITY			
Cropping intensity Index			
Crop/ Satellite	0, 1, 2, or 3; Number of crops growing over a year for each pixel	Cropping intensity index describes the extent to which arable land is used over a year. It is the ratio of the total crop area of all planting seasons in a year to the total area of arable land.	Cropping intensity is presented as maps by pixels or spatial average pixels values for MPZs, 31 countries, and 7 regions for China. Values are compared to the average of the previous five years, with departures expressed in percentage.
NDVI			
Normalized Difference Vegetation Index			
Crop/ Satellite	[0.12-0.90] number, pixel or CWSU average	An estimate of the density of living green biomass.	NDVI is shown as average profiles over time at the national level (cropland only) in crop condition development graphs, compared with

INDICATOR			
			previous year and recent five-year average (2012-2016), and as spatial patterns compared to the average showing the time profiles, where they occur, and the percentage of pixels concerned by each profile.
RADPAR			
CropWatch indicator for Photosynthetically Active Radiation (PAR), based on pixel based PAR			
Weather /Satellite	W/m², CWSU	The spatial average (for a CWSU) of PAR accumulation over agricultural pixels, weighted by the production potential.	RADPAR is shown as the percent departure of the RADPAR value for the reporting period compared to the recent fifteen-year average (2002-2016), per CWSU. For the MPZs, regular PAR is shown as typical time profiles over the spatial unit, with a map showing where the profiles occur and the percentage of pixels concerned by each profile.
RAIN			
CropWatch indicator for rainfall, based on pixel-based rainfall			
Weather /Ground and satellite	Liters/m², CWSU	The spatial average (for a CWSU) of rainfall accumulation over agricultural pixels, weighted by the production potential.	RAIN is shown as the percent departure of the RAIN value for the reporting period, compared to the recent fifteen-year average (2002-16), per CWSU. For the MPZs, regular rainfall is shown as typical time profiles over the spatial unit, with a map showing where the profiles occur and the percentage of pixels concerned by each profile.
TEMP			
CropWatch indicator for air temperature, based on pixel-based temperature			
Weather /Ground	℃, CWSU	The spatial average (for a CWSU) of the temperature time average over agricultural pixels, weighted by the production potential.	TEMP is shown as the departure of the average TEMP value (in degrees Centigrade) over the reporting period compared with the average of the recent fifteen years (2002-16), per CWSU. For the MPZs, regular temperature is illustrated as typical time profiles over the spatial unit, with a map showing where the profiles occur and the percentage of pixels concerned by each profile.
VCIx			
Maximum vegetation condition index			
Crop/ Satellite	Number, pixel to CWSU	Vegetation condition of the current season compared with historical data. Values usually are [0, 1], where 0 is "NDVI as bad as the worst recent year" and 1 is "NDVI as good as the best recent year." Values can exceed the range if the current year is the best or the worst.	VCIx is based on NDVI and two VCI values are computed every month. VCIx is the highest VCI value recorded for every pixel over the reporting period. A low value of VCIx means that no VCI value was high over the reporting period. A high value means that at least one VCI value was high. VCI is shown as pixel-based maps and as average value by CWSU.
VHI			
Vegetation health index			
Crop/ Satellite	Number, pixel to CWSU	The average of VCI and the temperature condition index (TCI), with TCI defined like VCI but for temperature. VHI is based on the assumption that "high temperature is bad" (due to moisture stress), but ignores the fact that low temperature may be equally "bad" (crops develop	Low VHI values indicate unusually poor crop condition, but high values, when due to low temperature, may be difficult to interpret. VHI is shown as typical time profiles over Major Production Zones (MPZ), where they occur, and the percentage of pixels concerned by each profile.

INDICATOR			
		and grow slowly, or even suffer from frost).	
VHIn			
Minimum Vegetation health index			
Crop/ Satellite	Number, pixel to CWSU	VHIn is the lowest VHI value for every pixel over the reporting period. Values usually are [0, 100]. Normally, values lower than 35 indicate poor crop condition.	Low VHIn values indicate the occurrence of water stress in the monitoring period, often combined with lower than average rainfall. The spatial/time resolution of CropWatch VHIn is 16km/week for MPZs and 1km/dekad for China.

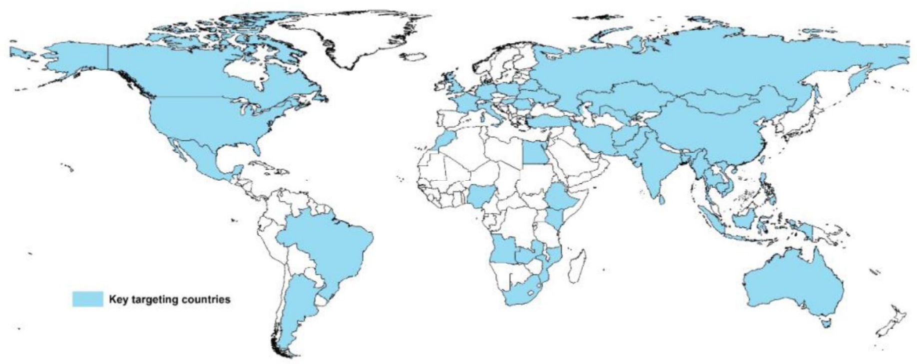
Note: Type is either "Weather" or "Crop"; source specifies if the indicator is obtained from ground data, satellite readings, or a combination; units: in the case of ratios, no unit is used; scale is either pixels or large scale CropWatch spatial units (CWSU). Many indicators are computed for pixels but represented in the CropWatch bulletin at the CWSU scale.

CropWatch spatial units (CWSU)

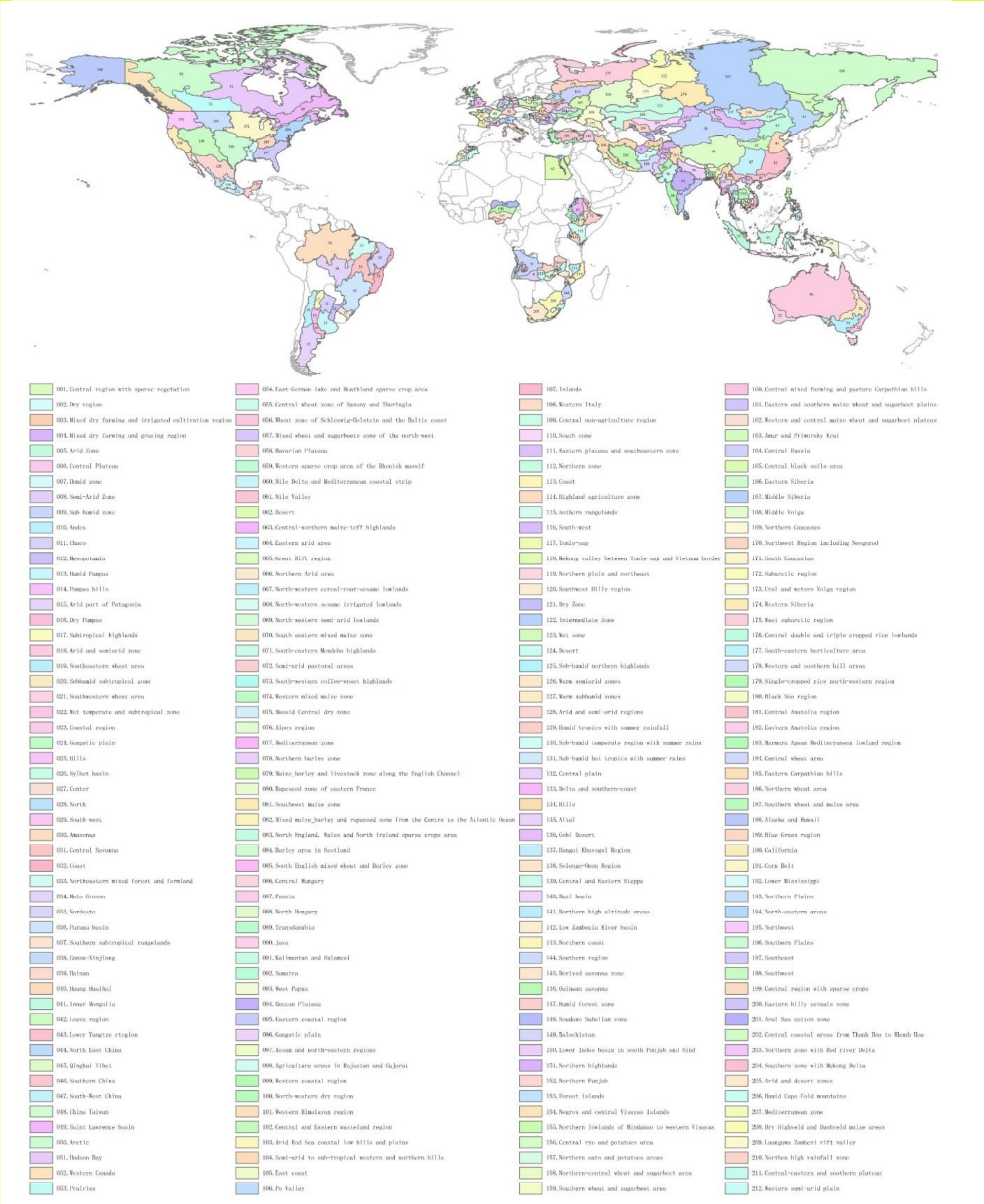
CropWatch analyses are applied to four kinds of CropWatch spatial units (CWSU): Countries, China, Major Production Zones (MPZ), and global crop Monitoring and Reporting Units (MRU). The tables below summarize the key aspects of each spatial unit and show their relation to each other. For more details about these spatial units and their boundaries, see the CropWatch bulletin online resources.

SPATIAL LUNITS	
CHINA	
Overview	*Description*
Seven monitoring regions	The seven regions in China are agro-economic/agro-ecological regions that together cover the bulk of national maize, rice, wheat, and soybean production. Provinces that are entirely or partially included in one of the monitoring regions are indicated in color on the map below.

Countries (and first-level administrative districts, e.g., states and provinces)	
Overview	*Description*
“Forty one plus one” countries to represent main producers/exporters and other key countries.	CropWatch monitored countries together represent more than 80% of the production of maize, rice, wheat and soybean, as well as 80% of exports. Some countries were included in the list based on criteria of proximity to China (Uzbekistan, Cambodia), regional importance, or global geopolitical relevance (e.g., four of five most populous countries in Africa). The total number of countries monitored is “forty one plus one,” referring to forty one countries and China itself. For the nine largest countries—, United States, Brazil, Argentina, Russia, Kazakhstan, India, China, and Australia, maps and analyses may also present results for the first-level administrative subdivision. The CropWatch agroclimatic indicators are computed for all countries and included in the analyses when abnormal conditions occur. Background information about the countries’ agriculture and trade is available on the CropWatch Website, **www.cropwatch.com.cn**.

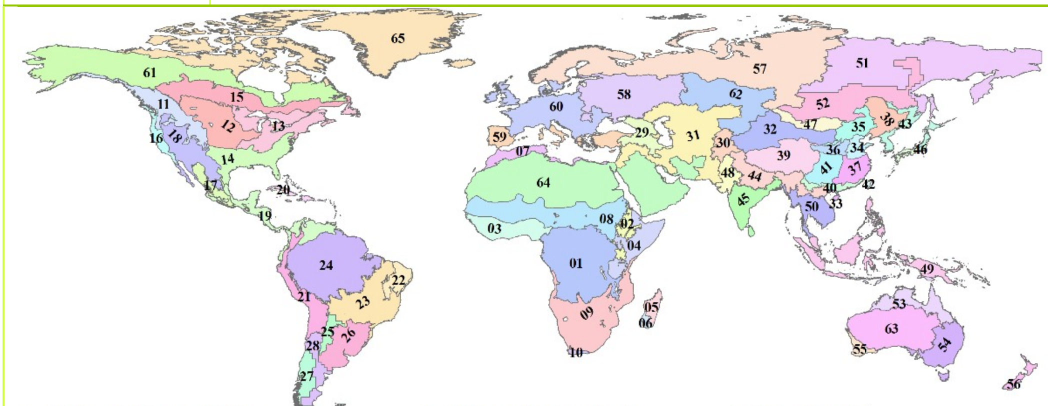


Agro-ecological Zones for 42 key countries	42 key agricultural countries are divided into 212 sub-national regions based on cropping systems, climatic zones, and topographic conditions. Each countries are considered separately. A limited number of regions are not relevant for the crops currently monitored by CropWatch but are included to allow for more complete coverage of the 42 key countries. Some regions are more relevant for rangeland and livestock monitoring which is also essential for food security.


001. Central region with sparse vegetation
002. Dry region
003. Mixed dry farming and irrigated cultivation region
004. Mixed dry farming and grazing region
005. Arid Zone
006. Central Plateau
007. Humid zone
008. Semi-Arid Zone
009. Sub humid zone
010. Andes
011. Chaco
012. Mesopotamia
013. Humid Pampas
014. Pampas hills
015. Arid part of Patagonia
016. Dry Pampas
017. Subtropical highlands
018. Arid and semiarid zone
019. Southeastern wheat area
020. Subhumid subtropical zone
021. Southwestern wheat area
022. Wet temperate and subtropical zone
023. Coastal region
024. Gangetic plain
025. Hills
026. Sylhet basin
027. Center
028. North
029. South west
030. Amazonas
031. Central Savanna
032. Coast
033. Northeastern mixed forest and farmland
034. Mato Grosso
035. Nordeste
036. Parana basin
037. Southern subtropical rangelands
038. Gansu-Xinjiang
039. Hainan
040. Huang Huaihai
041. Inner Mongolia
042. Loess region
043. Lower Yangtze rtegion
044. North East China
045. Qinghai Tibet
046. Southern China
047. South-West China
048. China Taiwan
049. Saint Lawrence basin
050. Arctic
051. Hudson Bay
052. Western Canada
053. Prairies
054. East-German lake and Heathland sparse crop area
055. Central wheat zone of Saxony and Thuringia
056. Wheat zone of Schleswig-Holstein and the Baltic coast
057. Mixed wheat and sugarbeets zone of the north-west
058. Bavarian Plateau
059. Western sparse crop area of the Rhenish massif
060. Nile Delta and Mediterranean coastal strip
061. Nile Valley
062. Desert
063. Central-northern maize-teff highlands
064. Eastern arid area
065. Great Rift region
066. Northern Arid area
067. North-western cereal-root-sesame lowlands
068. North-western sesame irrigated lowlands
069. North-western semi-arid lowlands
070. South eastern mixed maize zone
071. South-eastern Mendebo highlands
072. Semi-arid pastoral areas
073. South-western coffee-enset highlands
074. Western mixed maize zone
075. Massif Central dry zone
076. Alpes region
077. Mediterranean zone
078. Northern barley zone
079. Maize, barley and livestock zone along the English Channel
080. Rapeseed zone of eastern France
081. Southwest maize zone
082. Mixed maize, barley and rapeseed zone from the Centre to the Atlantic Ocean
083. North England, Wales and North Ireland sparse crops area
084. Barley area in Scotland
085. South English mixed wheat and Barley zone
086. Central Hungary
087. Puszta
088. North Hungary
089. Transdanubia
090. Java
091. Kalimantan and Sulawesi
092. Sumatra
093. West Papua
094. Deccan Plateau
095. Eastern coastal region
096. Gangetic plain
097. Assam and north-eastern regions
098. Agriculture areas in Rajasthan and Gujarat
099. Western coastal region
100. North-western dry region
101. Western Himalayan region
102. Central and Eastern wasteland region
103. Arid Red Sea coastal low hills and plains
104. Semi-arid to sub-tropical western and northern hills
105. East coast
106. Po Valley
107. Islands
108. Western Italy
109. Central non-agriculture region
110. South zone
111. Eastern plateau and southeastern zone
112. Northern zone
113. Coast
114. Highland agriculture zone
115. nothern rangelands
116. South-west
117. Tonle-sap
118. Mekong valley between Tonle-sap and Vietnam border
119. Northern plain and northeast
120. Southwest Hilly region
121. Dry Zone
122. Intermediate Zone
123. Wet zone
124. Desert
125. Sub-humid northern highlands
126. Warm semiarid zones
127. Warm subhumid zones
128. Arid and semi-arid regions
129. Humid tropics with summer rainfall
130. Sub-humid temperate region with summer rains
131. Sub-humid hot tropics with summer rains
132. Central plain
133. Delta and southern-coast
134. Hills
135. Altai
136. Gobi Desert
137. Hangai Khuvsgul Region
138. Selenge-Onon Region
139. Central and Eastern Steppe
140. Buzi basin
141. Northern high altitude areas
142. Low Zambezia River basin
143. Northern coast
144. Southern region
145. Derived savanna zone
146. Guinean savanna
147. Humid forest zone
148. Soudano Sahelian zone
149. Balochistan
150. Lower Indus basin in south Punjab and Sind
151. Northern highlands
152. Northern Punjab
153. Forest islands
154. Negros and central Visayas Islands
155. Northern lowlands of Mindanao to western Visayas
156. Central rye and potatoes area
157. Northern oats and potatoes areas
158. Northern-central wheat and sugarbeet area
159. Southern wheat and sugarbeet area
160. Central mixed farming and pasture Carpathian hills
161. Eastern and southern maize wheat and sugarbeet plains
162. Western and central maize wheat and sugarbeet plateau
163. Amur and Primorsky Krai
164. Central Russia
165. Central black soils area
166. Eastern Siberia
167. Middle Siberia
168. Middle Volga
169. Northern Caucasus
170. Northwest Region including Novgorod
171. South Caucasian
172. Subarctic region
173. Ural and wetsrn Volga region
174. Western Siberia
175. West subarctic region
176. Central double and triple cropped rice lowlands
177. South-eastern horticulture area
178. Western and southern hill areas
179. Single-cropped rice north-eastern region
180. Black Sea region
181. Central Anatolia region
182. Eastern Anatolia region
183. Marmara Agean Mediterranean lowland region
184. Central wheat area
185. Eastern Carpathian hills
186. Northern wheat area
187. Southern wheat and maize area
188. Alaska and Hawaii
189. Blue Grass region
190. California
191. Corn Belt
192. Lower Mississippi
193. Northern Plains
194. North-eastern areas
195. Northwest
196. Southern Plains
197. Southeast
198. Southwest
199. Central region with sparse crops
200. Eastern hilly cereals zone
201. Aral Sea cotton zone
202. Central coastal areas from Thanh Hoa to Khanh Hoa
203. Northern zone with Red river Delta
204. Southern zone with Mekong Delta
205. Arid and desert zones
206. Humid Cape Fold mountains
207. Mediterranean zone
208. Dry Highveld and Bushveld maize areas
209. Luangwa Zambezi rift valley
210. Northen high rainfall zone
211. Central-eastern and southern plateau
212. Western semi-arid plain

Major Production Zones (MPZ)	
Overview	*Description*
Seven globally important areas of agricultural production	The six MPZs include West Africa, South America, North America, South and Southeast Asia, Western Europe and Central Europe to Western Russia. The MPZs are not necessarily the main production zones for the four crops (maize, rice, soybean, wheat) currently monitored by CropWatch, but they are globally or regionally important areas of agricultural production. The seven zones were identified based mainly on production statistics and distribution of the combined cultivation area of maize, rice, wheat and soybean.

Global Monitoring and Reporting Unit (MRU)	
Overview	*Description*
65 agro-ecological/agro-economic units across the world	MRUs are reasonably homogeneous agro-ecological/agro-economic units spanning the globe, selected to capture major variations in worldwide farming and crops patterns while at the same time providing a manageable (limited) number of spatial units to be used as the basis for the analysis of environmental factors affecting crops. Unit numbers and names are shown in the figure below. A limited number of units (e.g., MRU-63 to 65) are not relevant for the crops currently monitored by CropWatch but are included to allow for more complete coverage of global production. Additional information about the MRUs is provided online under **www.cropwatch.com.cn** .



01:Equatorial central Africa
02:East African highlands
03:Gulf of Guinea
04:Horn of Africa
05:Madagascar (main)
06:Southwest Madagascar
07:North Africa Mediterranean
08:Sahel
09:Southern Africa
10:Western Cape (South Africa)
11:British Columbia to Colorado
12:Northern Great Plains
13:Corn Belt
14:Cotton Belt to Mexican Noreste
15:Sub-boreal America
16:West Coast (North America)
17:Sierra Madre
18:Southwest U.S. and north Mexican highlands
19:Northern South and Central America
20:Caribbean
21:Central-northern Andes
22:Nordeste (Brazil)
23:Central eastern Brazil
24:Amazon
25:Central-north Argentina
26:Pampas
27:Western Patagonia
28:Semi-arid Southern Cone
29:Caucasus
30:Pamir area
31:Western Asia
32:Gansu-Xinjiang (China)
33:Hainan (China)
34:Huanghuaihai (China)
35:Inner Mongolia (China)
36:Loess region (China)
37:Lower Yangtze (China)
38:Northeast China
39:Qinghai-Tibet (China)
40:Southern China
41:Southwest China
42:Taiwan (China)
43:East Asia
44:Southern Himalayas
45:Southern Asia
46:Southern Japan and Korea
47:Southern Mongolia
48:Punjab to Gujarat
49:Maritime Southeast Asia
50:Mainland Southeast Asia
51:Eastern Siberia
52:Eastern Central Asia
53:Northern Australia
54:Queensland to Victoria
55:Nullarbor to Darling
56:New Zealand
57:Boreal Eurasia
58:Ukraine to Ural mountains
59:Mediterranean Europe and Turkey
60:W. Europe (non Mediterranean)
61:Boreal America
62:Ural to Altai mountains
63:Australian desert
64:Sahara to Afghan deserts
65:Sub-arctic America

Production estimation methodology

The main concept of the CropWatch methodology for estimating production is the calculation of current year production based on information about last year's production and the variations in crop yield and cultivated area compared with the previous year. The equation for production estimation is as follows:

$$Production_i = Production_{i-1} * (1 + \Delta Yield_i) * (1 + \Delta Area_i)$$

Where i is the current year, $\Delta Yield_i$ and $\Delta Area_i$ are the variations in crop yield and cultivated area compared with the previous year; the values of $\Delta Yield_i$ and $\Delta Area_i$ can be above or below zero.

For the 31 countries monitored by CropWatch, yield variation for each crop is calibrated against NDVI time series, using the following equation:

$$\Delta Yield_i = f(NDVI_i, NDVI_{i-1})$$

Where $NDVI_i$ and $NDVI_{i-1}$ are taken from the time series of the spatial average of NDVI over the crop specific mask for the current year and the previous year. For NDVI values that correspond to periods after the current monitoring period, average NDVI values of the previous five years are used as an average expectation. $\Delta Yield_i$ is calculated by regression against average or peak NDVI (whichever yields the best regression), considering the crop phenology of each crop for each individual country.

A different method is used for areas. For China, CropWatch combines remote-sensing based estimates of the crop planting proportion (cropped area to arable land) with a crop type proportion (specific type area to total cropped area). The planting proportion is estimated based on an unsupervised classification of high resolution satellite images from HJ-1 CCD and GF-1 images. The crop-type proportion for China is obtained by the GVG instrument from field transects. The area of a specific crop is computed by multiplying farmland area, planting proportion, and crop-type proportion of the crop.

To estimate crop area for wheat, soybean, maize, and rice outside China, CropWatch relies on the regression of crop area against cropped arable land fraction of each individual country (paying due attention to phenology):

$$Area_i = a + b * CALF_i$$

Where a and b are the coefficients generated by linear regression with area from FAOSTAT or national sources and CALF the Cropped Arable Land Fraction from CropWatch estimates. $\Delta Area_i$ can then be calculated from the area of current and the previous years.

The production for "other countries" (outside the 31 CropWatch monitored countries) was estimated as the linear trend projection for 2014 of aggregated FAOSTAT data (using aggregated world production minus the sum of production by the 31 CropWatch monitored countries).

Methods for crop pest and disease monitoring

For the crop pest and disease monitoring part, we bring together and produce cutting edge research to provide pest and disease monitoring and forecasting information, integrating multi-source (Earth Observation-EO, field survey, meteorological, entomological and plant pathological, etc.) data to monitor pests and diseases damaged areas and levels. For different type of pest or disease, different models are developed, which are as follows.

Wheat stripe rust

For wheat stripe rust (Puccinia striiformis), it forms yellow stripe or oval-shaped spots on the leaves of wheat, which results in leaf yellowing, chlorophyll content and water content reduction. In this report, the standard for wheat stripe rust is based on China's "Rules for investigation and forecasting of wheat stripe rust"(GB/T15795 −2011), and the detail standards is listed in Table B.1. Based on the standards, the ground survey data and remote sensing observation data were obtained through the integrated experiment of crop diseases on satellite ground synchronization. Additionally, the levels 1 and 2 in Table 1 refer to the slight occurrence of wheat rust, the level 3 refers to moderate, and levels 4 and 5 refer to severe.

Firstly, the spatial distribution of wheat stripe rust is taken as prior knowledge based on literature research and ground survey. Then Wheat Rust Index (WRI) is constructed based on Plant Senescence Reflectance Index (PSRI) (Equation 1) and Red-edge Vegetation Stress Index (RVSI) (Equation 2) to monitor wheat stripe rust, for which WRI (Equation 3) considering crop growth, chlorophyll content and their variation characteristics. At last, we integrated with disease habitat information including land surface temperature (LST, MODIS product), rainfall and wind (meteorological data), also historical data to construct Disease Index (DI) (Equation 4) for wheat stripe rust monitoring.

$$\mathrm{PSRI} = (PR - RB)/RNIR \tag{1}$$

$$\mathrm{RVSI} = ((R712 + R752)/2) - R732 \tag{2}$$

$$\mathrm{WRI} = \mathrm{f}(\Delta PSRI, \Delta \mathrm{RVSI}) \tag{3}$$

$$\mathrm{DI} = \mathrm{f}(\mathrm{WRI}, LST - LST_{avg}, \mathrm{R} - \mathrm{R}_{avg}, \mathrm{W}) \tag{4}$$

Where, RR, RB and RNIR are the reflectance of red, blue, and near infrared (NIR) band, R712, R752 and R732 are the reflectance of 712nm, 752nm and 732nm band. LST is land surface temperature while LSTavg is the average historical land surface temperature. R is rainfall while Ravg is the average historical rainfall. W is wind direction. f and g are constructed with regression analysis based on filed survey datasets. The data range of DI is 0~100%. When 0 < DI ≤ 30%, the damaged level of stripe rust is slight, 30% < DI ≤ 60% is moderate, DI > 60% is severe.

Table B.1. Wheat stripe rust field investigation indices

Index	Level				
	1	2	3	4	5
Disease index	0.001<Y≤5	5＜Y≤ 10	10＜Y≤20	20＜Y≤30	Y＞30
The rate of disease field / %	1<R≤5	5＜R≤10	10＜R≤20	20＜R≤30	R＞35

*Note: Y is the disease index, which is used to reflect the severity of disease occurrence. The calculation formula is Y=F*D*100, F is the disease leaf rate, and D is the average severity of the disease leaf. R is the disease field rate, referring to the percentage of the number of damaged fields in the total field.Reference: http://doc.mbalib.com/view/2e0ae53c7f397af70deb37edb07c5a12.html*

Wheat Fusarium head blight

For wheat Fusarium head blight (Fusarium graminearum), it destroyed the cellular integrity of the impacted tissues leading to cell death and degradation of chlorophylls. In this report, the standard for wheat Fusarium head blight is based on China's 'Rules for monitoring and forecasting of wheat head blight' (GB/T 15796 −2011), and the detail standards is listed in Table B.2. Based on the standards, the ground survey data and remote sensing observation data were obtained through the integrated experiment of crop diseases on satellite ground synchronization. Additionally, the levels 1 and 2 in Table 2 refer to the slight occurrence of wheat rust, the level 3 refers to moderate, and levels 4 and 5 refer to severe.

Firstly, the spatial distribution of wheat Fusarium head blight which provided by CAB international (CABI) is taken as prior knowledge based on literature research and ground survey. Then Wheat Fusarium Head Blight Index (WFHBI) is constructed based on Normalized Difference Vegetation Index (NDVI) (Equation 5) and Difference Vegetation Index (DVI) (Equation 6) to monitor wheat Fusarium head blight, for which WFHBI (Equation 7) considering spectral reflectance of ear and canopy, and their variation characteristics.

At last, integrated with disease habitat information including growth stage, LST and rainfall, also historical data to construct DI (Equation 8) for wheat fusarium head blight monitoring.

$$\mathrm{NDVI} = (RNIR - RR)/(RNIR + RR) \quad (5)$$

$$\mathrm{DVI} = RNIR - RR \quad (6)$$

$$\mathrm{WFHBI} = \mathrm{f}(\Delta NDVI, \Delta DVI) \quad (7)$$

$$\mathrm{DI} = \mathrm{g}(WFHBI, G, LST - LST_{avg}, \mathrm{R} - \mathrm{R}_{avg}) \quad (8)$$

Where, G is the wheat growth stage, f and g are constructed with regression analysis based on filed survey datasets. The data range of DI is 0~100%. When 0 < DI ≤ 30%, the damaged level of Fusarium head blight is slight, 30% < DI ≤ 60% is moderate, DI > 60% is severe.

Table B.2. Criteria for wheat sheath blight occurrence level

Index	Level				
	1	2	3	4	5
The ratio of diseased panicle / %	0. 1<Y≤10	10<Y≤20	20<Y≤30	30<Y≤40	Y>40
The incidence area ratio / %	R>30	R>30	R>30	R>30	R>30

Note: Y is the rate of diseased panicle, which refers to the ratio of the number of wheat ears to the total number of ears investigated, and R is the incidence area ratio. Reference: https://www.taodocs.com/p-86284688.html

Wheat sheath blight

For wheat sheath blight (Rhizotonia cerealis), its main damage to wheat is appearing brown spot around leaf sheath and water loss of stem wall, which results in nutrient and water deficiency and death. In this report, the standard for wheat sheath blight is based on China's 'Rules for investigation and forecasting of wheat sheath blight' (NY/T 614 −2002), and the detail standards is listed in Table B.3. Based on the standards, the ground survey data and remote sensing observation data were obtained through the integrated experiment of crop diseases on satellite ground synchronization. Additionally, the levels 1 and 2 in Table 3 refer to the slight occurrence of wheat sheath blight, the level 3 refers to moderate, and levels 4 and 5 refer to severe.

Firstly, the spatial distribution of wheat sheath blight is taken as prior knowledge based on literature research and ground survey. Then Wheat Sheath Blight Index (WSBI) is constructed based on Triangular Vegetation Index (TVI) (Equation 9) and Normalized Difference Water Index (NDWI) (Equation 10) to monitor wheat sheath blight, for which WSBI (Equation 11) considering crop growth and its variation characteristics. At last, integrated with disease habitat information including LST and rainfall, also historical data to construct DI (Equation 12) for wheat sheath blight monitoring.

$$\mathrm{TVI} = 0.5 * (120 * (RNIR - RG) - 200 * (RR - RG)) \quad (9)$$

$$\mathrm{NDWI} = (RG - RNIR)/(RG + RNIR) \quad (10)$$

$$\mathrm{WSBI} = \mathrm{f}(\Delta TVI, \Delta \mathrm{N}DWI) \quad (11)$$

$$\mathrm{DI} = \mathrm{g}(WSBI, LST - LST_{avg}, \mathrm{R} - \mathrm{R}_{avg}) \quad (12)$$

Where, RG is the reflectance of green band. f and g are constructed with regression analysis based on filed survey datasets. The data range of DI is 0~100%. When 0 < DI ≤ 30%, the damage level of sheath blight is slight, 30% < DI ≤ 60% is moderate, DI > 60% is severe.

Table B.3. Wheat sheath blight field investigation indices

Index	Level				
	1	2	3	4	5
Disease index	Y≤5	5＜Y≤15	15＜Y≤25	25＜Y≤35	Y＞35

Source: https://max.book118.com/html/2017/0718/122811227.shtm

Wheat aphid

For wheat aphid (Sitobion avenae and Rhopalosiphum padi), its main damage to wheat is feeding on the sap of young or senescent leaves, stalks and heads, which endangers the normal growth of wheat, and the honeydew emitted by aphids adheres to the leaf surface, seriously affects the photosynthesis of wheat leaves, cause the wheat seedlings becoming yellow and die. In this report, the standard for wheat aphid is based on China's 'Rules for investigation and forecasting of wheat aphid' (NY/T612-2002), and the detail standards are listed in Table B.4. Based on the standards, the ground survey data and remote sensing observation data were obtained through the integrated experiment of crop pests on satellite ground synchronization. Additionally, the levels 1 and 2 in Table 4 refer to the slight occurrence of wheat aphid, the level 3 refers to moderate, and levels 4 and 5 refer to severe.

Firstly, the spatial distribution of wheat aphid is taken as prior knowledge based on literature research and ground survey. Then Wheat Aphid Damage Index (WADI) is constructed based on NDVI and Photochemical Reflectance Index (PRI) (Equation 13) to monitor wheat aphid, for which WADI (Equation 14) considering crop growth and its variation characteristics. At last, integrated with pest habitat information including LST and rainfall, also historical data to construct Pest Index (PI) (Equation 15) for wheat aphid monitoring.

$$\mathrm{PRI} = (R531 - R570)/(R531 + R570) \tag{13}$$

$$\mathrm{WADI} = \mathrm{f}(\Delta NDVI, \Delta \mathrm{PR}I) \tag{14}$$

$$\mathrm{PI} = \mathrm{g}(WADI, LST - LST_{avg}, \mathrm{R} - \mathrm{R}_{avg}) \tag{15}$$

Where, R531 and R570 are the reflectance of 531nm and 570nm bands. f and g are constructed with regression analysis based on filed survey datasets. The data range of PI is 0~100%. When 0 < PI≤ 30%, the damaged level of aphid is slight, 30% < PI≤ 60% is moderate, PI > 60% is severe.

Table B.4. Wheat aphid field investigation indices

Index	Level				
	1	2	3	4	5
Aphid number of hundred plants（head, Y）	Y≤500	500＜Y≤1500	1500＜Y≤2500	2500＜Y≤3500	Y＞3500

Source: https://max.book118.com/html/2017/0718/122811227.shtm