

THE GLOBAL AGRO-ECOLOGICAL ZONING version 4

Crop profile: Wheat

GENERAL DESCRIPTION

Wheat is an annual grass growing to between 50 to 125 cm in height, with a long stalk that terminates in a tightly formed cluster of plump kernels enclosed by a beard of bristly spikes. The crop is grown as a rain-fed crop in the temperate climates, in the sub-tropics with winter rainfall, in the tropics near the equator in the highlands with altitudes of more than 1500 m, and in the tropics away from the equator where the rainy season is long and where the crop is grown as a winter crop.

Wheat belongs to the C3 crop group (C3 I) which is characterized with optimum photosynthesis and growth at temperatures between 15°C and 20°C. Temperatures above 20°C lead to lower photosynthesis, and temperatures above 30°C cause growth cycle curtailment and severe heat stress, both leading to lower yields. The length of the total growing period of spring wheat ranges from 100 to 130 days while winter wheat needs about 180 to 250 days to mature.

Day length and temperature requirements are key factors in variety selection. Varieties can be grouped as winter or spring types according to chilling requirements, winter hardiness and day length sensitivity. Winter wheat requires a cold period or chilling (vernalization) during early growth for normal heading under long days. Winter wheat in its early stages of development exhibits a strong resistance to frost, down to - 20°C. In areas of severe winters, cold winds and little snow, spring wheat varieties are grown. Spring wheat does not require chilling for heading and it is day-neutral. However, it is also sensitive to frost. For winter and spring wheat minimum daily temperature for measurable growth is about 5°C.

After rice and maize, wheat is the third most-produced cereal worldwide, and the second-most-produced for human consumption, covering about 219 M ha (Figure 1), and accounting for 761 M tons (FAOSTAT, 2022). The majority of global wheat production comes from just a handful of countries, with China as the world's largest wheat producer, with 18% of total production from 2000-2020. The second-largest wheat-producing country is India. Over the last two decades, India has produced 12.5% of the world's wheat. Like China, India keeps most of its wheat domestic because of significant food demand across the country.



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Taxonomy

Taxon name: *Triticum aestivum* L.

Family: Poaceae Barnhart

Genus: *Triticum* L.

FAOSTAT Statistics for 2020

Total global production

761 M tons

Total global harvested area

219 M ha

Additional resources link

ECOCROP data sheet ([link](#))

FAO Land and Water information ([link](#))

Crop calendar ([link](#))

GAEZ ([link](#))

Disclaimer

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Contacts

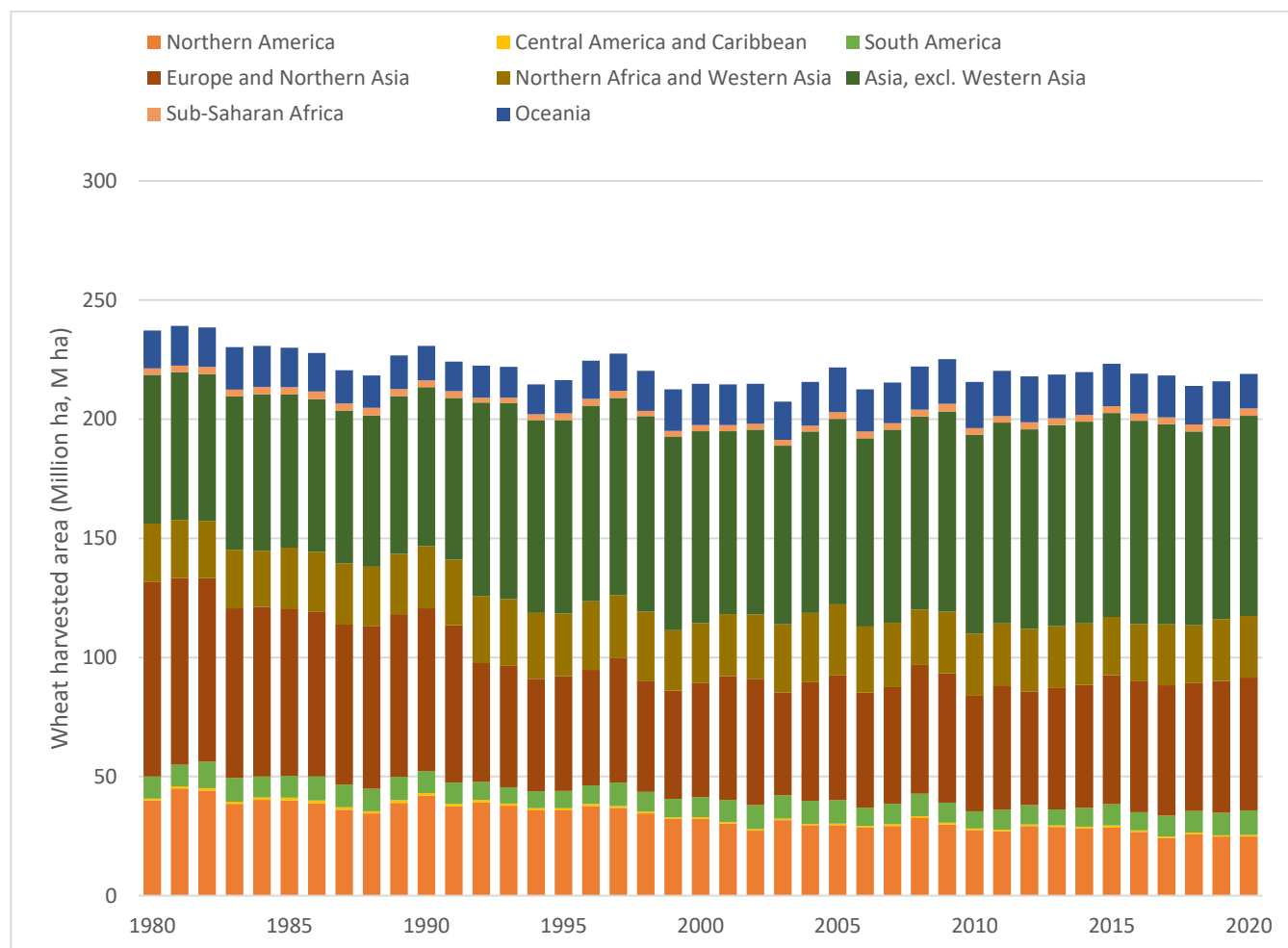
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Figure 1. Wheat harvested area by continental region.



Source: FAOSTAT (available at <http://www.fao.org/faostat/en/#data/QC>).

USES

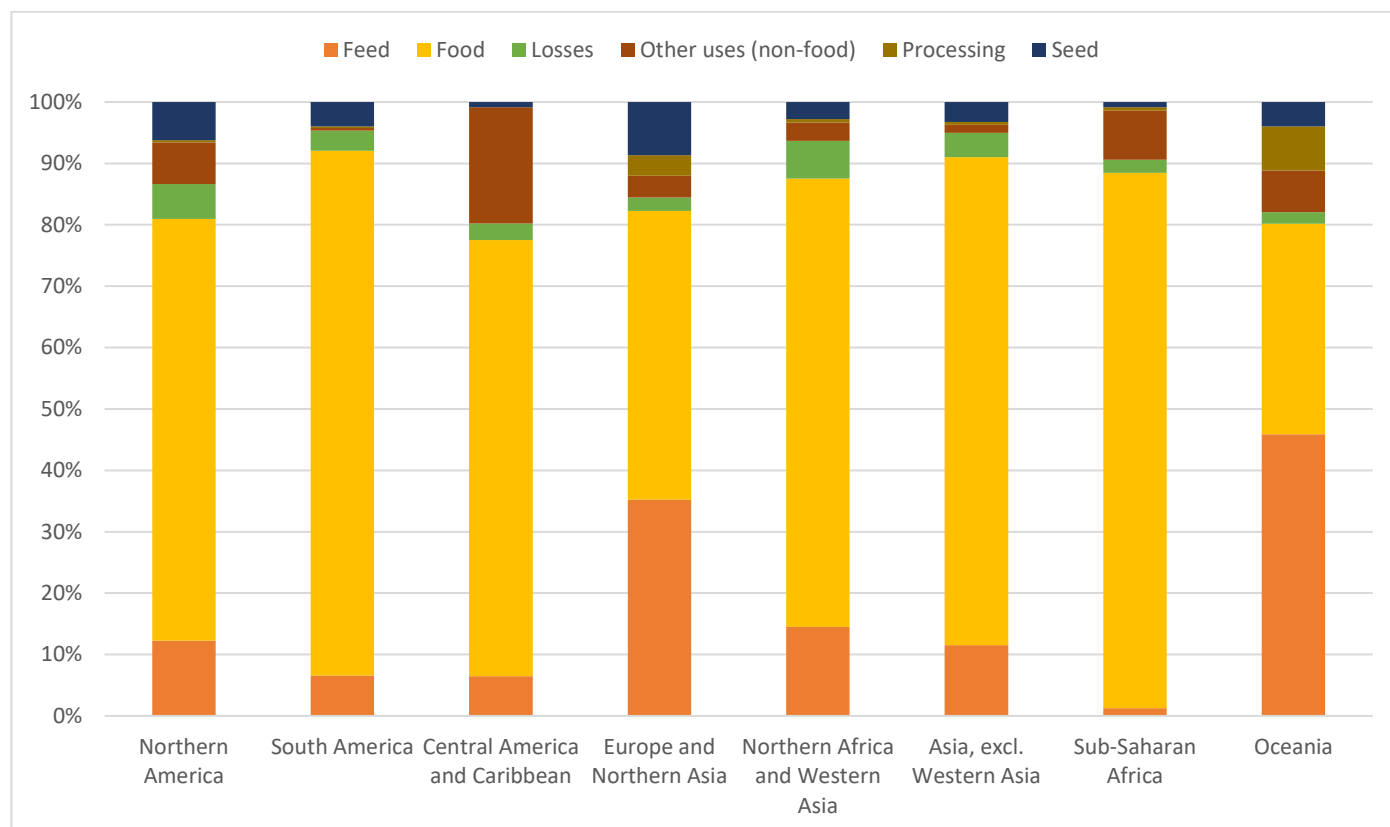
Wheat is a dietary staple for millions of people around the world, accounting for 20% of all calories consumed by humans. Wheat is primarily produced for food (66% of global production) but a fifth of the grain is used as feed.

Wheat use presents a marked divergence between country income status. In low and lower-middle income countries, food use predominates (79%), with feed use only 10%; and relatively lower seed and processing use, and higher losses (5%). In contrast, in upper-middle and high income countries food use drops to 60%, with feed use increasing to 26%; and relatively higher seed, processing and non-food uses, and lower losses (Erenstein *et al.*, 2022). Furthermore, feed use is concentrated in selected geographies (Figure 2), being particularly high in Australia, followed by Europe. The percentage of food use is particularly high in South Asia, Sub-Saharan Africa and South America (Erenstein *et al.*, 2022).

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Figure 2. Wheat utilization in 2019 by continental region.



Source: FAOSTAT (available at <https://www.fao.org/faostat/en/#data/FBS>).

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Introduction on Global Agro-Ecological Zoning version 4

Global Agro-Ecological Zoning version 4 (GAEZ v4), developed by the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied System Analysis (IIASA) is built on the fundamental and robust principles of land evaluation (FAO, 1976). The GAEZ v4 methodology (Fischer *et al.*, 2021) is a successful approach to support sustainable agricultural development by providing information about current and future crop suitability, agricultural production risks and opportunities, irrigation water demand, and simulates crop development and adaptation options, while preserving environmental quality. The main objective of this crop profile is to summarize crop-specific information for fostering sustainable land use planning and decision making for food security and agricultural development. This assessment uses [GAEZ v4 Data Portal](#) as the primary source for data.

Crop suitability

The suitability of a crop to be cultivated on a given tract of land depends on specific crop requirements as compared to the prevailing agro-climatic and agro-edaphic conditions at a location. GAEZ combines these two components systematically by successively modifying grid cell specific agro-climatic potential yields according to assessed soil limitations and terrain constraints. As summarized in Table 1, global results show that about 54% of the rain-fed cropland was assessed as potentially suitable for rain-fed wheat production, and nearly 80% of current land equipped for irrigation. Due to climatic conditions, suitability of wheat is particularly high in Northern America (89% of cropland) and Europe & Northern Asia (87%). It is lowest in Central America (33%) and in Sub-Saharan Africa (31 %).

Table 1. Suitability of wheat on rain-fed and irrigated cropland in 1981-2010, by continental region. The values shown are suitable extents and potential production on rain-fed and irrigated cropland, under baseline climate conditions (1981-2010, source CRUTS32) and at high input level. Suitable area= VS+S+MS (VS - Very suitable, S - Suitable, MS - Moderately Suitable).

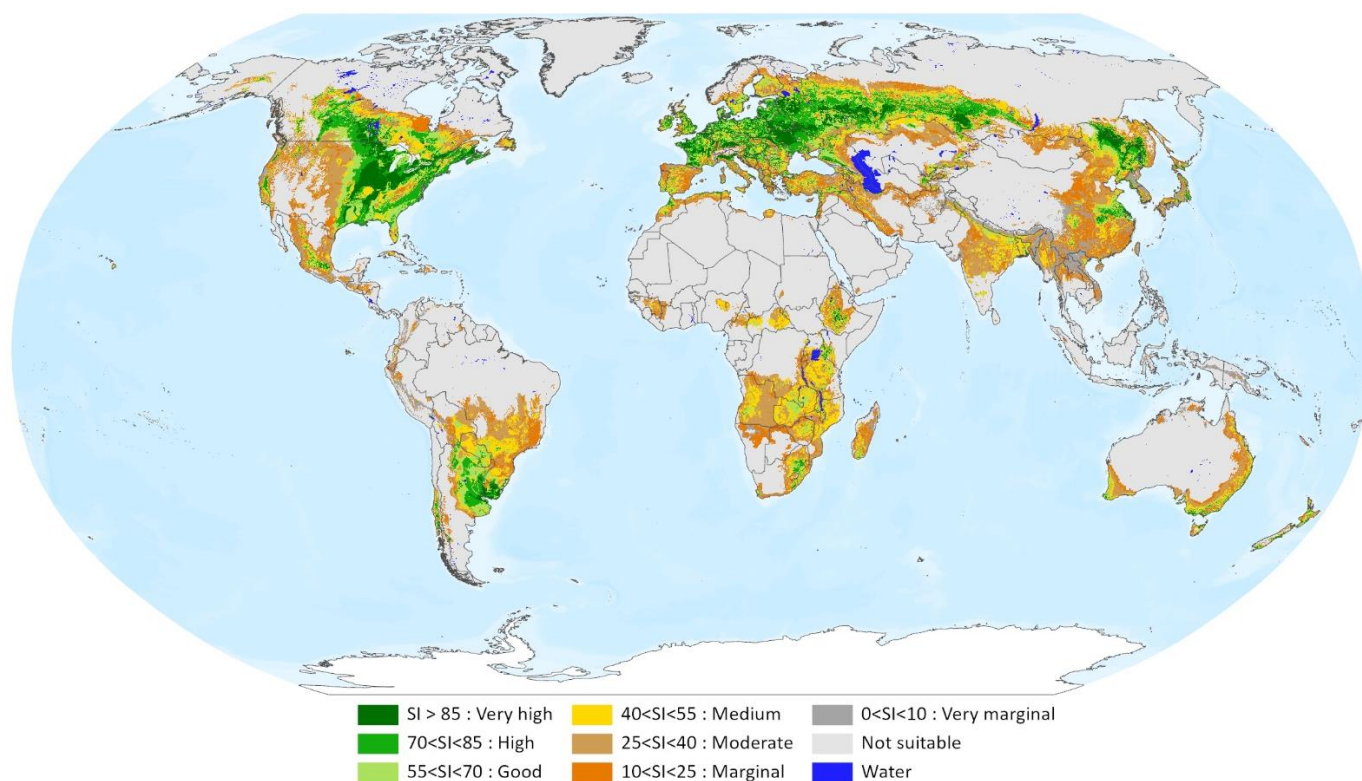
Continental Region	Rain-fed Cropland 1000 ha	Suitable area and potential production			Irrigated Cropland 1000 ha	Suitable area and potential production		
		Area 1000 ha	Production 1000 tons	Yield tons/ha		Area 1000 ha	Production 1000 tons	Yield tons/ha
Northern America	179,315	157,338	898,894	6.3	27,335	26,945	196,351	8.1
Central America and Caribbean	32,242	7,653	29,288	4.3	8,540	5,957	28,757	5.4
South America	129,636	70,643	298,606	4.7	15,840	7,768	41,277	5.9
Europe and Northern Asia	264,219	228,698	1,122,350	5.5	25,361	23,796	187,289	8.7
Northern Africa and Western Asia	66,710	27,969	124,203	4.9	23,830	20,169	138,278	7.6
Asia, excl. Western Asia	295,041	91,178	333,722	4.1	212,435	158,584	867,983	6.1
Sub-Saharan Africa	210,056	62,070	232,313	4.2	5,584	3,716	19,310	5.8
Oceania	46,154	16,472	73,907	5.0	3,258	3,144	18,685	6.6
GLOBAL	1,223,372	662,020	3,113,283	4.9	322,184	250,079	1,497,929	6.8

Note: Yields shown in Table 1 are simulated average potential attainable wheat yields of best performing wheat types in suitability classes VS, S and MS. Estimation was separately performed for rain-fed cropland and land equipped for irrigation.

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Figure 3. Suitability index (range 0-100) by class for rain-fed wheat. Results are for baseline climate (1981-2010) and assumed advanced level of inputs and management.



Source: FAO and IIASA. 2021. Global Agro Ecological Zones version 4 (GAEZ v4). URL: <http://www.fao.org/gaez/>

The geographical distribution of land suitable for wheat cultivation is shown in Figure 3, with most suitable wheat land found in temperate and selected sub-tropical regions.

Table 2 presents an overview of climate change impacts on the extents of cropland suitable for wheat on current cropland. Results refer to the ensemble means of crop simulation outcomes using climate projections of five climate models and for two RCPs, namely RCP 2.6 and RCP 8.5. The AEZ assessment indicates that under a pathway of rapid and continued warming, such as RCP 8.5, the area of current cropland suitable for wheat cultivation may decrease by as much as 20% (Table 2), even when considering selection of best adapted cultivars and shifts of crop calendars to optimize temperature and moisture conditions in individual years of analysis.

The severe impacts of climate change on wheat cultivation in current cropland are also revealed by the decline of wheat production capacity in almost all continental regions (Figure 4), with only modest impacts in Northern America, Europe, Northern Asia and Oceania. Very serious decreases of wheat production potential are projected for Central America and Sub-Saharan Africa.

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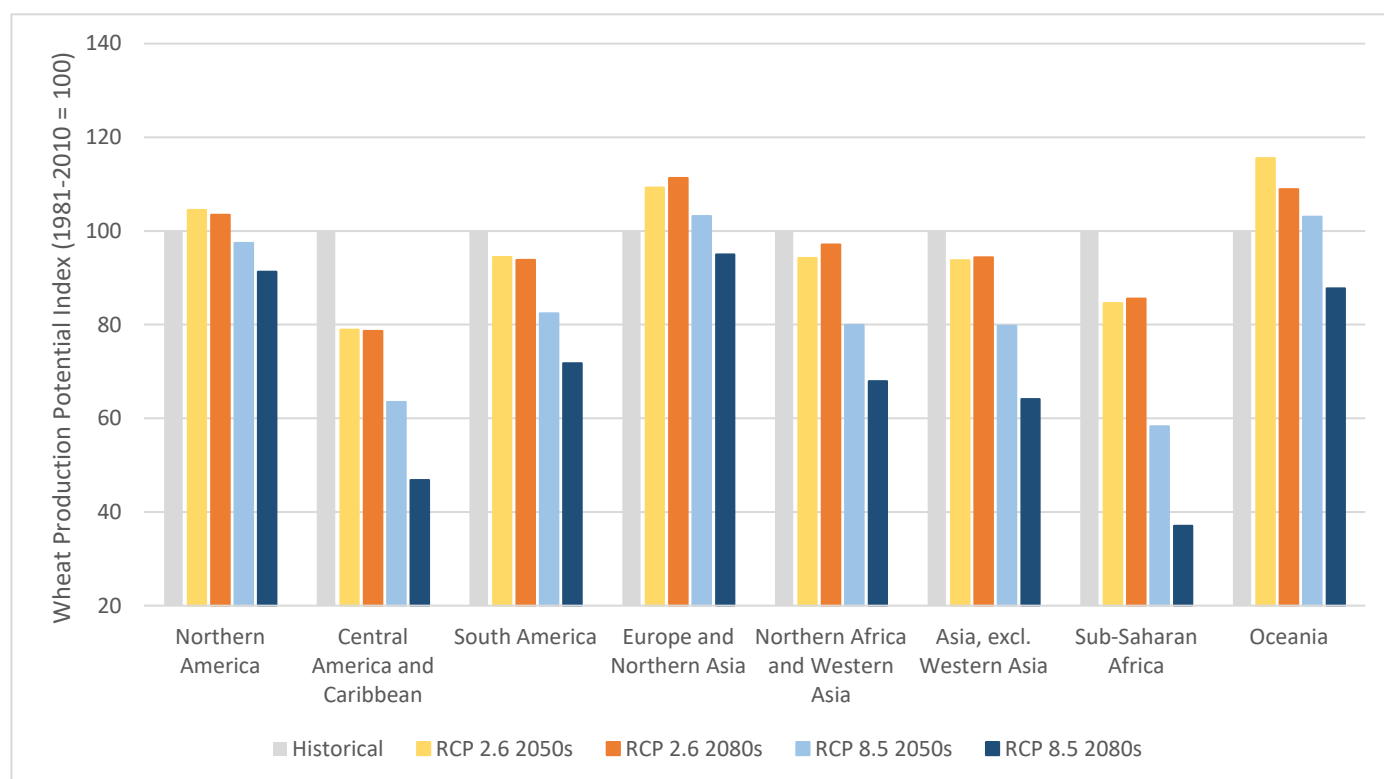
Table 2. Climate change impacts on the total extent of suitable cropland for wheat by continental region. Percentage changes were calculated relative to the outcomes of historical period 1981–2010. Suitable extents were taken to be very suitable (VS), suitable (S) and moderately suitable (MS) areas on respectively rain-fed and irrigated cropland. Results refer to the ensemble means of crop simulation outcomes using climate projections of five climate models and for two Reference Concentration Pathways (RCPs), namely RCP 2.6 and RCP 8.5.

Continental Region	Suitable area 1981-2010 1000 ha	% Change relative to 1981-2010			
		RCP 2.6		RCP 8.5	
		2050s	2080s	2050s	2080s
Northern America	184,283	2.1	2.5	-1.6	-6.4
Central America and Caribbean	13,610	-21.9	-22.4	-35.9	-50.5
South America	78,411	-8.8	-9.2	-19.9	-29.9
Europe and Northern Asia	252,494	4.4	5.3	2.4	-0.8
Northern Africa and Western Asia	48,138	-4.5	-2.1	-16.3	-25.9
Asia, excl. Western Asia	249,762	-4.1	-3.5	-17.4	-32.6
Sub-Saharan Africa	65,786	-14.1	-12.9	-39.9	-61.0
Oceania	19,615	17.1	10.7	3.8	-11.7
GLOBAL	912,099	-1.5	-0.9	-10.3	-19.8

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Figure 4. Index of potential production capacity for wheat (1981–2010 = 100). Results for wheat by continental region for respectively RCP 2.6 and RCP 8.5, using an index of potential wheat production in the 2050s and the 2080s and where each continental region's potential production during 1981–2010 is set to 100.



Source: FAO and IIASA. 2021. Global Agro Ecological Zones version 4 (GAEZ v4). URL: <http://www.fao.org/gaez/>

Agro-ecological potential attainable yield

Potential attainable yield provides crop-wise information about potential production and related crop cycle attributes, calculated using an eco-physiological crop growth model and spatially detailed soil/terrain characteristics (soil type, soil profile attributes, terrain slope gradient) and climate attributes (radiation, temperature and precipitation) during different crop development stages. Results account for temperature limitations and moisture constraints that are affecting crop growth and development, include yield reducing effects due to pests, diseases and weeds, climate related workability constraints and incorporate the influence of soil and terrain limitations.

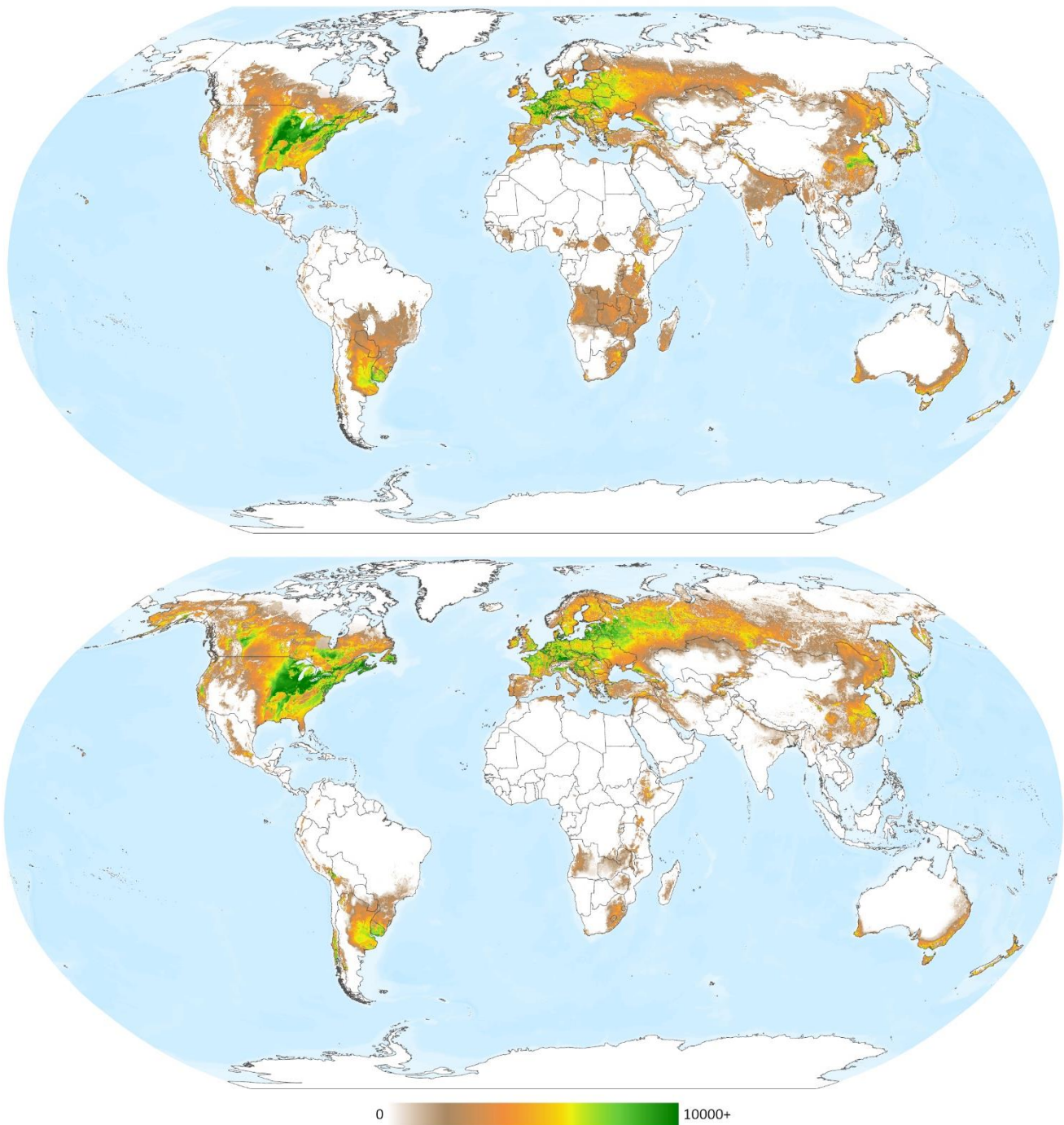
Figure 5 shows average potential attainable yields of rain-fed wheat simulated under high inputs and advanced management assumptions for reference climate conditions of 1981–2010 (see map on the top of Figure 5) and for an ensemble mean in period 2070–2099 calculated using climate projections of five earth system models under reference concentration pathway RCP 8.5 (see map on the bottom of Figure 5).

As is visible in these maps, substantial global warming projected under RCP 8.5 will cause a geographical shift of the production capacity toward higher latitudes and will severely curtail any existing wheat production potential in tropical regions.

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Figure 5. Potential attainable yield (kg DW/ha) of rain-fed wheat, high inputs, for the time period 1981-2010 (top) and 2071-2100 (bottom). Results for future scenario refer to the ensemble mean of crop simulation outcomes using climate projections of five climate models and for RCP 8.5.



Source: FAO and IIASA. 2021. Global Agro Ecological Zones version 4 (GAEZ v4). URL: <http://www.fao.org/gaez/>

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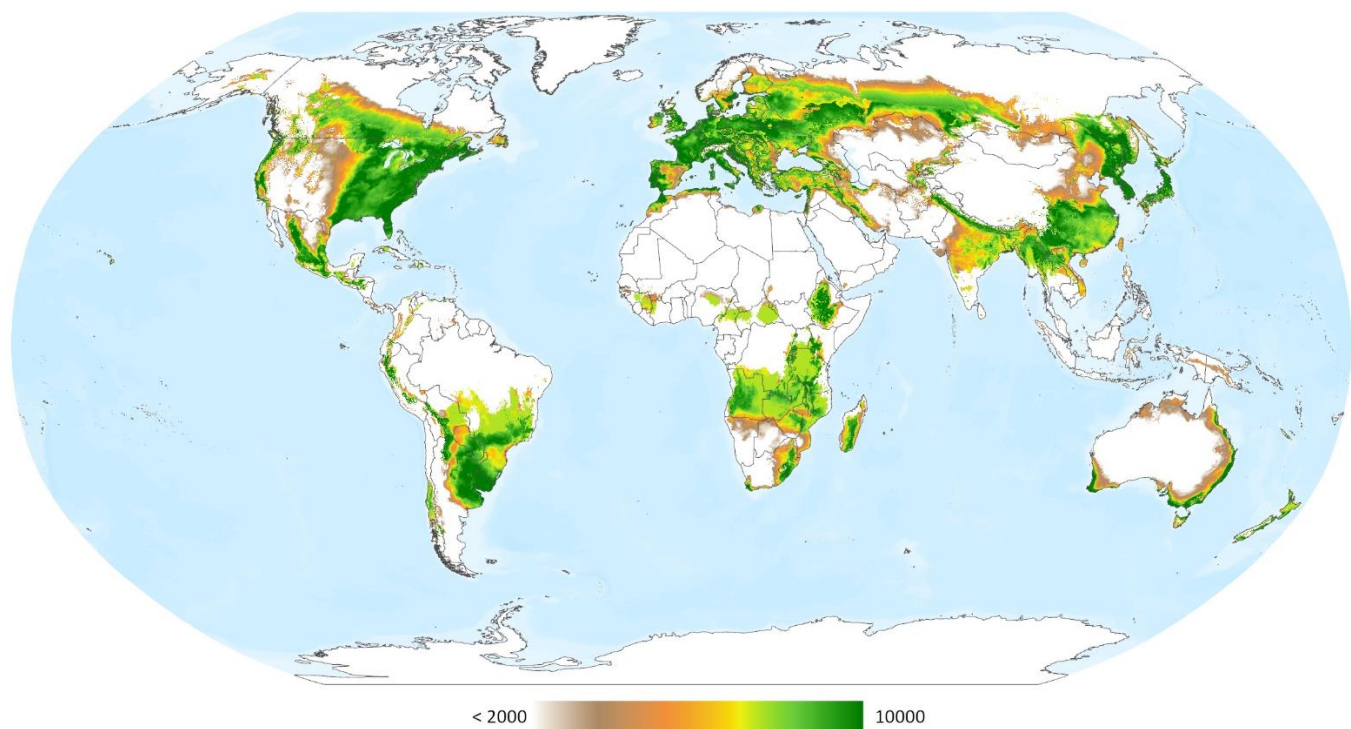
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Major crop constraints

GAEZ determines for each grid cell of the resource inventory the respective make-up of land units in terms of soil types and slope classes and applies yield reduction factors due to climate and the constraints induced by soil limitations and prevailing terrain-slope conditions. The quantified constraint factors include temperature constraints, moisture constraints, agro-climatic constraints, a resulting overall agro-climatic yield reduction factor (Figure 6) and a soil/terrain constraint factor (Figure 7).

Figure 6 presents an example for wheat showing the global distribution of the overall agro-climatic yield reduction factor, expressing the expected wheat production losses due to climate limitations. The indicator value ranges from 0 to 10000, from climatically unsuitable to perfect climatic match during the crop growth cycle. The latter, shown as dark green, indicates no expected losses due to agro-climatic conditions while indicator values below 5000 mean that half the potential yield or more may be lost due to unfavourable temperature and/or precipitation conditions. Crops are considered not viable when the overall agro-climatic constraint factor is below 2000.

Figure 6. Total climate related crop yield constraint factor for wheat, high inputs and rain-fed conditions, climate of 1981-2010.



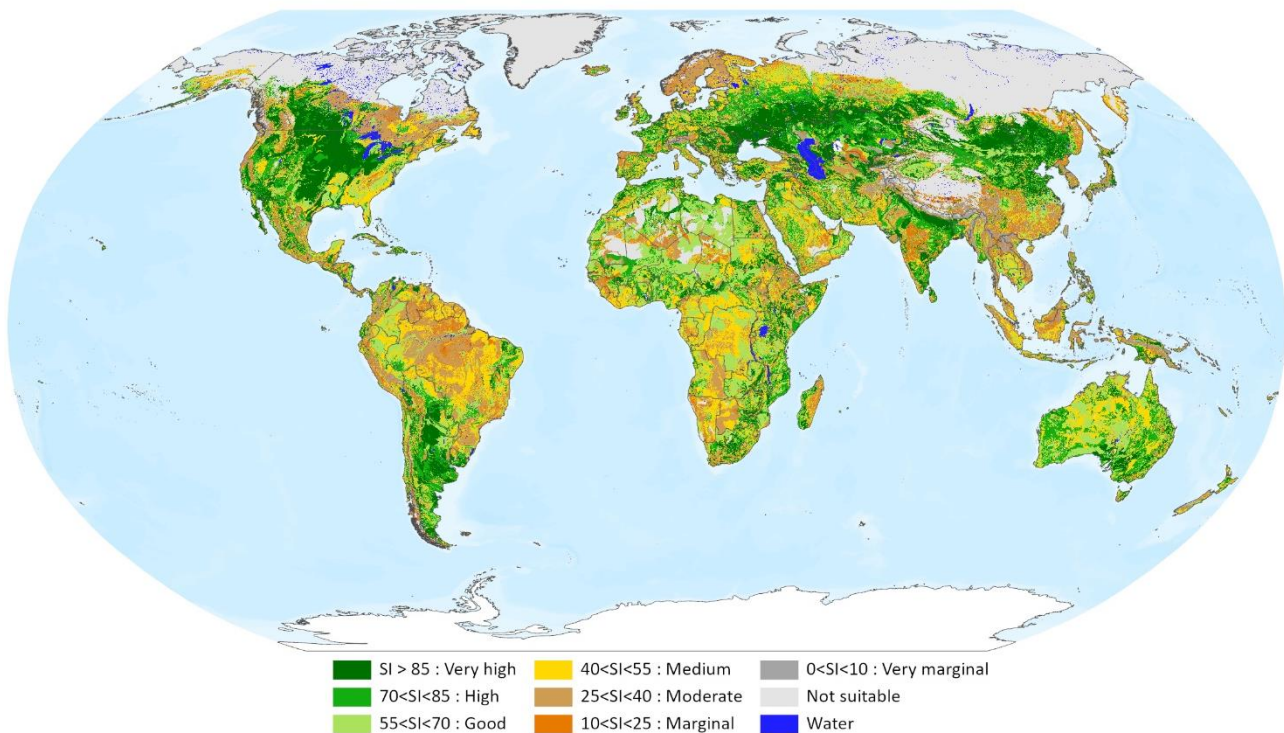
Source: FAO and IIASA. 2021. Global Agro Ecological Zones version 4 (GAEZ v4). URL: <http://www.fao.org/gaez/>

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In the GAEZ approach, crop responses to individual soil attribute conditions and relevant soil drainage and soil phase conditions are combined into soil quality ratings. Soil qualities quantify different aspects of a soil vis-à-vis crop soil requirements. Functional relationships of soil qualities have been formulated to assess crop suitability of soil units and are combined into crop specific soil suitability ratings, varying by location, by input and management level and by water supply system. Figure 7 presents soil and terrain suitability for rain-fed wheat under low level inputs and traditional management.

Figure 7. Soil and terrain suitability factor for rain-fed wheat, low input level.



Source: FAO and IIASA. 2021. Global Agro Ecological Zones version 4 (GAEZ v4). URL: <http://www.fao.org/gaez/>

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Irrigation water demand

GAEZ assesses crops separately for rain-fed and irrigated cultivation and applies a daily soil water balance calculation to determine soil moisture deficits and related net irrigation requirements, i.e., the amount of irrigation water that needs to reach the plant to fully meet crop water requirements, but without accounting for irrigation system efficiency and losses in providing irrigation.

Table 3 summarizes the changes in average irrigation requirements (mm) of wheat in potentially suitable irrigated cropland. Note, changes in crop-specific irrigation demand will generally be caused by a combination of different factors including a shift of the crop calendar, selection of a different most productive crop type, and of course due to changes in temperature regime and precipitation during the crop cycle.

Table 3. Climate change impacts on irrigation demand of irrigated wheat.

Continental Region	Net Irrigation Water Requirements (mm)	% Change relative to 1981-2010			
	Historical	RCP 2.6		RCP 8.5	
	1981-2010	2050s	2080s	2050s	2080s
Northern America	267	-7.6	-10.6	-6.7	-13.8
Central America and Caribbean	352	7.7	7.1	17.3	17.6
South America	205	-4.0	-2.9	-0.2	2.3
Europe and Northern Asia	172	-8.0	-11.7	-6.6	-6.3
Northern Africa and Western Asia	319	-11.7	-12.9	-10.1	-6.9
Asia, excl. Western Asia	245	-3.0	-1.9	-5.7	-10.0
Sub-Saharan Africa	356	-2.9	-5.5	-3.1	4.0
Oceania	235	-3.7	0.9	-0.9	-3.1
GLOBAL	250	-4.6	-4.6	-5.7	-8.7

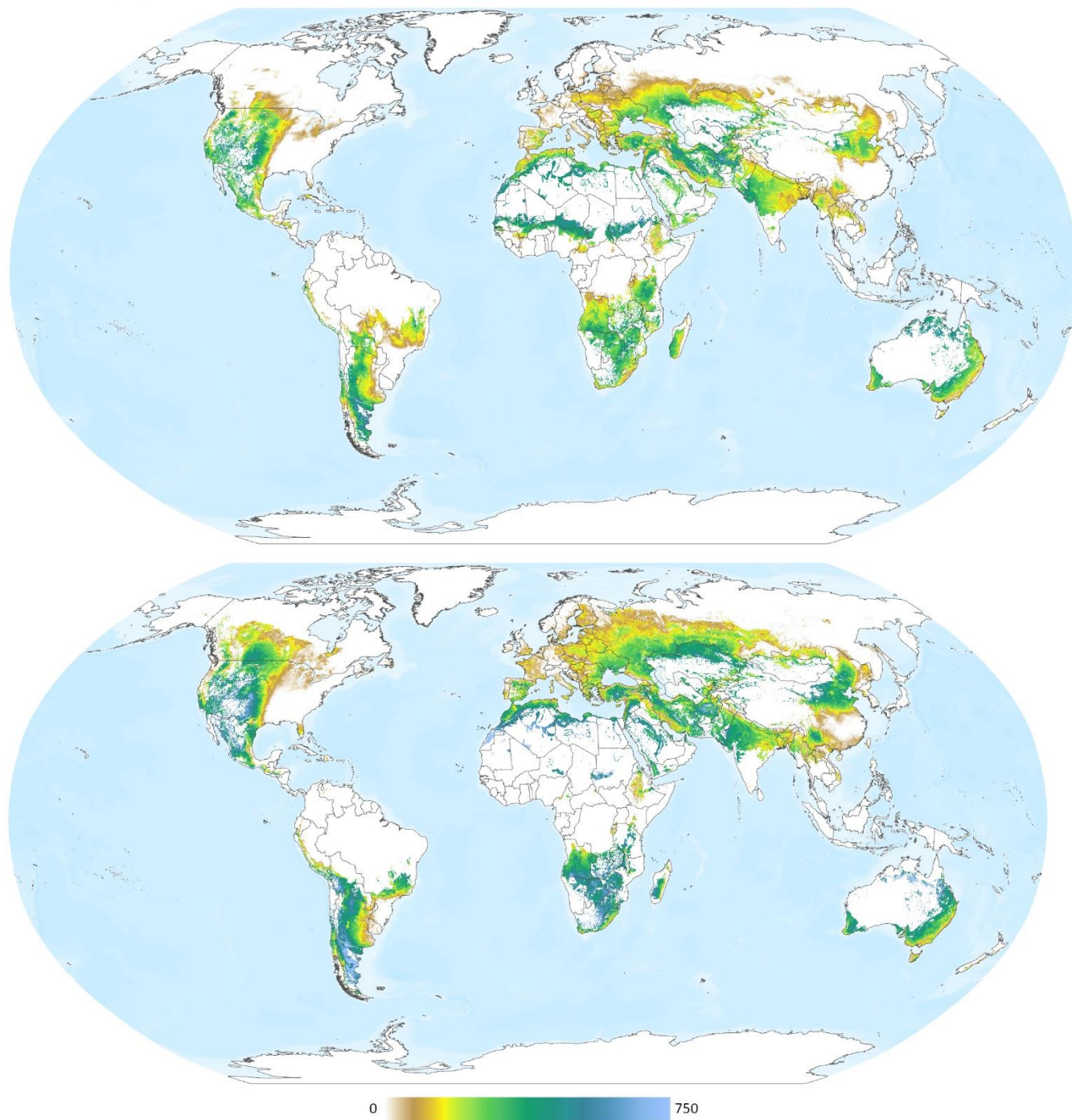
Note: The shown percentage changes were calculated relative to the historical average of 1981–2010. Average crop water demand and soil moisture deficits were calculated for irrigated cropland that is very suitable, suitable or moderately suitable for wheat. The values shown refer to net irrigation water requirements (i.e., the amount to be taken up by the plants) assuming any crop water deficit is fully met.

Figure 8 shows for current cropland areas with wheat production potential the amount of net irrigation (in mm) that would be required to cultivate in each location the most productive wheat type. The value ranges from no irrigation (0 mm) up to about 750 mm in some hot arid environments. Note that more than one third of the assessed wheat production potential occurs on land equipped with irrigation (Table 1).

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Figure 8. Net irrigation requirement (mm) during growth cycle of irrigated wheat in current cropland under high level input for current climate of 1981-2010 (top) and an ensemble mean of results for 2080s under RCP 8.5 (bottom).



Source: FAO and IIASA. 2021. Global Agro Ecological Zones version 4 (GAEZ v4). URL: <http://www.fao.org/gaez/>

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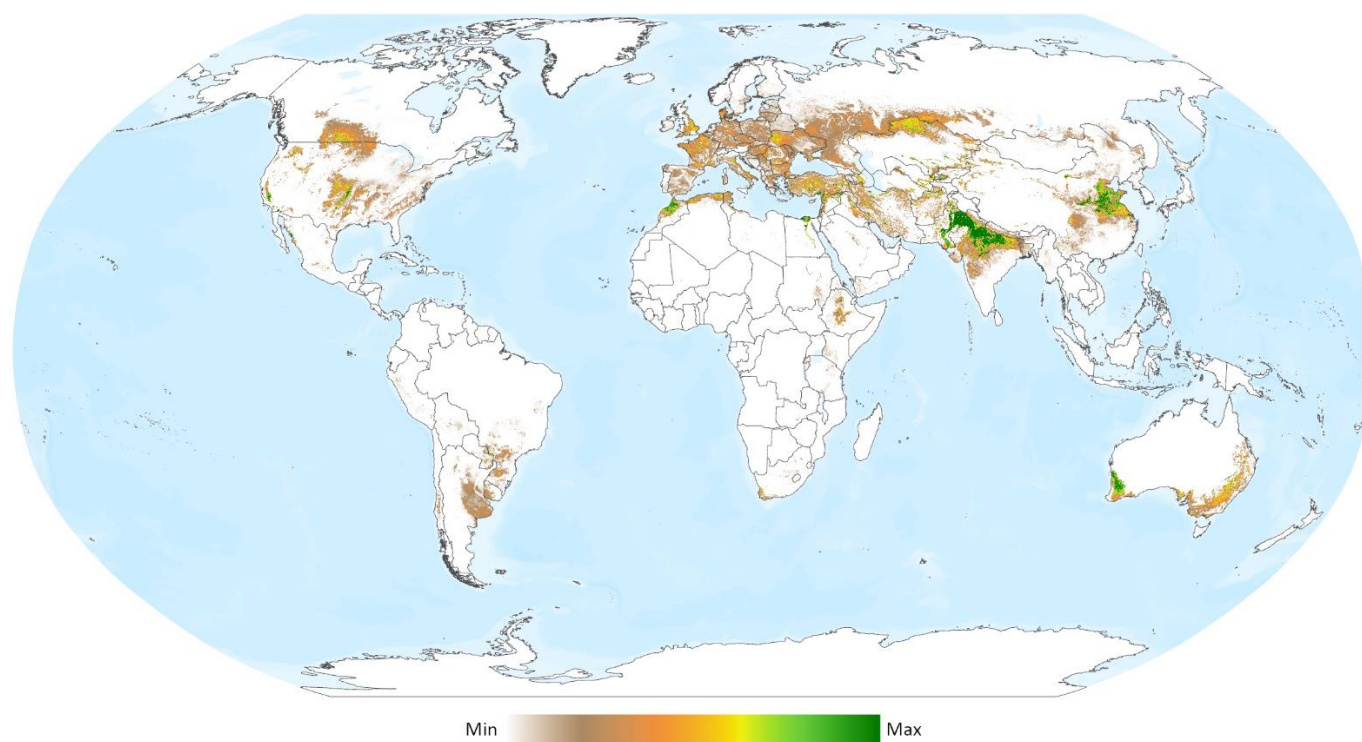
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Area harvested and yield gap

GAEZ allocates available crop production statistics to the spatial cropland units while meeting statistical accounts and respecting crop suitability and land capabilities reflected in the spatial land resources inventory (Fischer *et al.*, 2021).

Figure 9 presents the spatial distribution of harvested area for wheat as obtained by downscaling of statistical data of 2009–2011. For instance, as shown in Figure 9, the largest concentrations of wheat harvested area were found in the Indo Gangetic Plain, the Indus valley in Pakistan, and in the North China Plain.

Figure 9. Area harvested (1000 ha) for wheat for 2010 under total water supply conditions.



Source: FAO and IIASA. 2021. Global Agro Ecological Zones version 4 (GAEZ v4). URL: <http://www.fao.org/gaez/>

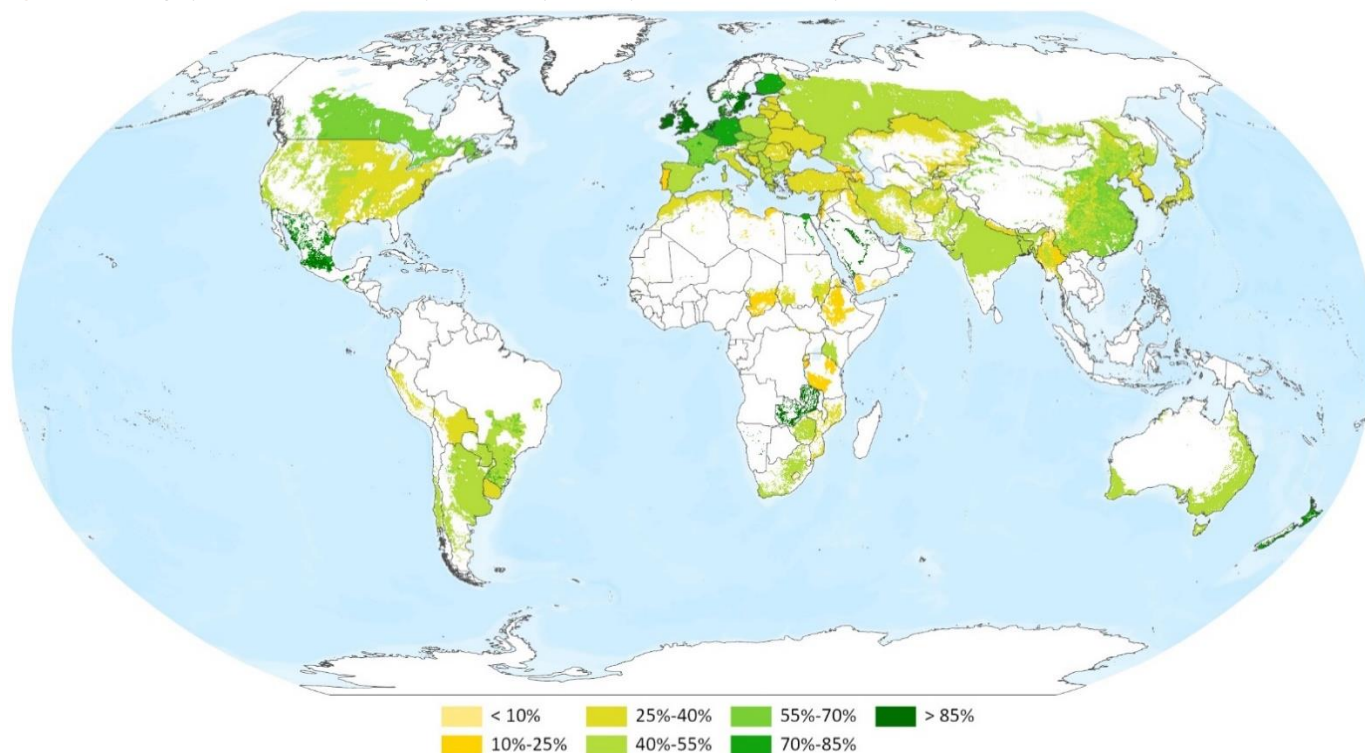
Apparent yield and production gaps have been estimated in GAEZ by comparing for actual harvested areas the potential attainable yields and production with actual yields and production obtained by downscaling statistical data for the years 1999–2001 and for 2009–2011 (statistical data derived from FAOSTAT and selected national sources).

Figure 10 presents calculated ‘yield achievement ratios’ (i.e., percent ratio of actual to potential production) comparing downscaled actual yields with potentials simulated under high input/advanced management assumptions. Apparent yield gaps are closely related to the calculated yield achievement factors, together summing up to 100 percent. For instance, a yield achievement factor of 75% would imply an apparent yield gap of 25%. According to this definition, the highest yield achievement ratios for wheat were estimated in Europe, the lowest occurred in some tropical countries of sub-Saharan Africa where wheat is however of minor importance in the crop mix (Figure 10).

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Figure 10. Average yield achievement ratio (100xactual/potential) for wheat in the cropland for 2010.



Source: FAO and IIASA. 2021. Global Agro Ecological Zones version 4 (GAEZ v4). URL: <http://www.fao.org/gaez/>

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