THE GLOBAL AGRO-ECOLOGICAL ZONING version 4

Crop profile: Maize

GENERAL DESCRIPTION

A tall, coarse grass and grain crop with strong erect stalks and long narrow leaves, maize can be found at elevations between sea level and 4,000 m and it can be grown at latitudes from 48°N to 40°S.

Maize (temperate, subtropical and tropical lowland cultivars for grain and silage maize with growth cycles of 90 to 180 days, tropical highland types of 120 up to 300 days) is an annual crop belonging to the group of crops with a C4 photosynthesis pathway (C4 II), which is characterized with optimum photosynthesis and growth at temperatures between 20°C and 30°C. Temperatures above 30°C lead to lower photosynthesis and temperatures between 35°C and 40°C may cause heat stress and eventually plant damage, especially during the reproductive phase. Both are leading to lower yields. Maize cannot withstand frost at any stage of its growth. Minimum temperature for germination is 10°C and ideally above 15°C. Annual rainfall requirements for maize may vary from 500 mm up to 2,000 mm depending on cultivar and environment.

The global maize area (for dry grain) in 2020 amounted to 202 M ha, making it the second most widely grown crop in the world after wheat. Around 36% of harvested maize area occurred in the Americas, 33% in Asia, mostly Eastern and Southern Asia, 21% in Africa and nearly 10% in Europe (FAOSTAT, 2022).

USES

Maize has been mainly grown for food and fodder, more recently also for non-food purposes. It is an established and important human food crop in a number of less developed countries, especially in Sub-Saharan Africa, Latin America, and a few countries in Asia, where maize consumed as human food contributes over 20% of food calories (Shiferaw *et al.*, 2011). Compared to wheat and rice, maize is a more versatile multi-purpose crop (Erenstein *et al.*, 2022). Since the 1960s, the global maize area under production nearly doubled, up from 107 M ha to the current 202 M ha (+89%), with an acceleration of area expansion since the early 2000s (Figure 1). The global average maize yields nearly tripled since 1961, up from 2 tons/ha to the current 5.8 tons/ha (FAOSTAT, 2022). At the global level, maize (dry grain) is primarily used as feed (59% of total production), 19% for non-food uses, and 13% for food (Figure 2).

Taxonomy

Taxon name: *Zea mays L.*

Family: Poaceae Barnhart

Genus: *Zea* L.

FAOSTAT Statistics for 2020

Total global production

1,162 M tons

Total global harvested area

202 M ha

Links to additional resources

ECOCROP data sheet (link)

FAO Land and Water information (link)

Crop calendar (link)

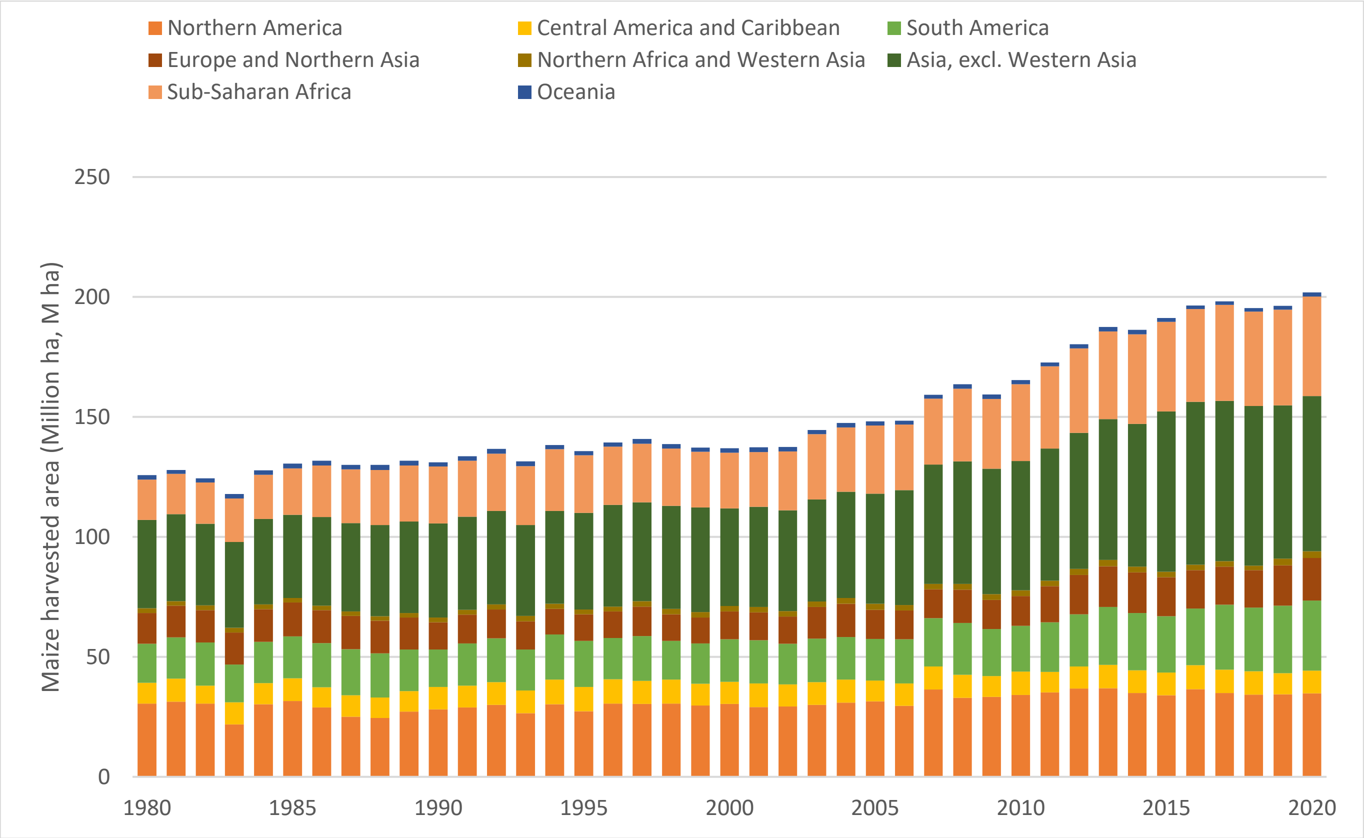
GAEZ (link)

Contacts

Geospatial Unit, Land and Water Division (NSL)

Email: GAEZ@fao.org

Figure 1. Maize harvested area by continental region.

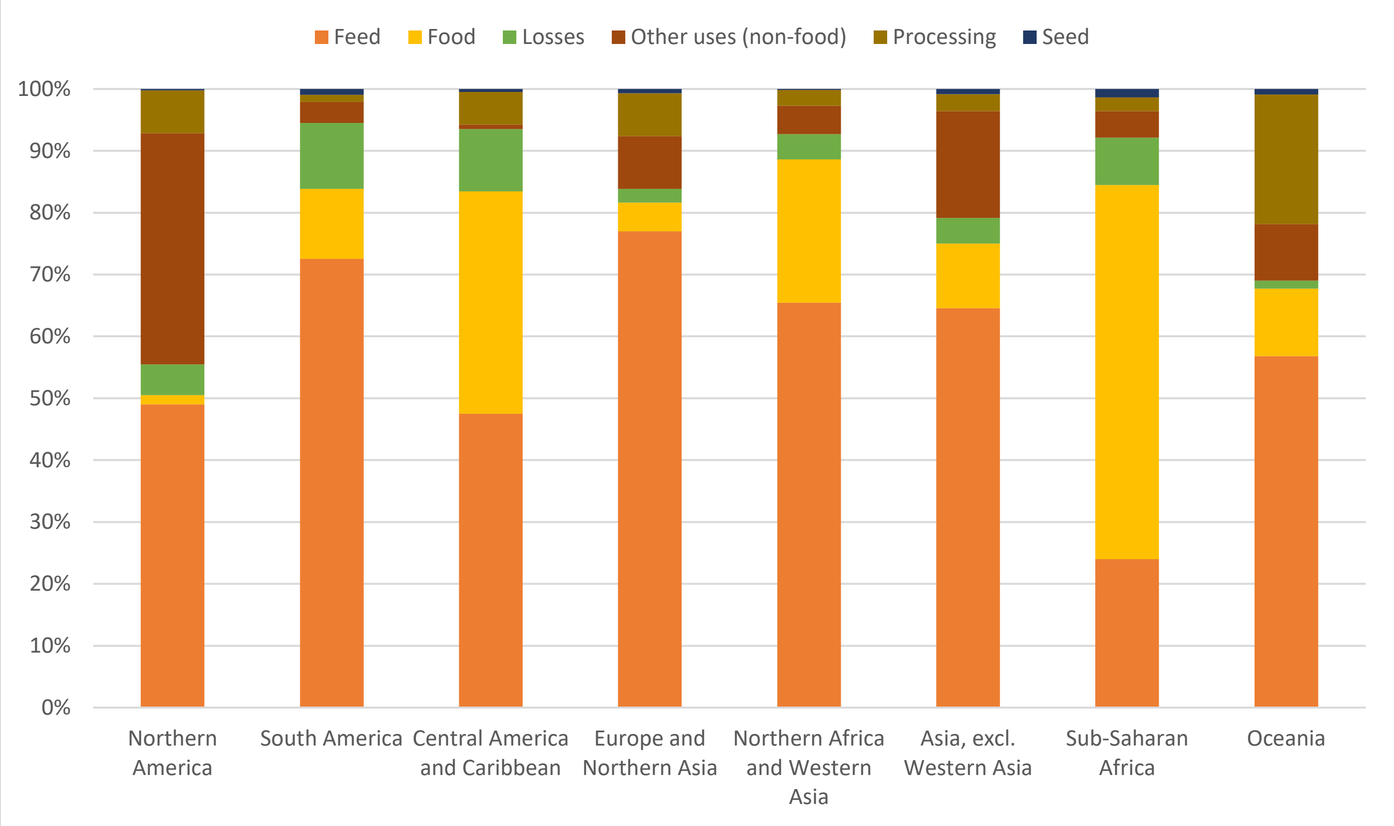


Source: FAOSTAT (available at http://www.fao.org/faostat/en/#data/QC).

In Africa, 30% of the total area under cereal production is maize which accounts for over 30% of the total calories and protein consumed (Cairns *et al*., 2013). Of the total maize production in the developing world, 67% comes from low and lower middle-income countries which shows that maize plays a crucial role in the livelihoods of a good number of poor farmers (Shiferaw *et al*., 2011).

Figure 2 indicates substantial regional differences in the utilization of maize. While feed use dominates in all but one region, the use for human food is most pronounced in Sub-Saharan Africa. Very noticeable is the use of maize for non-food purposes in some developed countries, e.g., for the production of bioethanol and other industrial products in Northern America.

Figure 2. Maize utilization in 2019 by continental region.



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

THE GLOBAL AGRO-ECOLOGICAL ZONING version 4

Crop profile: Maize

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

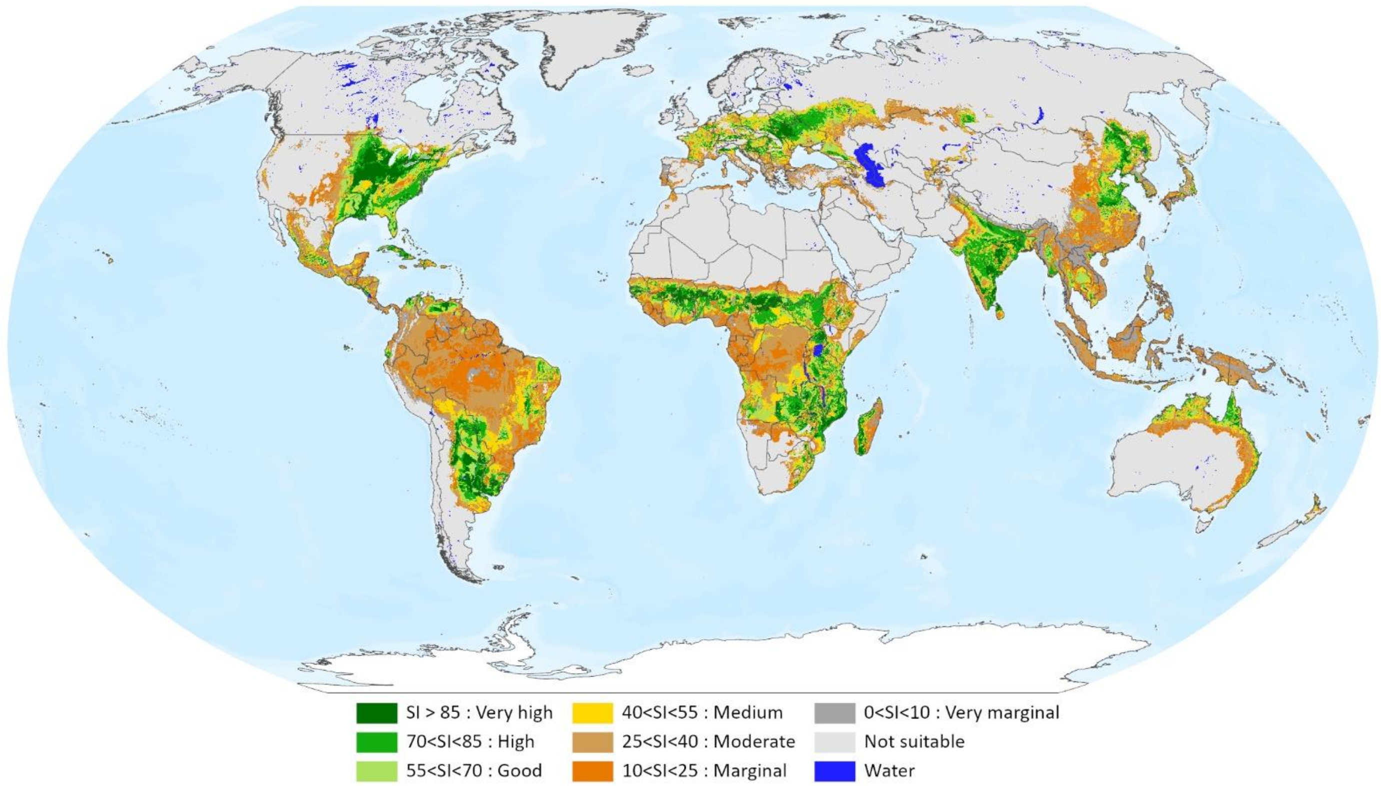
The suitability of a crop to be cultivated on a given tract of land depends on specific crop requirements as compared to the prevailing agro-climatic and agro-edaphic conditions at a location. GAEZ combines these two components systematically by successively modifying grid cell specific agro-climatic potential yields according to assessed soil limitations and terrain constraints. As summarized in Table 1, global results show that about 55% of the rain-fed cropland was assessed as potentially suitable for rain-fed maize production, and about 80% of current land equipped for irrigation.

Table 1. Suitability of maize 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	113,466	902,211	8.8	27,335	24,919	247,164	11.0
Central America and Caribbean	32,242	21,751	133,103	6.8	8,540	7,749	65,557	9.4
South America	129,636	81,806	565,350	7.7	15,840	9,646	83,934	9.7
Europe and Northern Asia	264,219	139,484	777,802	6.2	25,361	21,783	219,482	11.2
Northern Africa and Western Asia	66,710	9,481	45,718	5.4	23,830	22,060	239,575	12.1
Asia, excl. Western Asia	295,041	160,899	1,079,176	7.5	212,435	171,822	1,603,640	10.4
Sub-Saharan Africa	210,056	143,388	951,595	7.4	5,584	5,088	47,452	10.4
Oceania	46,154	5,247	33,862	7.2	3,258	2,532	27,068	11.9
GLOBAL	1,223,372	675,522	4,488,817	7.1	322,184	265,599	2,533,871	10.7

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

Figure 3 Suitability index (range 0-100) by class for rain-fed maize. 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/

Table 2 presents an overview of climate change impacts on the extents of cropland suitable for maize 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. In all continental regions, the extents suitable for maize increase with climate change by the 2050s due to land becoming suitable with warming at higher latitudes and altitudes. Note however, this trend stagnates or reverses with progressive climate change and in most regions suitable area in the 2080s is less compared to the 2050s.

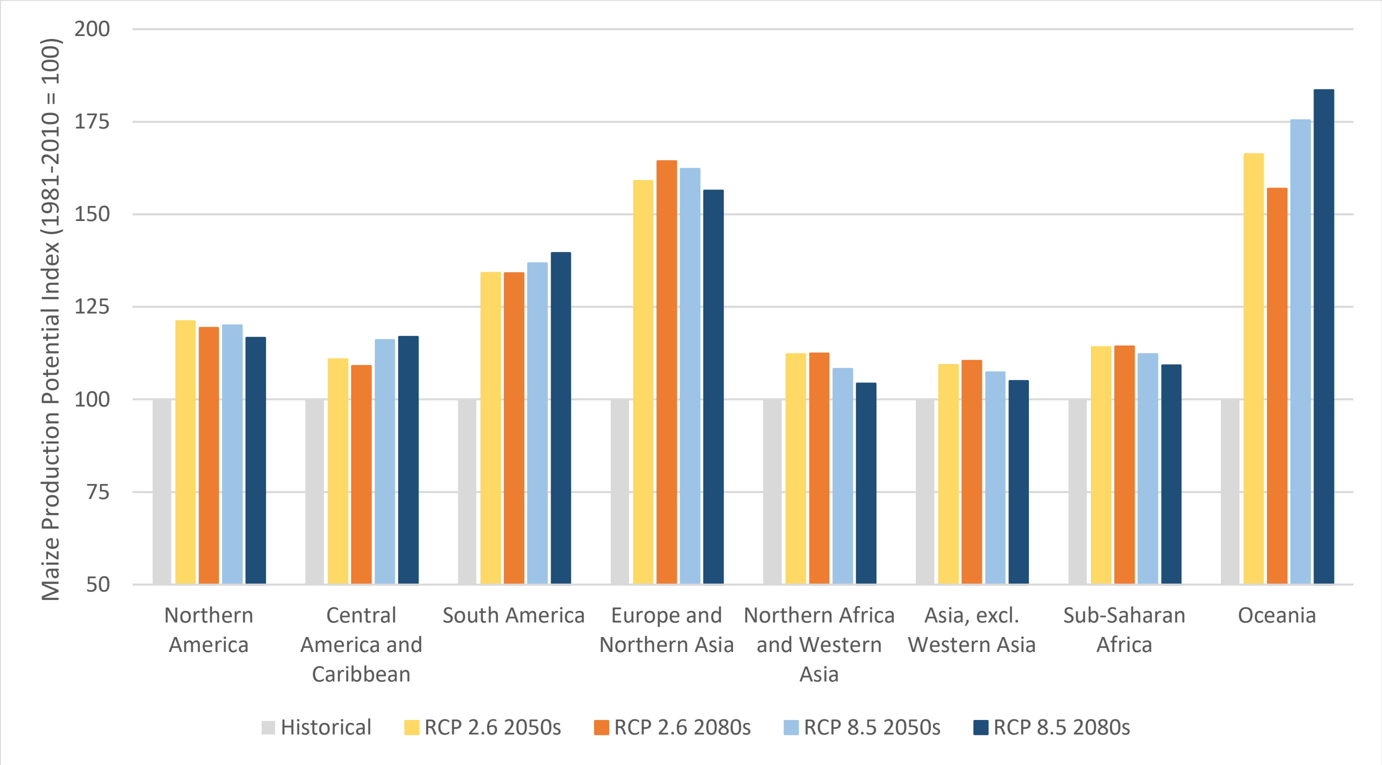
Annual crop field management practices may be adapted to changed temperature and rainfall conditions through crop calendar shifts and cultivar duration switches. The AEZ potential productivity assessment selects best adapted cultivars and shifts crop calendars to optimize temperature and moisture conditions in individual years of analysis.

The effect of climate change is also highlighted by the improvements of maize production capacity in all continental regions (Figure 4). Beyond these aggregate results, climate change impacts on maize productivity vary greatly among sub-continental regions and smallholder farmers in developing countries are the most vulnerable and disadvantaged people as they entirely depend on rain-fed agriculture.

Table 2. Climate change impacts on the total extent of suitable cropland for maize 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	138,385	22.0	20.9	27.1	25.8
Central America and Caribbean	29,499	8.2	6.7	11.1	10.8
South America	91,451	30.3	30.0	33.5	37.7
Europe and Northern Asia	161,267	42.7	45.6	44.1	40.1
Northern Africa and Western Asia	31,541	23.8	23.5	18.0	16.0
Asia, excl. Western Asia	332,721	9.3	9.8	8.5	7.2
Sub-Saharan Africa	148,476	12.8	13.2	12.3	11.2
Oceania	7,779	73.9	62.0	80.7	90.6
GLOBAL	941,120	20.5	20.9	21.4	20.3

Figure 4. Index of potential production capacity for maize (1981–2010 = 100). Results for maize by continental region for respectively RCP 2.6 and RCP 8.5, using an index of potential maize 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/

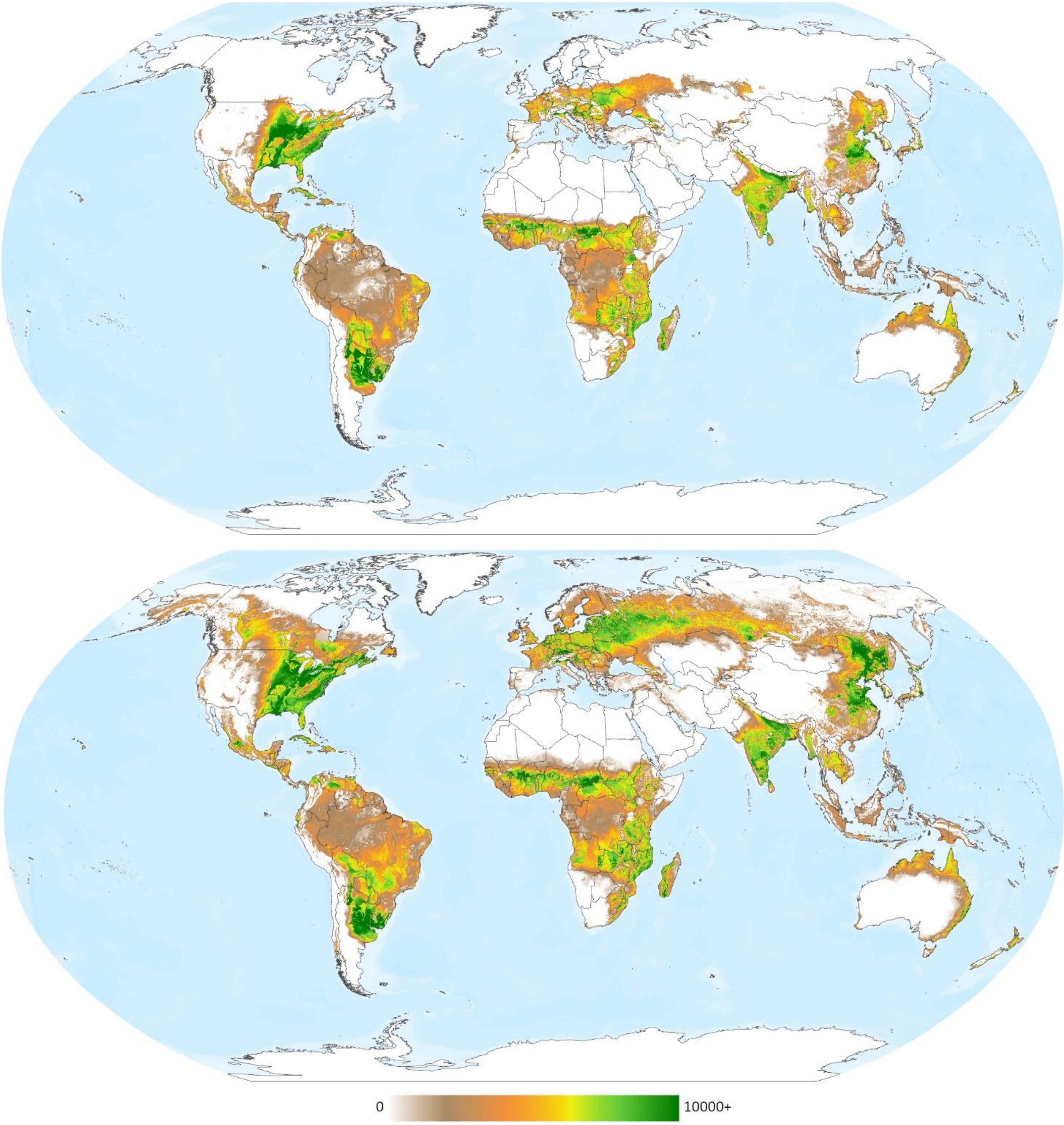
Agro-ecological potential attainable yield

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 and 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 maize 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 noticeable geographical expansion of the suitable area and potential attainable maize yields toward higher latitudes (Canada, Russia and Scandinavia) where maize cultivation is currently not possible mainly due to low-temperature limitations.

Figure 5. Potential attainable yield (kg DW/ha) of rain-fed maize, 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/

THE GLOBAL AGRO-ECOLOGICAL ZONING version 4

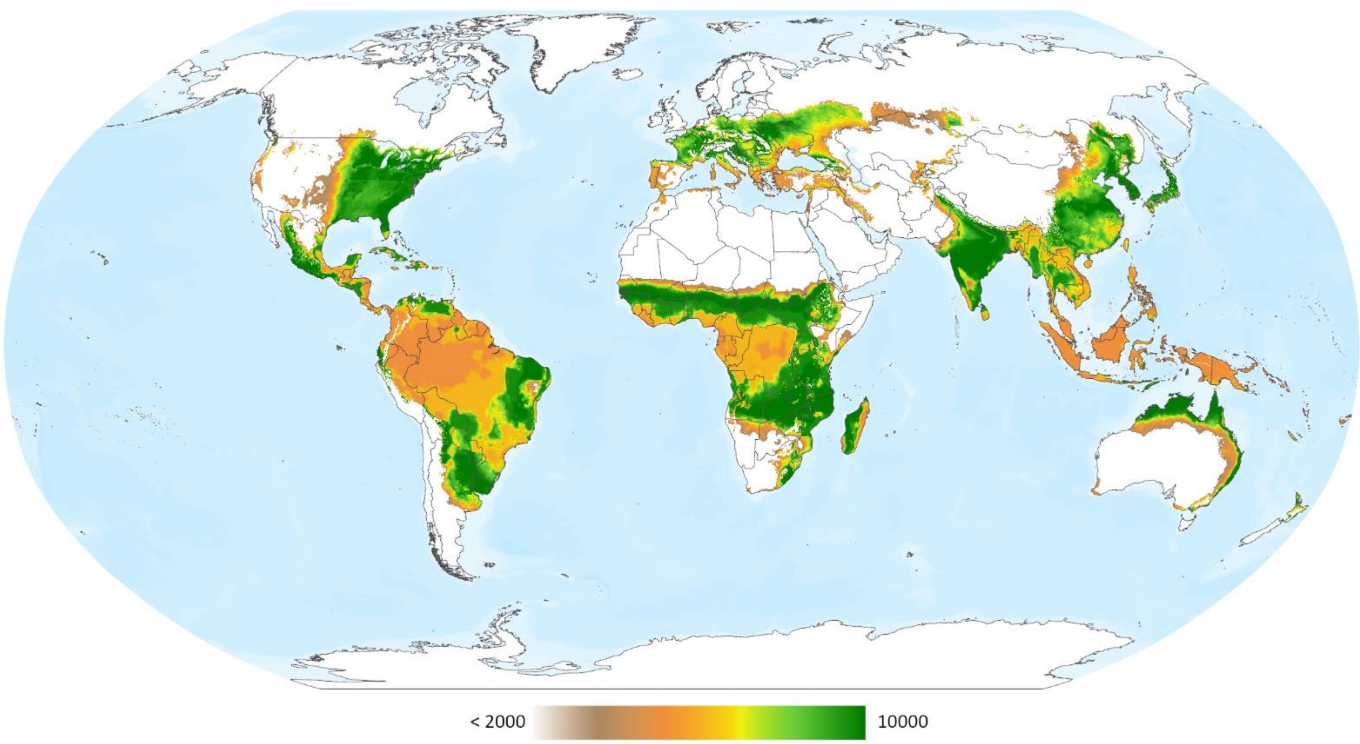
Crop profile: Maize

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 maize showing the global distribution of the overall agro-climatic yield reduction factor, expressing the expected maize 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. The map shows quite large impacts in humid tropical areas where pest and disease pressure and unfavourable working conditions are expected to cause severe losses. 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 maize, 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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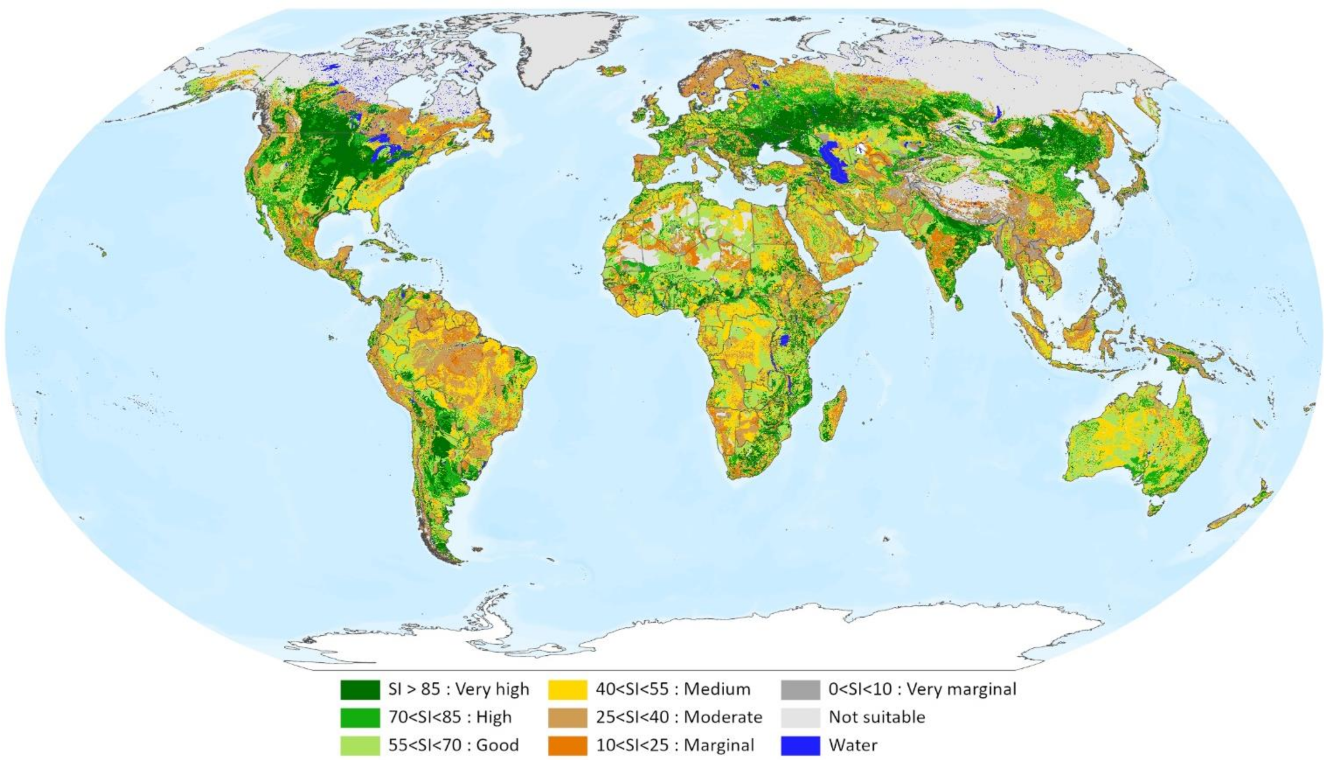
Crop profile: Maize

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 maize under low level inputs and traditional management.

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



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

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 maize 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.

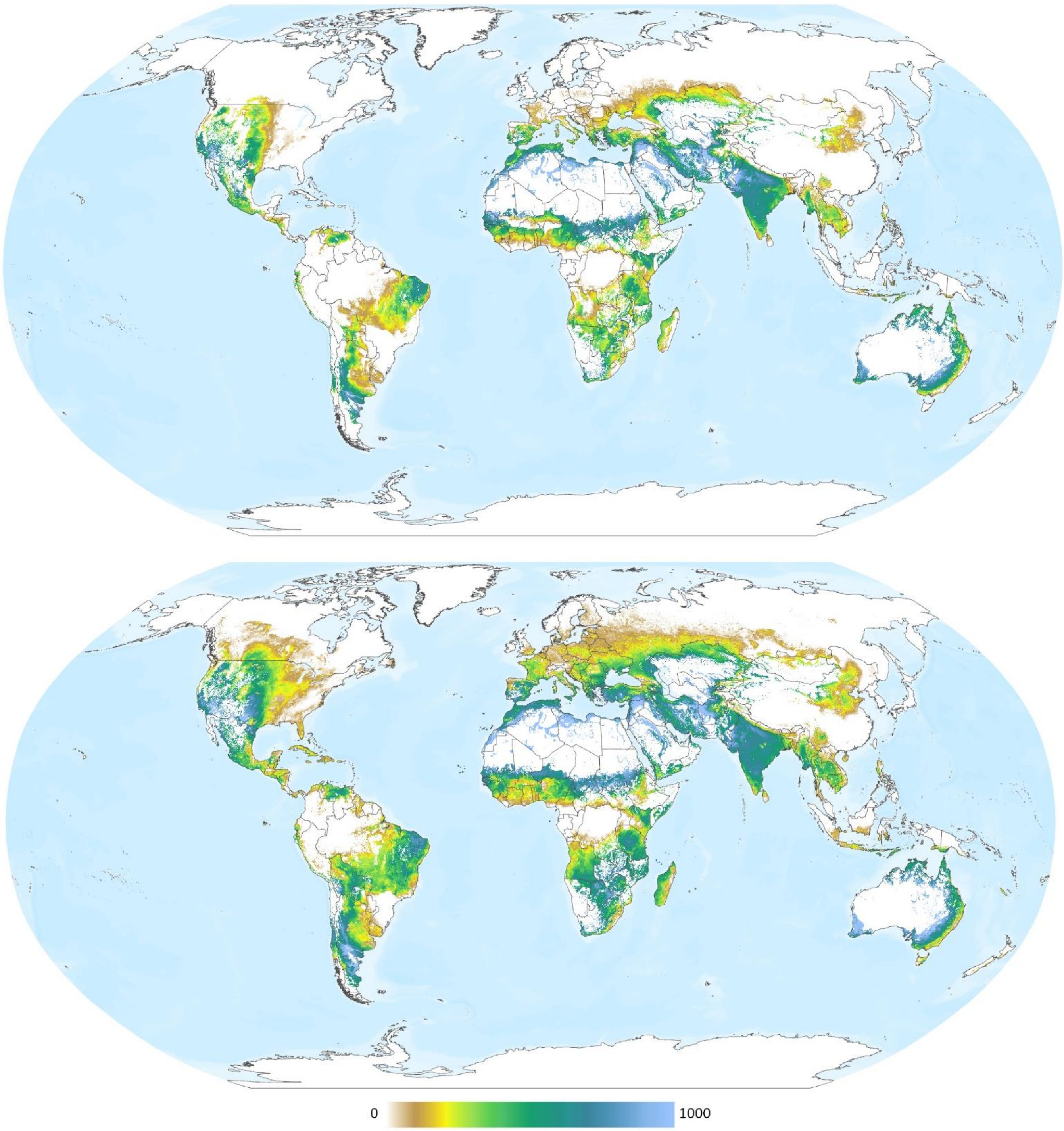
Table 3. Climate change impacts on irrigation demand of irrigated maize.

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	325	6.8	5.6	28.5	44.7
Central America and Caribbean	382	2.2	0.8	8.2	20.0
South America	295	-1.9	-2.3	8.5	17.2
Europe and Northern Asia	255	10.8	3.6	33.3	66.1
Northern Africa and Western Asia	729	1.4	1.7	5.9	8.1
Asia, excl. Western Asia	441	1.9	1.7	4.4	6.4
Sub-Saharan Africa	378	7.7	4.8	13.6	27.3
Oceania	499	-10.3	-5.8	-6.1	-0.4
GLOBAL	431	1.9	1.4	7.3	12.5

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 maize. 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 the amount of net irrigation (in mm) that would be required to cultivate in each location the most productive maize type. The value ranges from no irrigation (0 mm) up to about 1000 mm in some hot arid environments.

Figure 8. Net irrigation requirement (mm) during growth cycle of irrigated maize 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).



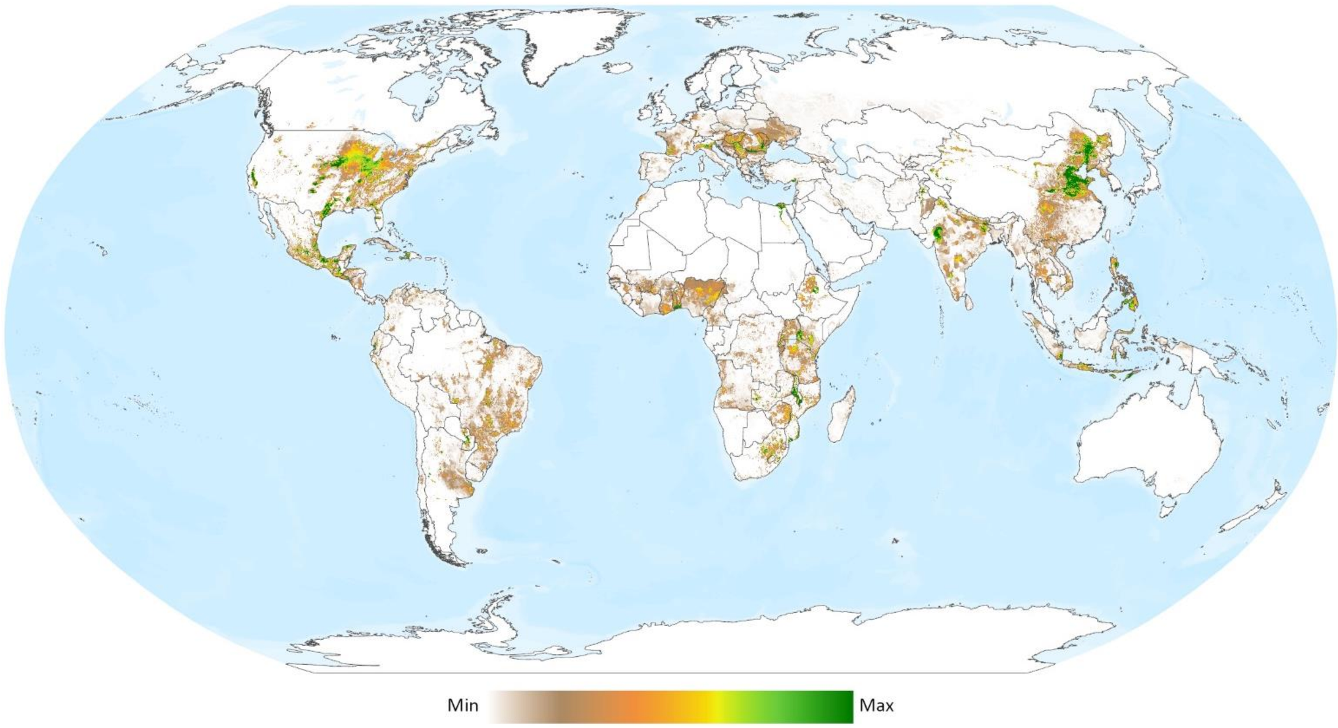
Source: FAO and IIASA. 2021. Global Agro Ecological Zones version 4 (GAEZ v4). URL: http://www.fao.org/gaez/

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 maize as obtained by downscaling of statistical data of 2009–2011. For instance, as shown in Figure 9, the largest concentrations of maize harvested area were found in north-east China and central USA.

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

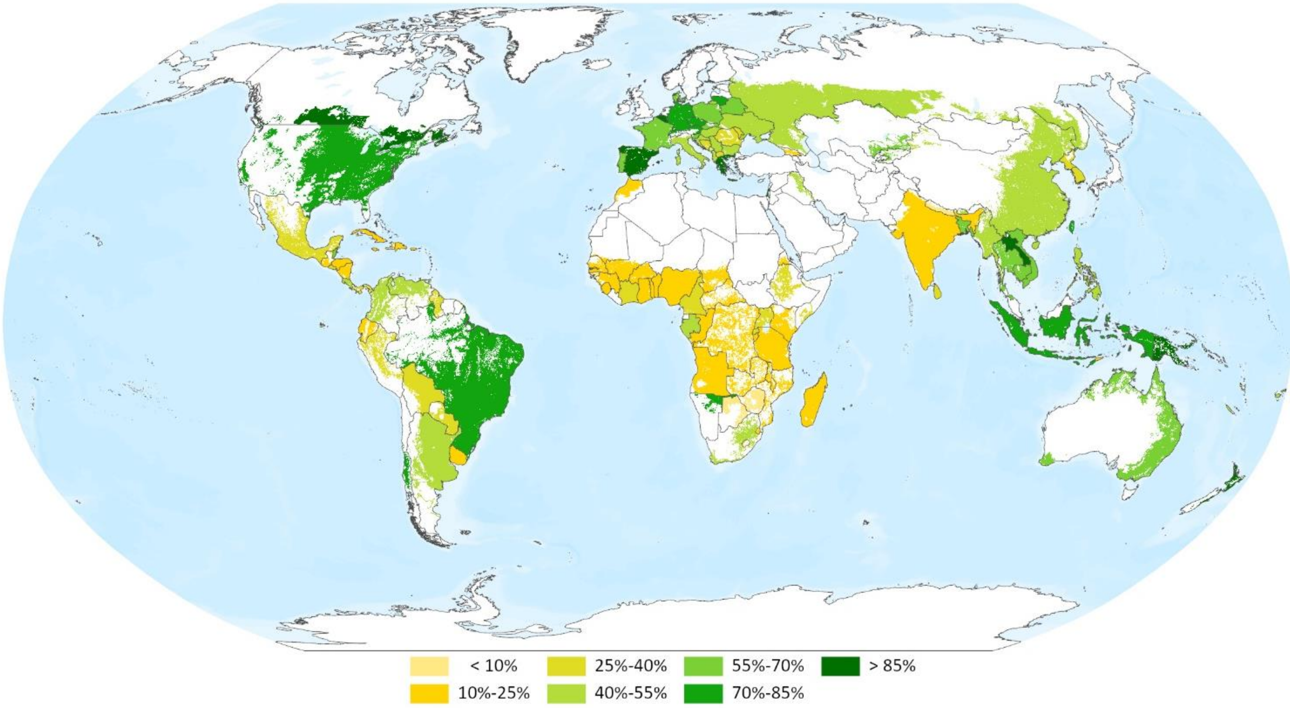


Source: FAO and IIASA. 2021. Global Agro Ecological Zones version 4 (GAEZ v4). URL: http://www.fao.org/gaez/

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., 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%. Available data suggests that in the recent past the highest yield achievement ratios for maize were obtained in Europe, North America and Brazil. Substantial yield gaps occurred in sub-Saharan Africa and countries of South Asia (Figure 10).

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



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