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Global Assessment of impacts of climate change on agricultural productivity – the FAO GAEZ portal

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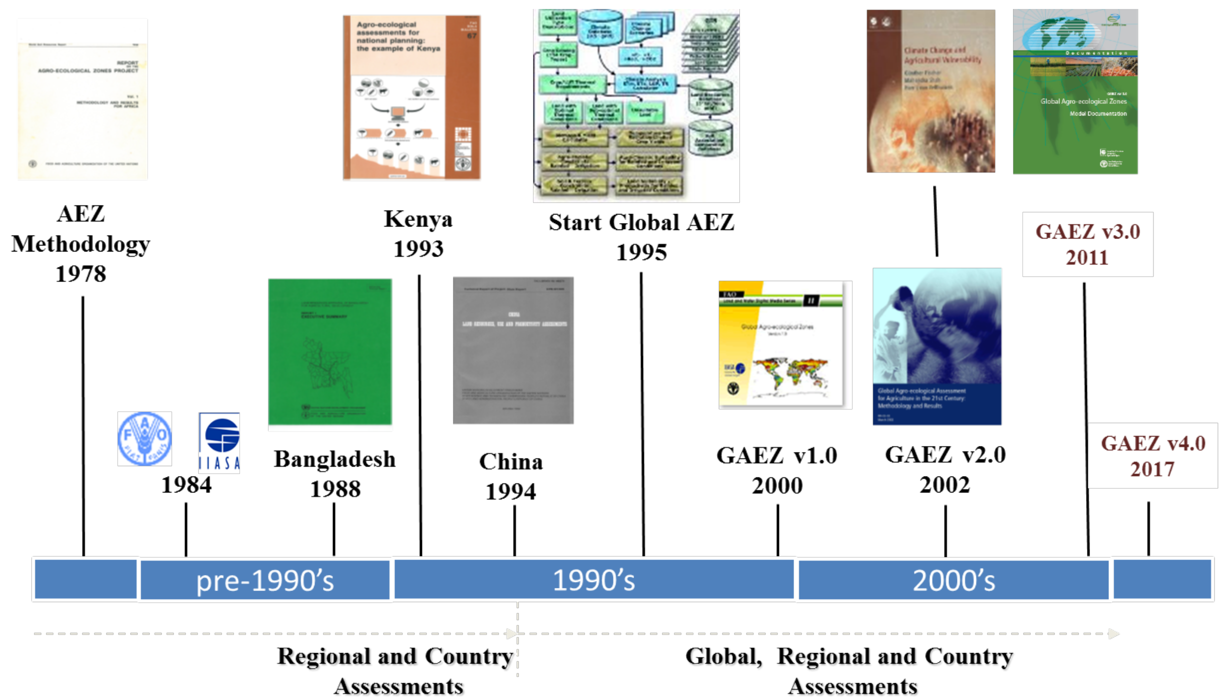
Background



FAO and IIASA have developed the spatial analysis system that enables:

- rational land-use planning
- based on the inventory of land, water and soil resources
- evaluation of biophysical limitations and production potentials of land
- using an environmental approach for evaluating sustainable alternative uses of land

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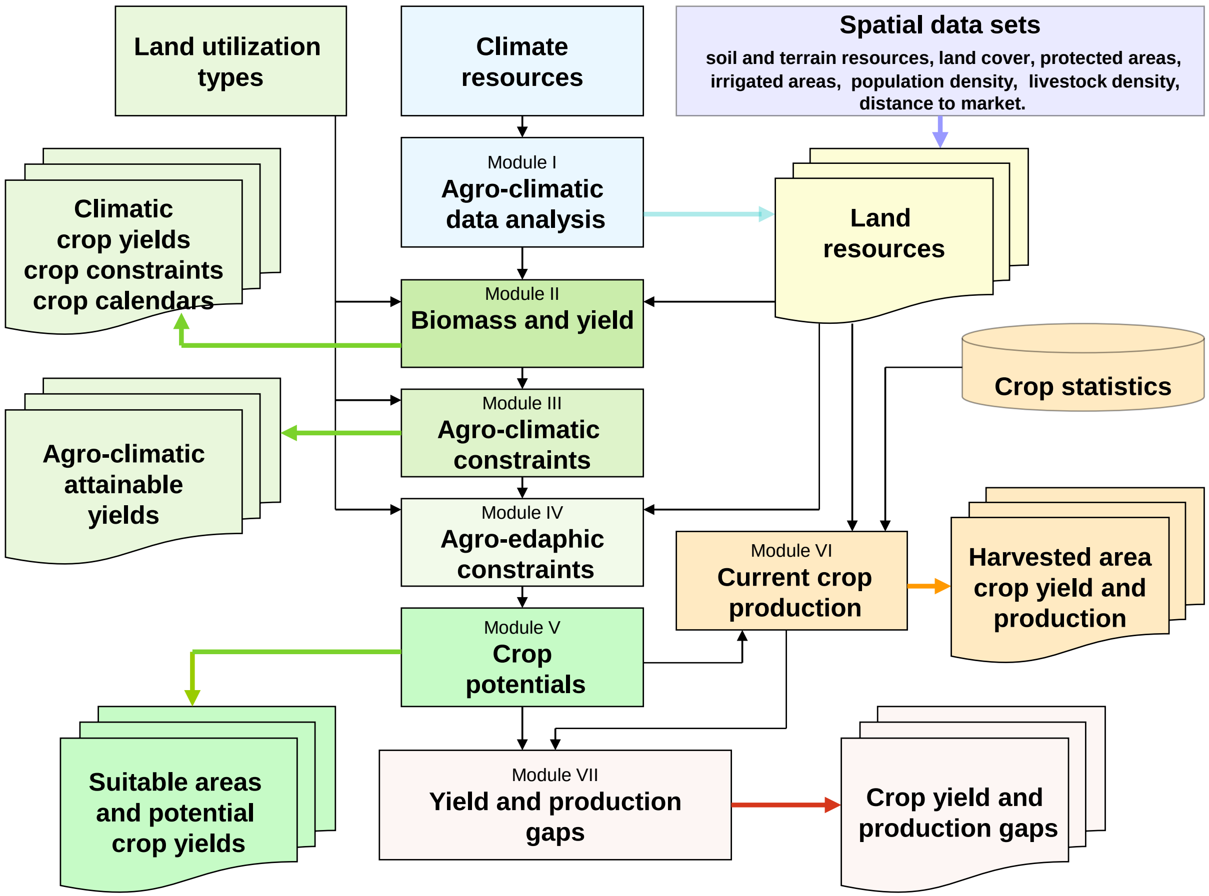
AEZ modules

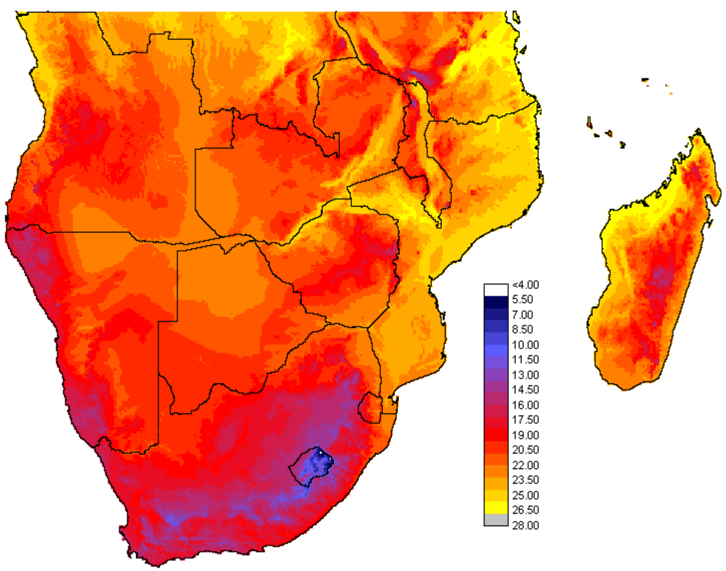


AEZ estimates crop cultivation potential i.e. the agronomically possible upper limit for the production of individual crops under given agro-climatic, soil and terrain conditions for a specific level of agricultural inputs and management conditions.

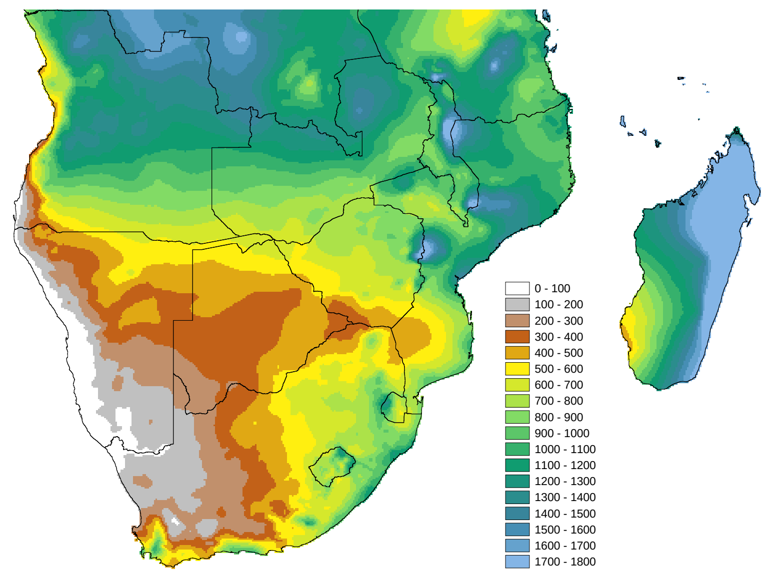
Module I: Agro-climatic analysis

Module I deals with temporal, interpolation, analysis and classification of climate data and creation of historical, base line and future gridded agro-climatic indicators relevant to plant production.

Temperature

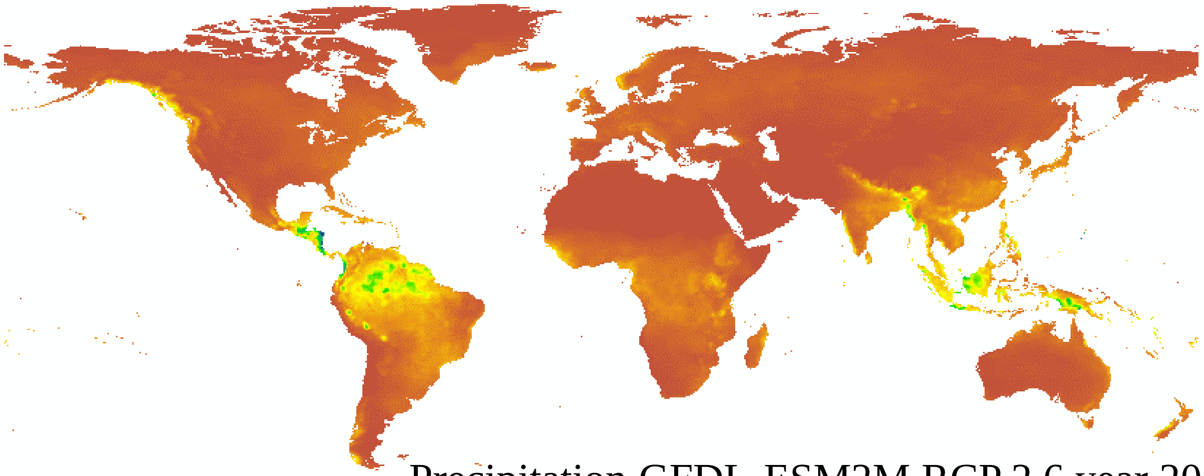


Precipitation



Climatic data

For the **historical assessment** WATCH global sub-daily data were accessed derived from ERA-40 and ERA-Interim Reanalysis. In order to remove model biases from the WATCH dataset, a bias-correction with monthly CRU v3.21 and GPCC v6 (for precipitation) data was computed. Then, WATCH Data was used to compute a within-month precipitation distribution and deviation of daily data temperature for each month for the period 1961-2010. Finally, 30-year baseline data were compiled for the periods 1961-1990, 1971-2000 and 1981-2010. IPCC AR5 climate modelled outputs were accessed from ISI-MIP servers at 0.5 degree for 5 climatic models and 4 RCPs and were used to generate climatic input data for 2020s, 2050s and 2080s.



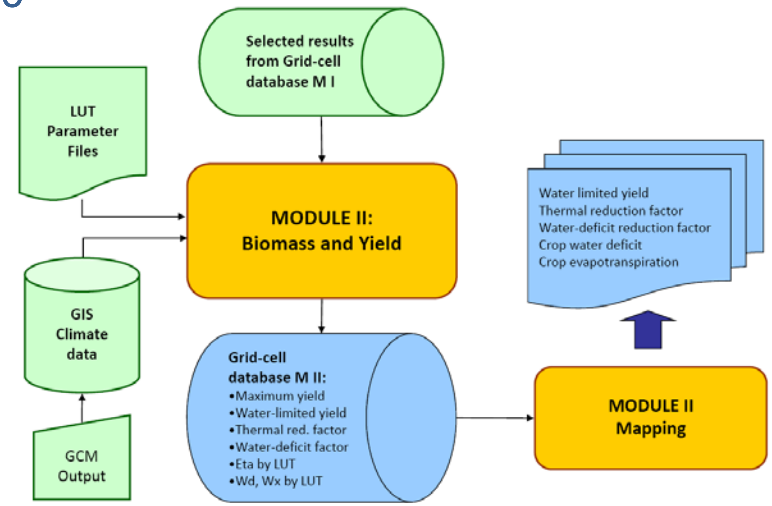
Precipitation GFDL-ESM2M RCP 2.6 year 2032

Module II: Biomass and yield

The main purpose of Module II is the calculation of agro-climatically attainable biomass and yield for specific land utilization types (LUTs) under various input/management levels for rain-fed and irrigated conditions.

The model requires the following crop characteristics:

i. Length of growth cycle (days from emergence to full maturity);
ii. minimum temperature requirements for emergence;
iii. maximum rate of photosynthesis,
iv. respiration rates for leguminous and non leguminous crops as functions of temperature;
v. length of yield formation period;
vi. leaf area index (LAI) at maximum growth rate;
vii. harvest index (Hi);
viii. crop adaptability group, and
ix. sensitivity of crop growth cycle length to heat provision.

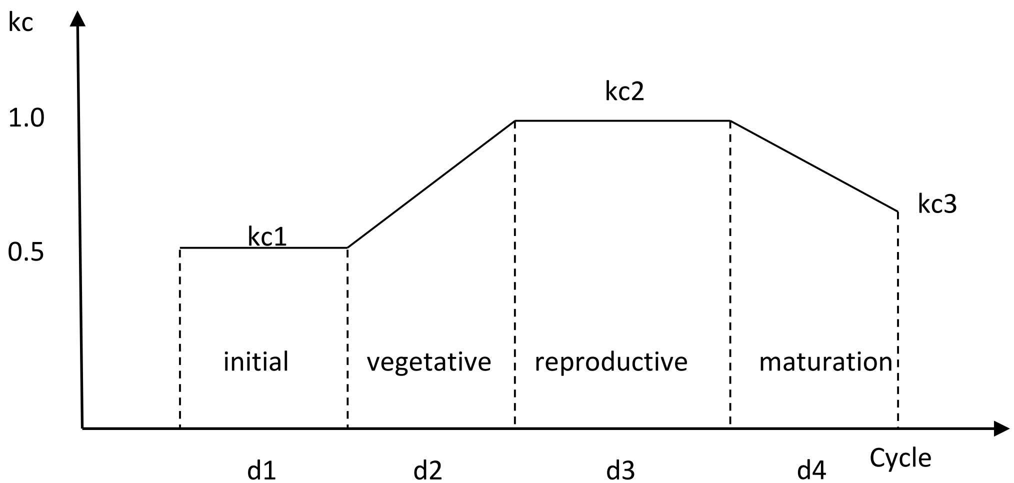


Water limited biomass production and yields

Under rain-fed conditions, water stress may occur during different stages of the crop development reducing biomass production and the yields achieved. Water requirements for each LUT are calculated and taken into account in the calculation of LUT-specific waterbalance and actual evapotranspiration in a grid-cell. A water-stress yield-reduction factor is calculated and applied to the net biomass and potential yield calculated.

Crop water requirement

The total water requirement of a crop without any water stress is assumed to be the crop-specific potential evapotranspiration (ETm). ETm is calculated in proportion to reference potential evapotranspiration (ETo), as in Module I, multiplied by crop and crop-stage specific parameters 'kc'. The values of kc for different stages of crop development are given as input parameters.



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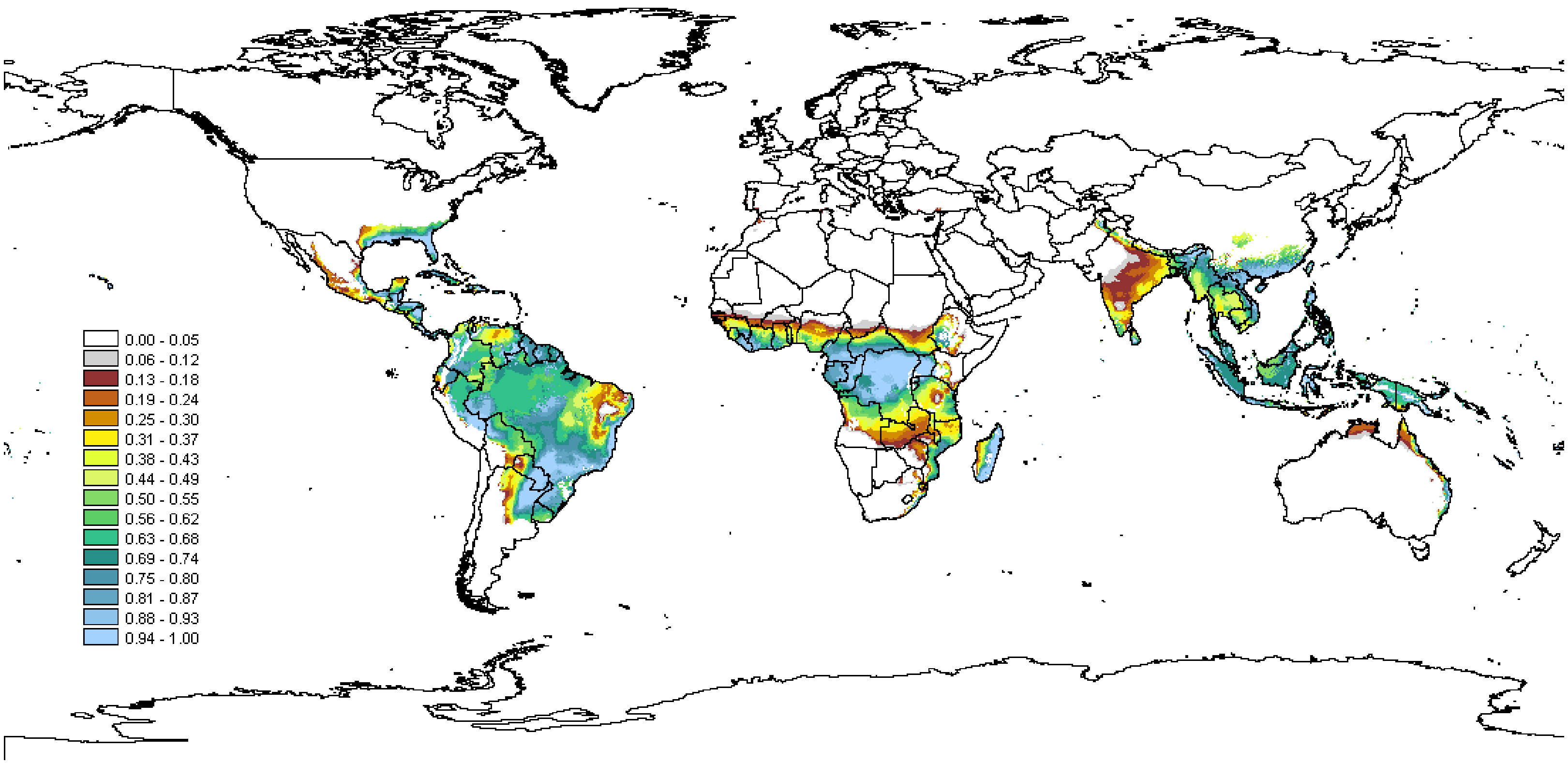
Normalized agro-climatically attainable yield of rain-fed sugarcane



Note: Maximum attainable yields in this global map are about 15 tons sugar per hectare.

Crop suitability

Table 1. Global availability and quality of land resources suitable for crop production

Land quality	Cultivated land (Mkm²)	Grass/wood-land (Mkm²)	Forest land (Mkm²)	Other land (Mkm²)	Total (Mkm²)
Prime land	4	4 (3)	5 (4)	0	13 (12)
Good land	8	11 (10)	11 (10)	0	31 (28)
Marginal land	3	5 (5)	3 (3)	0	11 (9)
Not suitable	0	26 (23)	18 (15)	34 (30)	78 (69)
Total	16 (15)	46 (41)	37 (32)	34 (30)	133 (118)

Source: GAEZ v3.0 simulations of crop suitability for cereals, roots and tubers, sugar crops, pulses, and oil crops. Values in brackets exclude land with protection status.

Global land resources suitable for agricultural production were estimated to comprise 13 Mkm2 of prime land, 31 Mkm2 of good and moderate land and 11 Mkm2 of marginal land

Very clearly, a large part of the suitable land is already in use or is not available for crop production due to its value or use. There is little to very little land per capita available in Northern Africa and Asia and these regions will have to achieve their utmost to overcome resource scarcities with technological improvements and efficiency gains through improved management of land and water resources.

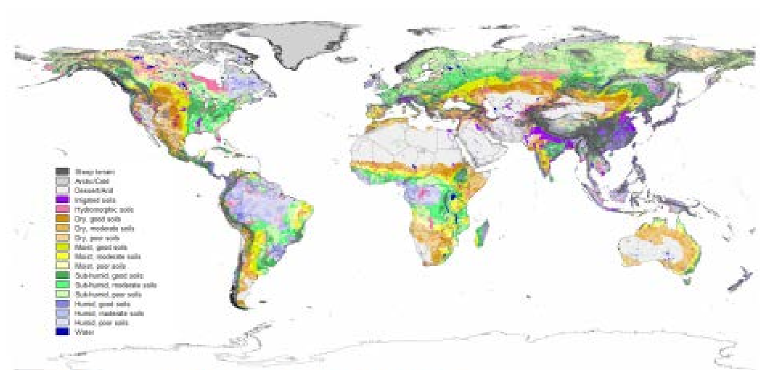
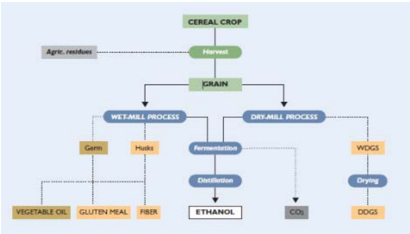


Figure 3: Global agro-ecological zones classification (GAEZ v3.0)

Biofuel expansion



Process flow and by-products of ethanol production from starch crops

Biofuels are being produced from:

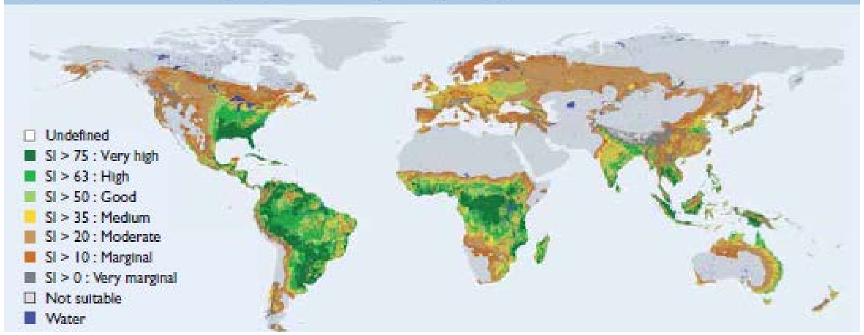
- ethanol (maize, sugarcane, wheat, sugar beet)
- biodiesel (rapeseed, oil palm, soya bean, jathropa)

An AEZ assessment has been conducted looking at relevant LUT to estimate rain-fed biofuel feedstock production under a high level of inputs/advanced management, which includes the main socio-economic and agronomic/farm-management components: market orientation, fully mechanized with low labor intensity, and assumes adequate applications of nutrients and chemical pest, disease and weed control.

Potential suitable areas for selected biofuel feedstocks (Mha) Table 2.7 - 3c

REGIONS	NOT PROTECTED	POTENTIALS *for currently not protected grassland and woodland*						
	Grassland and woodland	Sugarcane	Maize	Cassava	Rape	Soybean	Oil palm	Jatropha
North America	452	2	7	1	31	17	0	5
Europe & Russia	459	0	13	0	45	5	0	0
Oceania & Polynesia	496	2	49	8	13	38	2	8
Asia	511	8	18	10	38	19	5	18
Africa	878	70	326	188	92	346	12	219
Central Amer. & Carib.	71	4	10	4	6	10	2	6
South America	541	141	154	178	103	247	25	211
Developed	1,400	3	68	7	89	58	0	10
Developing	2,007	225	509	382	239	625	44	456
World	3,408	228	577	389	328	683	44	467

Global land suitability for second-generation feedstocks (herbaceous and woody lignocellulosic plant species) Figure 2.7 - 5



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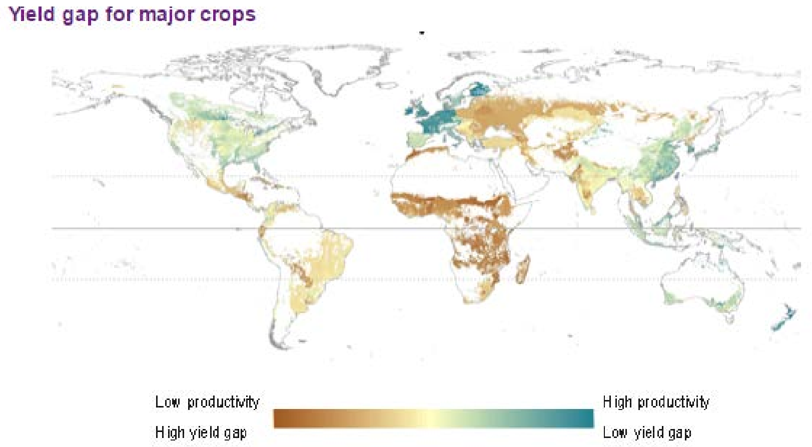
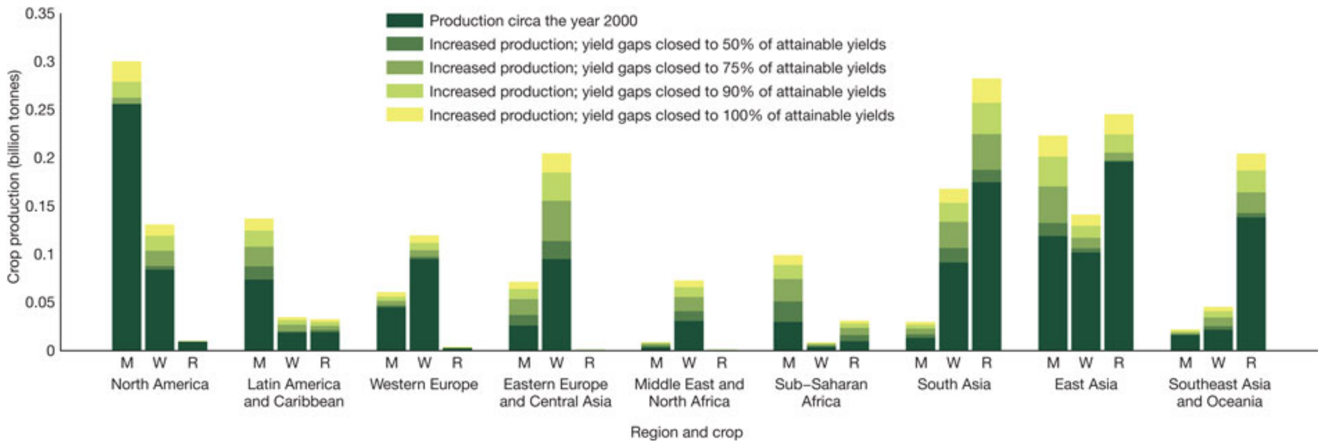
Yield gaps

Yield and production gaps are estimated by comparing potential attainable yields and production with actual achieved yields and production for main commodities.



Current production is extracted from FAOSTAT and downscaled according to a land cover dataset (GLC-Share) and specific crop suit abilities

Global production increases for maize, wheat and rice from closing yield gaps to 50%, 75%, 90% and 100% of attainable yields.
ND Mueller et al. Nature 000, 1-4 (2012) doi:10.1038/nature11420



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Climate change impacts

The availability of global and regional circulation models, allows to assess the agro-climatic crop potentials in future scenarios. By comparing the current and future potentials, the impact of climate change over the agricultural sector can be assessed.

Table 9-6. Impact of climate change on crop suitability and potential production

	Reference 1981-2010		Ensemble mean RCP6.0, 2050s with CO2 fertilization			Ensemble mean RCP6.0, 2050s without CO2 fertilization		
	VS+S mill. ha	VS+S+MS mill. ha	VS+S (Δ %)	VS+S+MS (Δ %)	Potential prod. (Δ %)	VS+S (Δ %)	VS+S+MS (Δ %)	Potential prod. (Δ %)
Major rice	10.1	17.9	-12.0	-4.4	-10.0	-34.3	-13.0	-16.8
Maize	8.9	15.6	35.0	6.9	8.1	19.1	6.0	4.1
Soybean	5.8	16.7	2.4	0.4	-1.1	-9.0	-4.3	-9.7
Cassava	8.8	17.5	-55.4	-25.0	-19.9	-70.8	-33.8	-25.8
Sugarcane	1.1	11.8	-82.5	-76.6	-32.0	-94.5	-78.0	-34.1
Oil palm	2.6	3.2	-26.4	-6.5	-49.0	-39.4	-9.9	-53.0
in South	2.5	2.8	-26.0	-6.1	-12.8	-37.9	-8.6	-19.7
Rubber	1.7	2.9	-20.6	-19.9	-55.0	-28.8	-27.2	-58.5
in South	1.6	2.5	-17.5	-11.4	-11.9	-25.4	-19.4	-18.7
Coffee	0.5	2.4	-96.6	-98.1	-97.5	-98.5	-98.3	-97.7
All 8 crops*	16.9	19.9	-3.7	-0.8	-9.6	-15.5	-2.6	-23.7

Note: VS=very suitable, S=suitable, MS=moderately suitable; * 'Umbrella' of crops giving highest net revenue

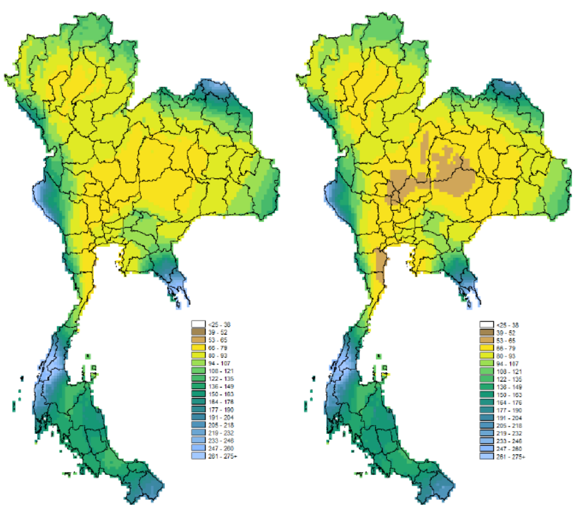

Figure 3-2. Annual P/ET$_0$ ratio for period 1981-2010 and ensemble mean of RCP6.0 in 2041-2070

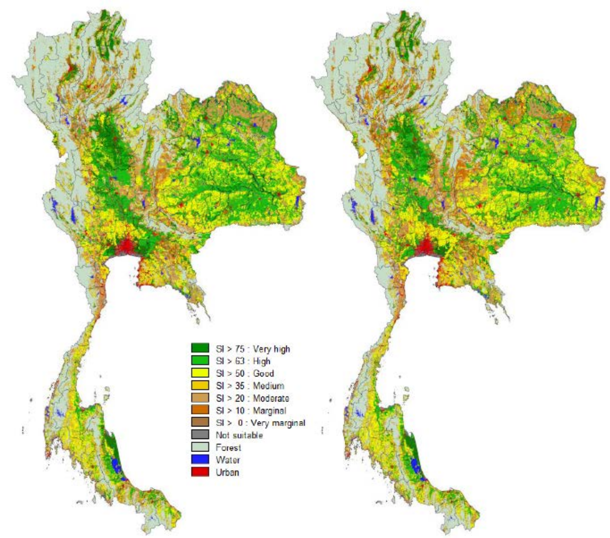

Figure 9-3. Suitability of rain-fed major rice in 1981-2010 and ensemble mean of RCP6.0 in 2041-2070

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Land balance

Gross land balance = the extent of suitable land remaining after deduction of actual cropland
Net land balance = Suitable land minus cultivated land, forest, protected areas and settlements

The land balance is very unevenly distributed among regions and countries. Some 90 percent of the remaining 1.8 billion ha is in Latin America and sub-Saharan Africa, and more than half of the total is concentrated in just seven countries (Brazil, the Democratic Republic of the Congo, the Sudan, Angola, Argentina, Colombia and Bolivia). At the other extreme, there is virtually no spare land available for agricultural expansion in South Asia and the Near East/North Africa. In fact, in a few countries in these two latter regions, the land balance is negative, i.e. land classified as not suitable is made productive through human intervention such as terracing of sloping land, irrigation of arid and hyper-arid land, etc. and is in agricultural use.

World agriculture: an FAO perspective

	Total land surface	Suitable land*	Of which		Of which in use as (1999/2001)		Gross balance	Not usable**	Net balance
			Prime land	Good land	Rainfed land	Irrigated land			
World	13 295	4 495	1 315	3 180	1 063	197	3 236	1 824	1 412
Developing countries	7 487	2 893	816	2 077	565	138	2 190	1 227	963
Sub-Saharan Africa	2 281	1 073	287	787	180	3	890	438	451
Latin America	2 022	1 095	307	788	137	15	943	580	363
Near East / North Africa	1 159	95	9	86	38	12	45	9	37
South Asia	411	195	78	117	85	55	55	43	11
East Asia	1 544	410	126	283	122	53	234	140	94
Other developing countries	70	25	9	15	2	0	23	16	7
Developed countries	5 486	1 592	496	1 095	497	58	1 037	590	447
Rest of the world***	322	11	3	8	2	0	8	7	1

Source: GAEZ-v3.0 in Fischer *et al.* (2011).
* Crops considered: cereals, roots and tubers, sugar crops, pulses and oil-bearing crops. Includes Very Suitable, Suitable and Moderately Suitable land.
** Land under forest, built-up or strictly protected.
*** Countries not included in the regions above and not covered in this study.

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Agro-economic analysis

Based on the spatial evaluation of agro-ecologically attainable yields, the production cost structure of 2014 and using average farm gate prices of 2010-2014, attainable net revenues were calculated for eight major crops – rice, maize, cassava, soybeans, oil palm, para-rubber, sugarcane and coffee. Where production costs exceed gross returns (i.e. price times attainable yield), grid-cells were marked as economically unsuitable for the respective crop.

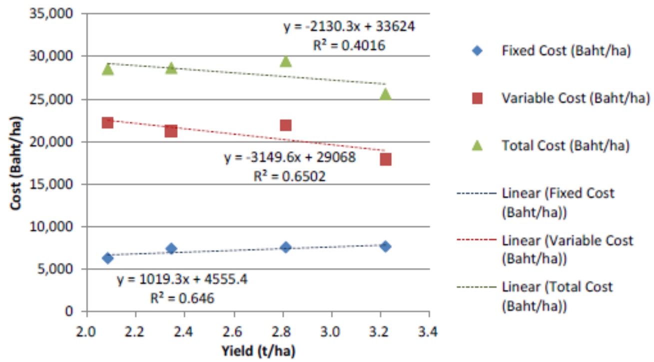

Figure 8-2. Cost of production vs Yield in 2014, Major Rice

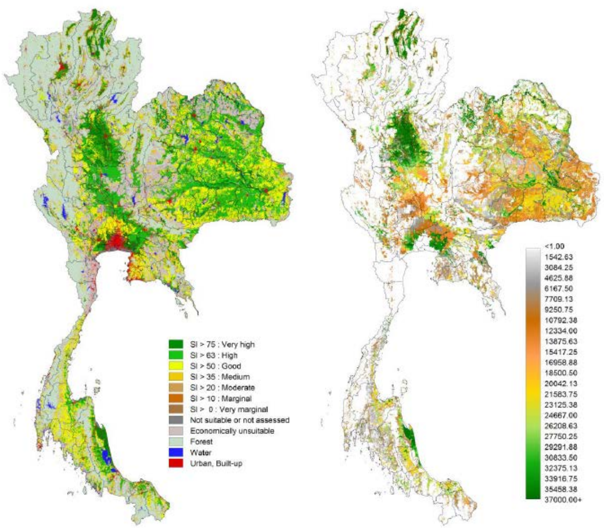

Figure 8-9. Suitability in economically viable areas (left) and potential net revenue (right) of major rice

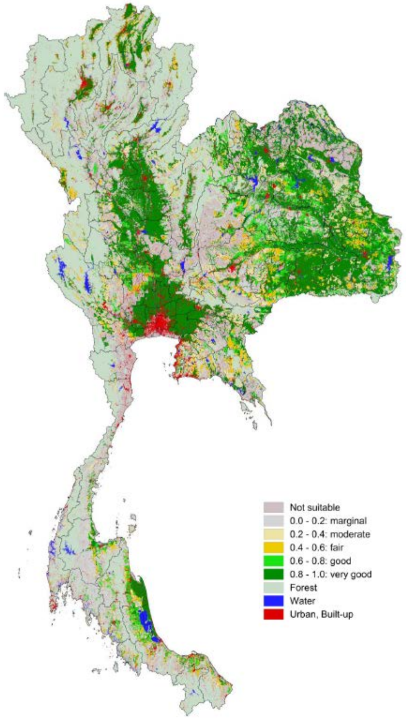

Figure 8-10. Comparative economic performance of major rain-fed rice relative to 'umbrella'

FAO GAEZ data portal

- Designed to facilitate access to the GAEZ database and resources, it delivers terabytes of spatial data, maps, tables, statistics, metadata, reports
- Fully documented (Data model, User's Manual, GAEZ definitions, FAQ, limitations, and hints available)
- Compliant with FAO definitions, classifications and standards, ISO metadata standards to feed FAO GeoNetwork
- Based on a multi-dimensional database
- It enables public access to data and information, becoming a gateway global, regional and local geospatial and tabular information on agricultural resources and potential productivity

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GAEZ factsheet - Dimensions

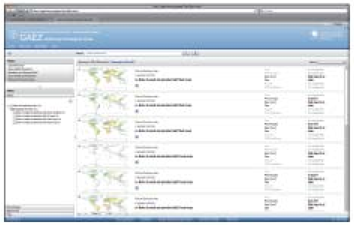
- THEMES
  - *5 thematic areas (> 350,000 global datasets at mainly 5 arc-minutes*
- CROPS
  - 11 crop groups, 49 crops, 92 crop types and 280 Crop/LUTs
  - downscaling of 23 crops/commodities are available for 23 crop/commodities
  - yield and production gap analysis for 17 crops/commodities
- WATER SUPPLY
  - *5 water supply types* (rain*-fed, irrigation, gravity, sprinkler, drip)*
- INPUT LEVELS
  - *4 Input levels (High, Intermediate, Low, Mixed)*
- TIME PERIOD
  - *Historical 1961-2000, 30 year average (1961-1990) and Future, 2020s, 2050s, 2080s)*
- 4 RCPs

GAEZ database outputs

- Geospatial datasets (raster format)
- Tabular data aggregated for current major land use/cover patterns
- Reports in PDF format
- Screenshots for quick presentation
- Metadata (dynamic: created on-the-fly using ISO metadata standards)
- Documentation and manuals

ORGANIZED BY 5 MAJOR THEMATIC AREAS:

- LAND & WATER RESOURCES
- AGRO-CLIMATIC RESOURCES
- AGRICULTURAL SUITABILITY & POTENTIAL YIELDS
- ACTUAL YIELDS AND PRODUCTION
- YIELD AND PRODUCTION GAPS



http://gaez.fao.org/Main.html#