


Global analysis using crop modeling and agro-ecological databases to assess global food production trends

‘Global Food Production under Changing Climate and Increased Variability’

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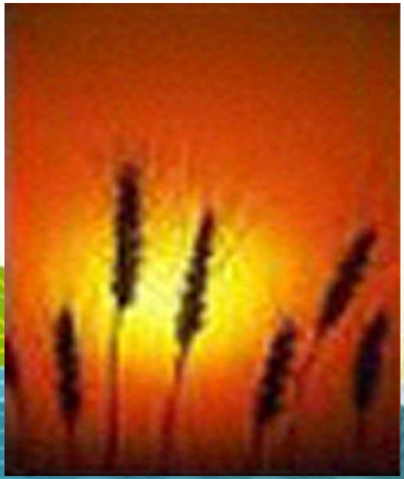
Land & Water: Some key issues

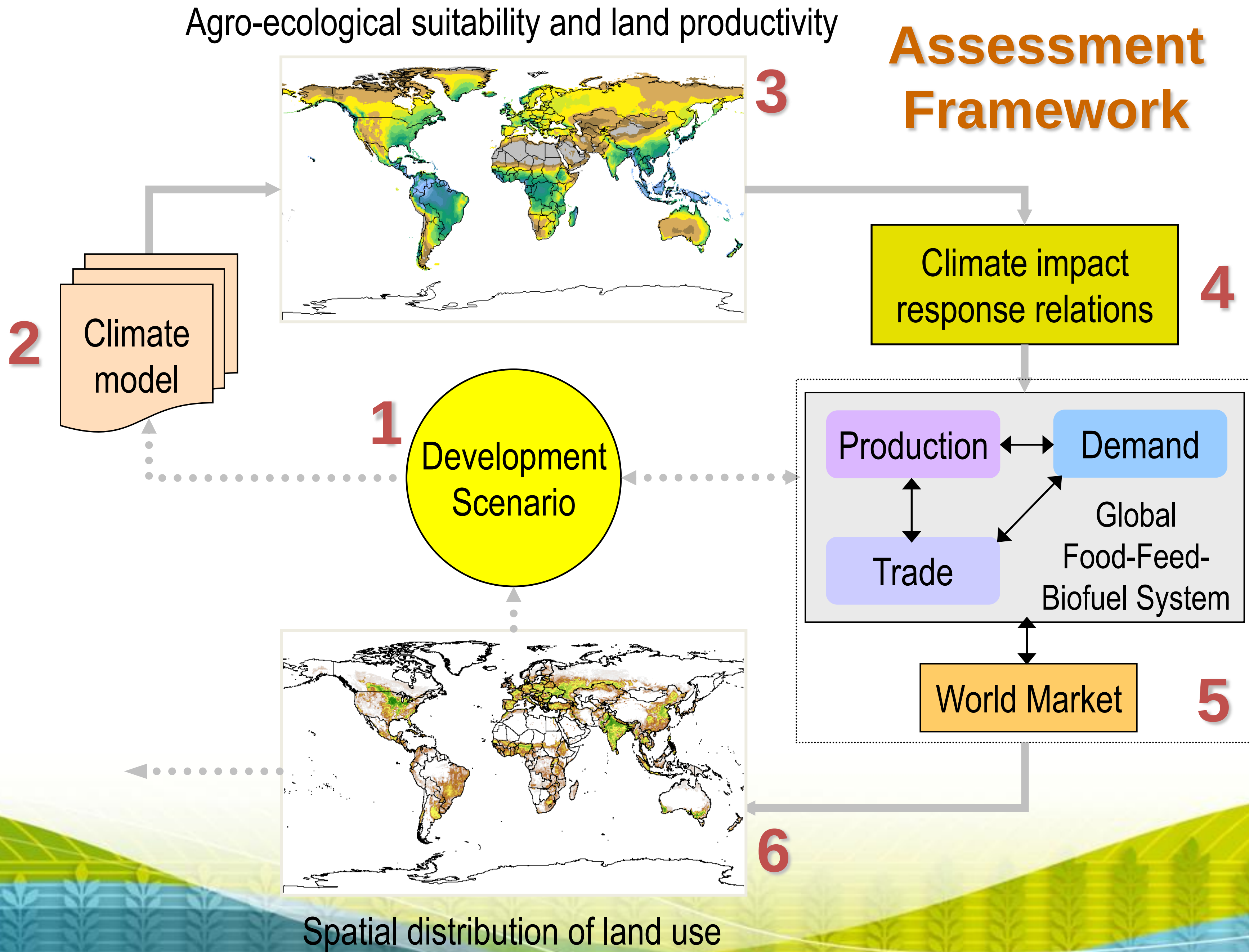
- Population increase by 2050 expected to be +50% globally; +60% in less developed countries; more than doubling in Sub-Saharan Africa.

- Agriculture is the largest user of water; the sector is highly dependent on water resources, accounting for 70% of total water withdrawals; some 40% of the global food crop is derived from irrigated agriculture.
- Agriculture is in competition with other water users and has impacted negatively on the environment.



- Food and water supply are key human sectors exposed to climate change. Climate-change impacts are already being felt in many countries; further global warming will be unavoidable.
- Agriculture is a major source and sink of greenhouse gases via land use changes, land management and livestock production.

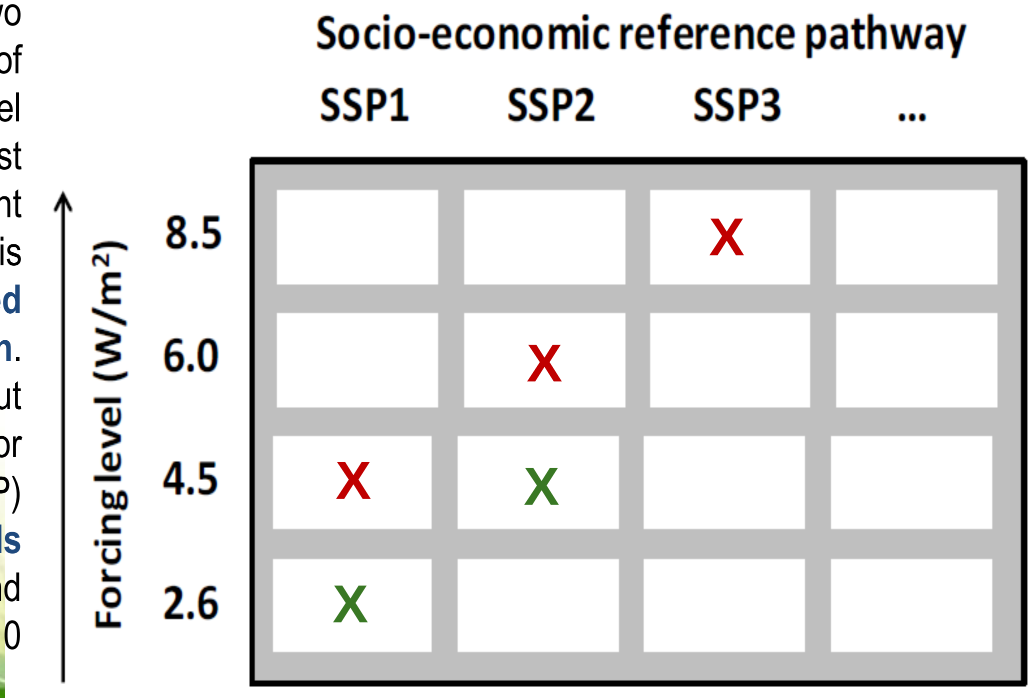
Assessment Framework



Linkages to IPCC process: RCPs and SSPs

Representative Concentration Pathways (RCP): Representative Concentration Pathways (RCPs) are a set of **four greenhouse gas concentration (not emissions) trajectories** developed for the climate modeling community as a basis for long-term and near-term modeling experiments adopted by the IPCC for its fifth Assessment Report (AR5). The four RCPs together **span the range of year 2100 radiative forcing values found in the open literature**, i.e. from 2.6 to 8.5 W/m2 (van Vuuren et al., 2011). The four RCPs – RCP2.6, RCP4.5, RCP6, and RCP8.5 – are named after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6.0, and 8.5 W/m2, respectively).

Shared Socioeconomic Pathways (SSP): Based on the overall framework laid out in a publication in Nature (Moss et al., 2010), the Shared Socioeconomic Pathways (SSPs) process is an effort by the scientific community to develop the next generation of global socio-economic scenarios, to be used in both emission **mitigation analyses** and for **impacts, adaptation and vulnerability studies**. The SSPs define the state of human and natural societies at a macro scale and have two elements: a narrative storyline and a set of quantified measures that define the high-level state of society as it evolves over the 21st century under the assumption of no significant climate feedback on the pathway. This assumption allows the **SSP to be formulated independently of a climate change projection**. At this stage, the preliminary storylines about future changes and quantitative scenarios for **key drivers** (population, urbanization and GDP) **have been described for five possible worlds** based on different challenges for mitigation and adaptation and have been developed since 2010 during a series of workshops.



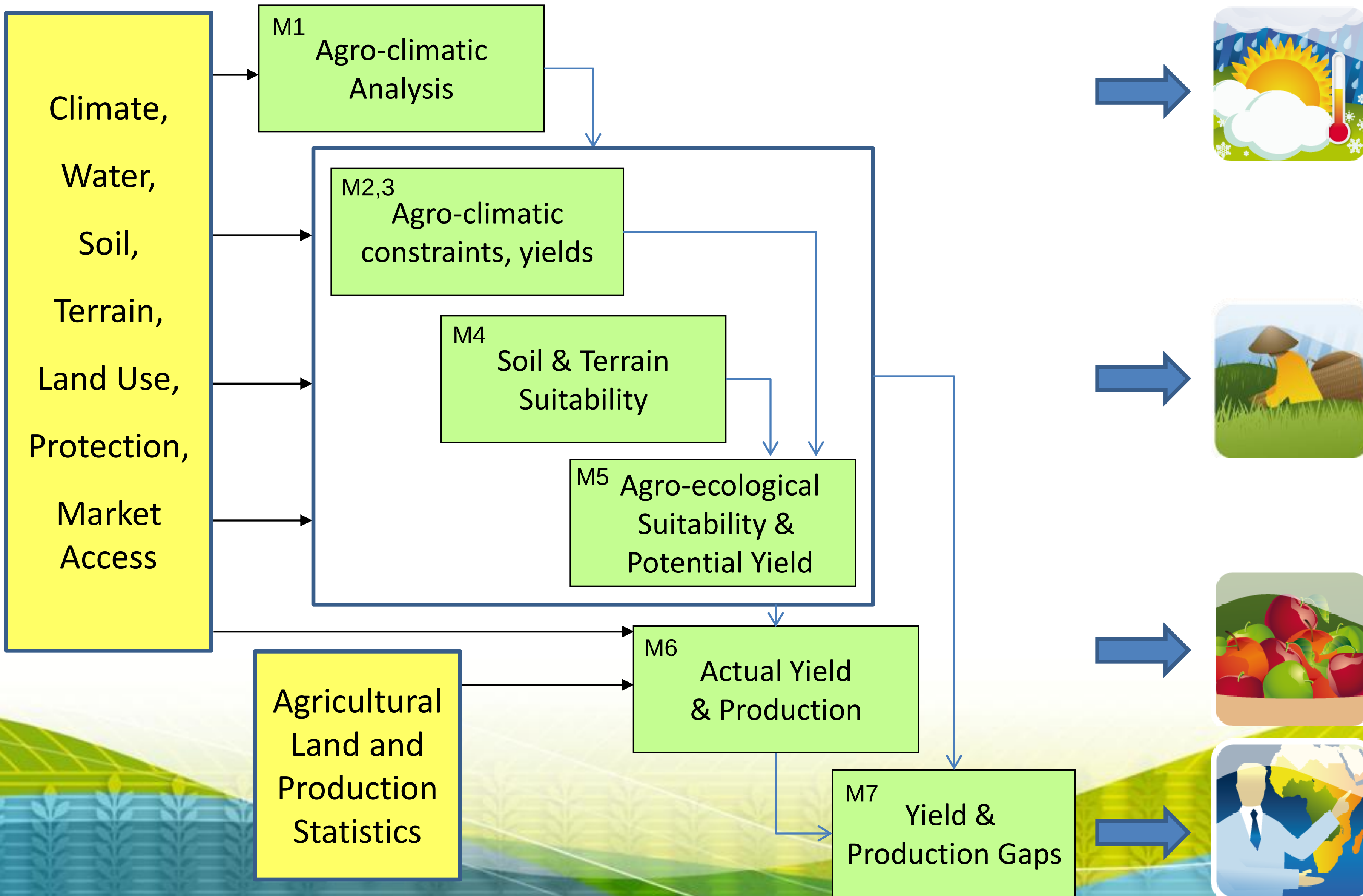
Land Resources & Agro-ecological Zoning:

- FAO and IIASA have developed a spatial analysis system that enables rational land-use planning on the basis of an inventory of land resources and evaluation of biophysical limitations and production potentials of land.
- The AEZ methodology follows an environmental approach; it provides a standardized framework for analyzing synergies and trade-offs of alternative uses of agro-resources (land, water, technology) for producing food and energy, while preserving environmental quality.

- The AEZ analysis yields knowledge about current and future production potentials of land, helps identify land and water limitations and provides insight into current yield and production gaps and their causes.

GAEZ
Global Agro-Ecological Zones

GAEZ v3.0 Modules



GAEZ Global Agro-Ecological Zones

FAO LAND & WATER

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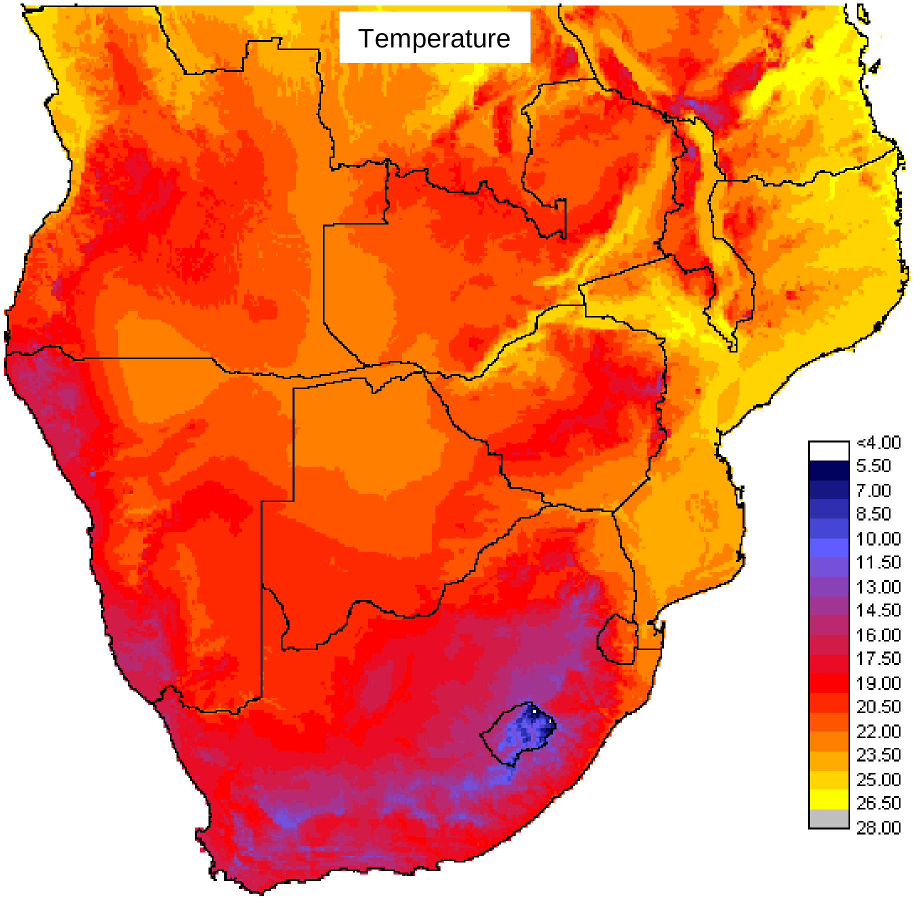
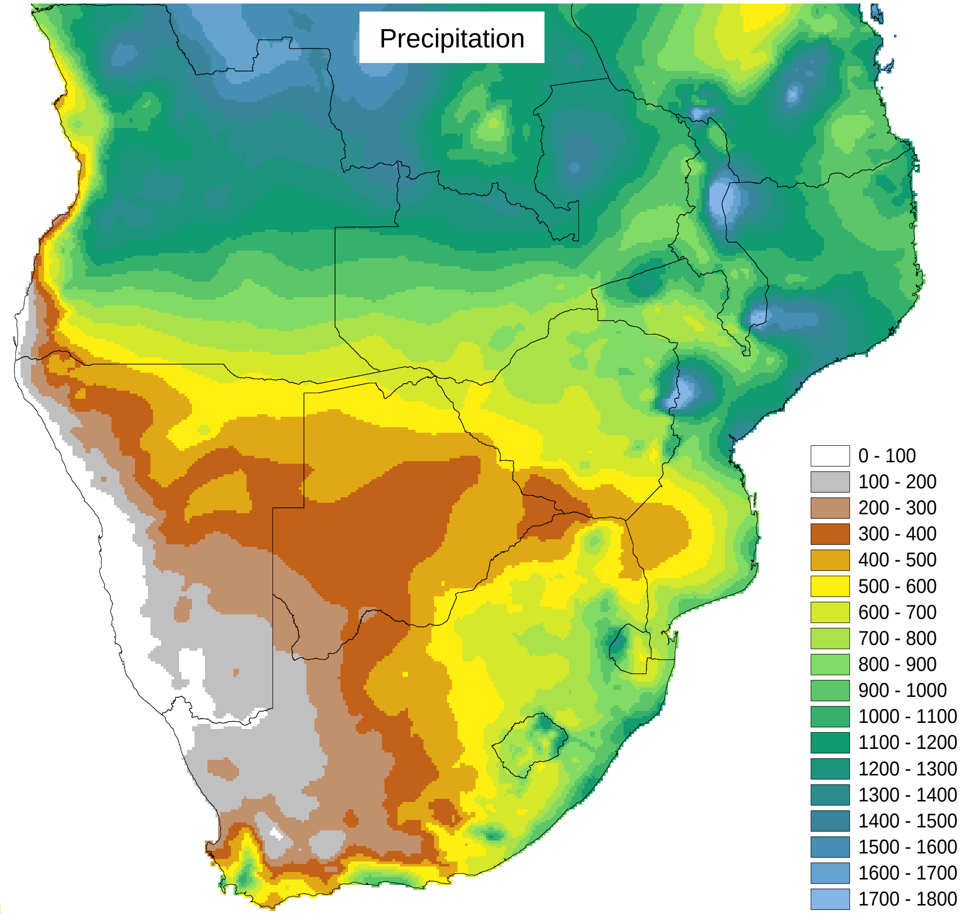
Global Agro-ecological Zones
Land Characterization Database (Climate)





Monthly climatology 1901 – 2011; CRU at University of East Anglia; interpolated at 5 arcmin latitude/longitude (example: average annual temperature, mean annual precipitation)

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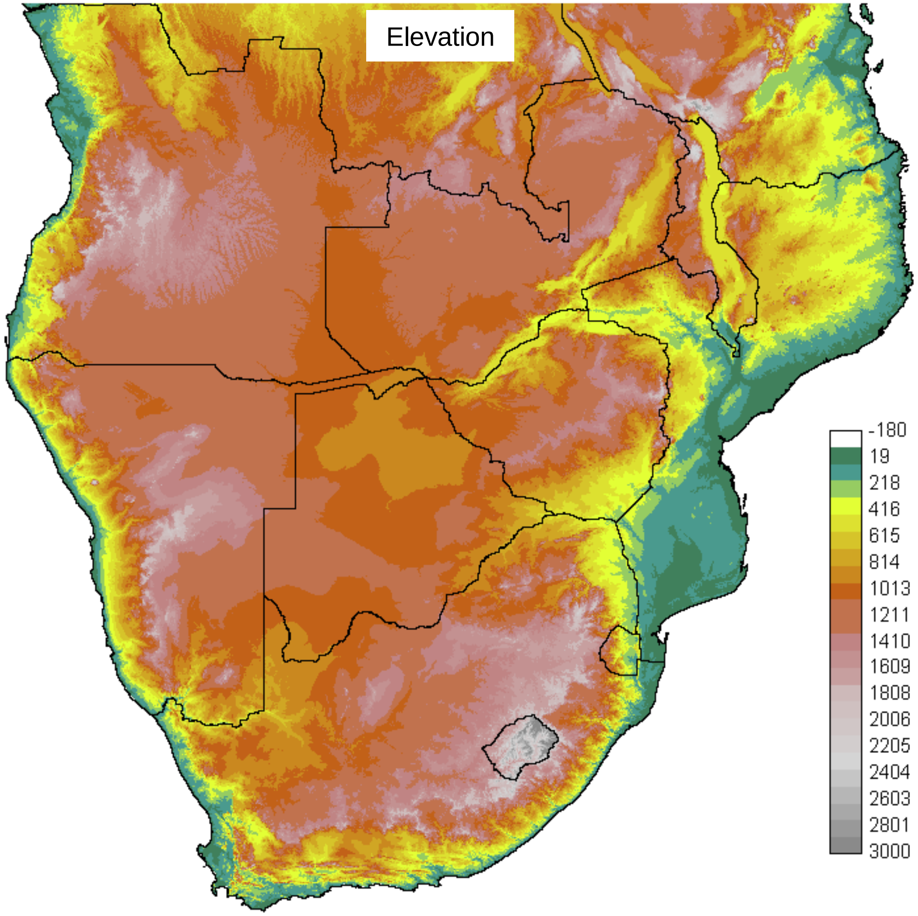
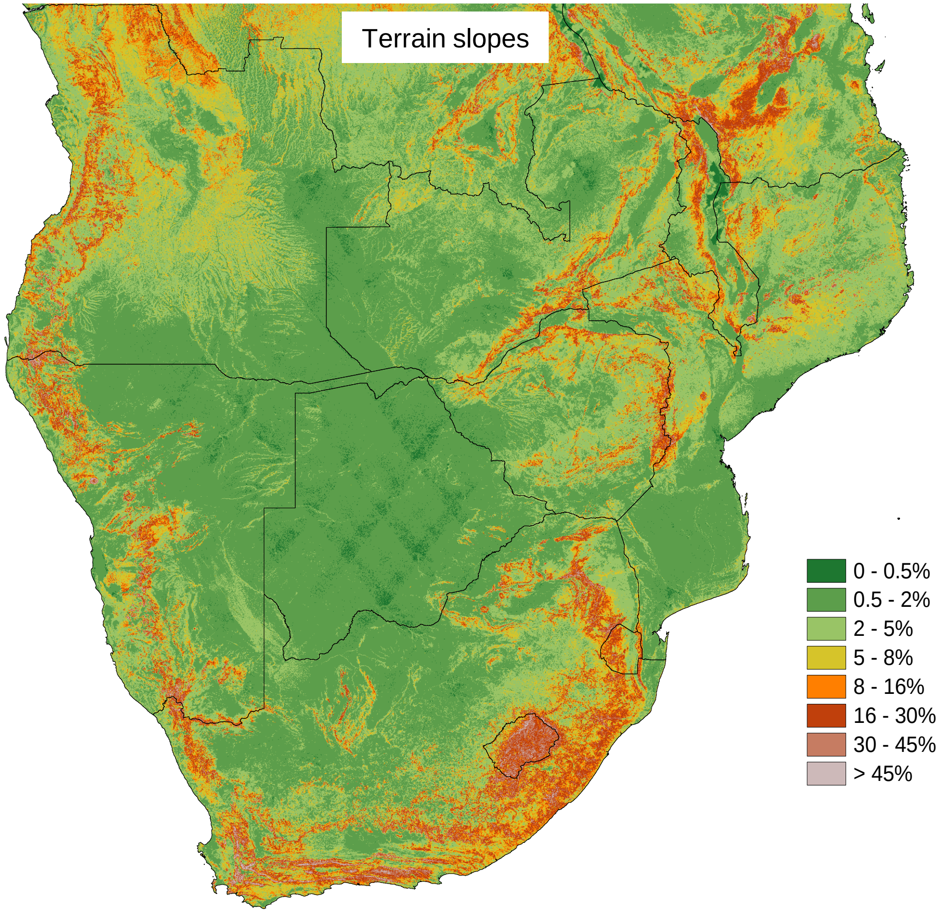
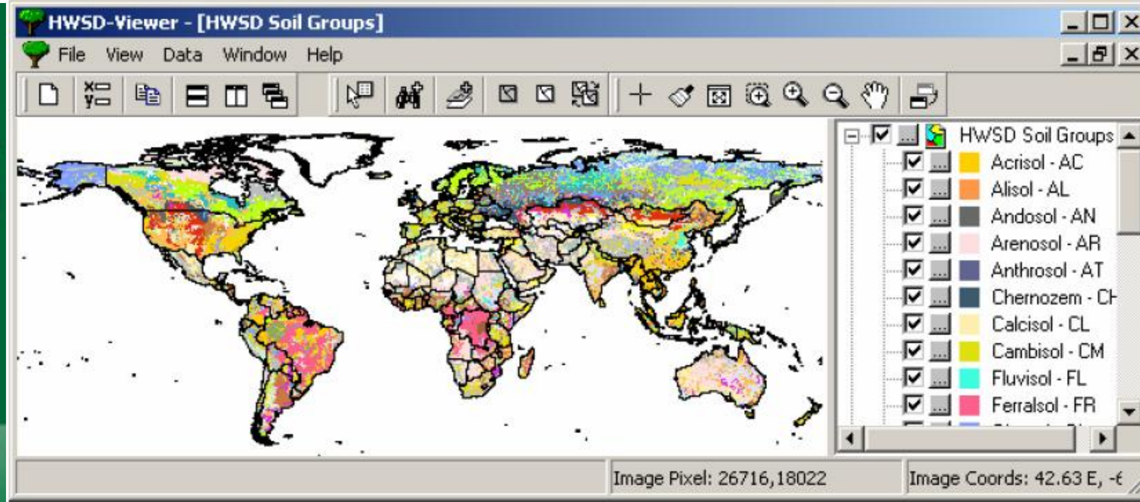
Land Characterization Database (Terrain)





Median altitude, terrain slope and aspect database derived from NASA-SRTM digital elevation data at 3 arc-seconds latitude/longitude

Harmonized World Soil Database

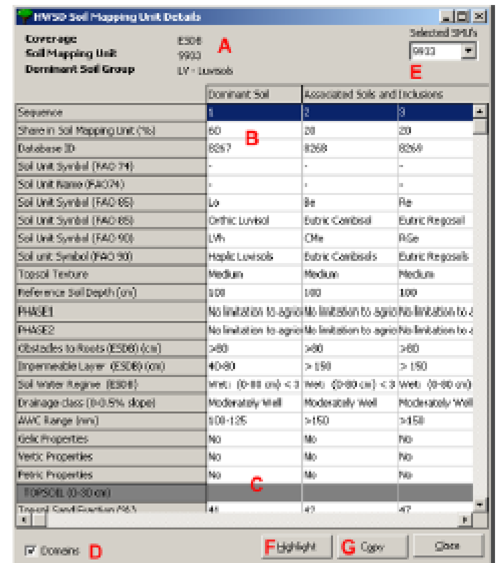


IIASA and FAO with other partners have produced a **new harmonized world soil database** (HWSD) by combining the major regional soil/SOTER maps/databases produced over the last 10 years and using soil profile information derived from WISE and other sources.

The HWSD Soil Mapping Unit Details

The HWSD Soil Mapping Unit Details page lists the soil mapping unit properties for the selected soil unit in the HWSD.

There are seven areas (A to G) in the form.



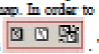
A The most important properties of the selected SMU: the coverage, the SMU identifier (MU_GLOBAL) and the Soil Mapping Unit code.

B The data area, listed by share, with the dominant soil in the first column.

C Beginning of the soil physico-chemical properties (scroll down).

D Display the domain values of data or the numerical entries from the database.

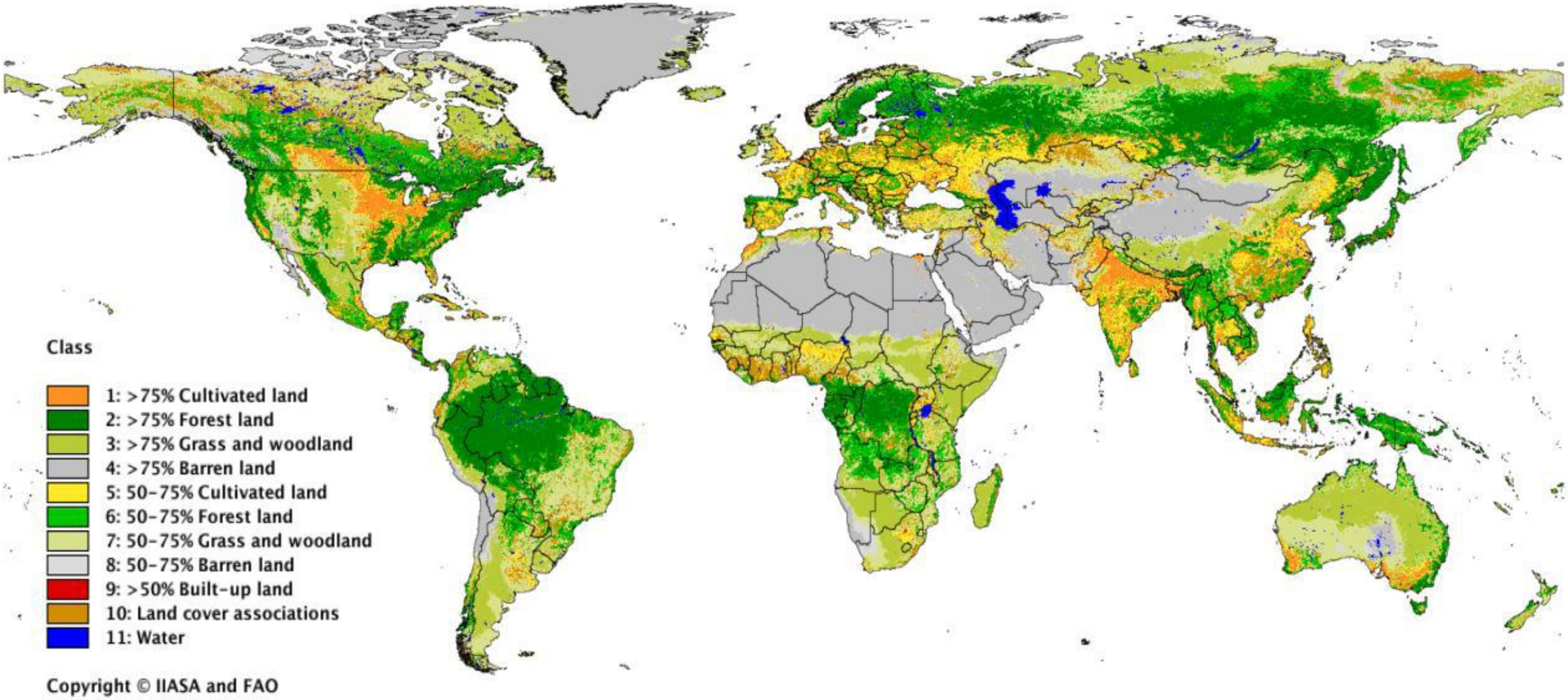
E List of selected SMUs. You can return here to a previously selected unit and display its properties.

F Highlight the selected SMU on the map. In order to find the selected SMUs, you might need to use the legend manipulation tools in the icons . The selection color can be changed from the *HWSD Query Tool*.

G Copy the contents of the table to the clipboard, to be directly pasted in Microsoft Excel.

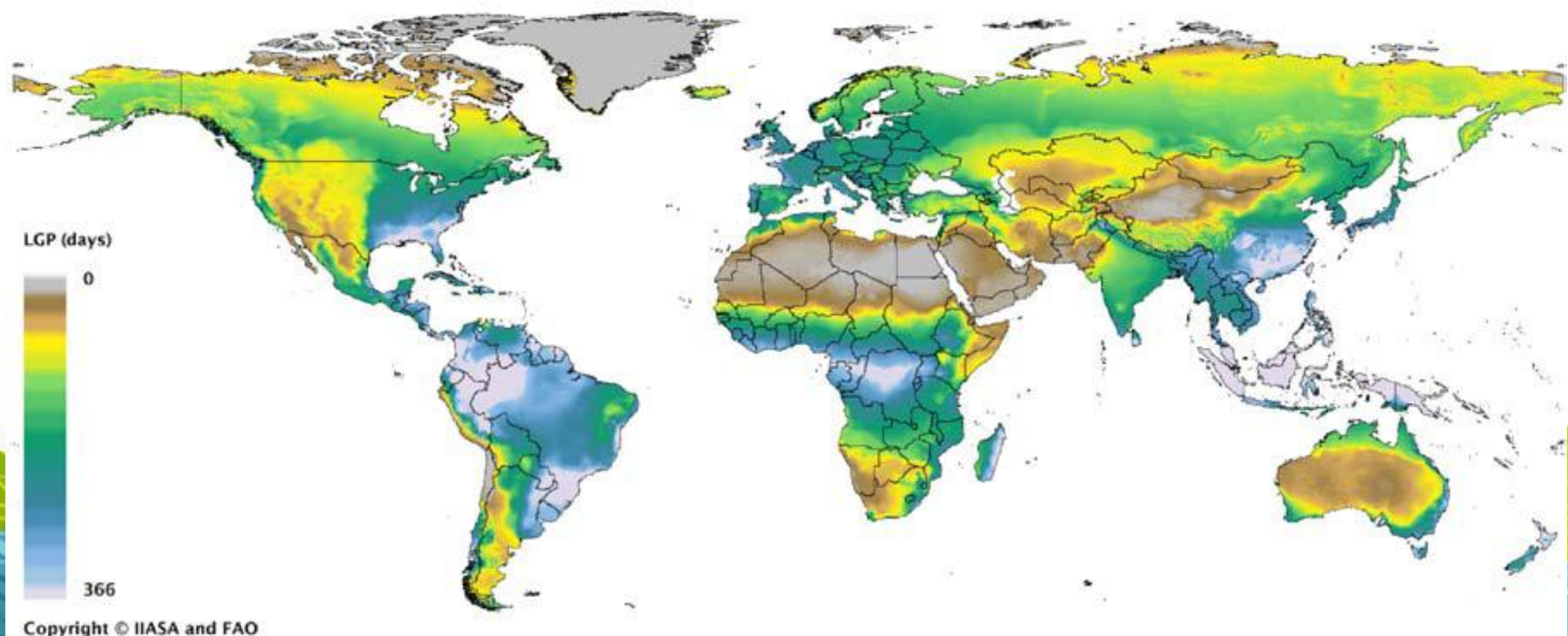
For establishing consistent land balances, the major land use/land cover categories are expressed as percentage occurrence in each grid-cell:

1. Rain-fed cultivated land
2. Irrigated cultivated land
3. Forest
4. Grassland and other vegetated land
5. Barren and very sparsely vegetated land
6. Water
7. Urban land and land used for housing and infrastructure.



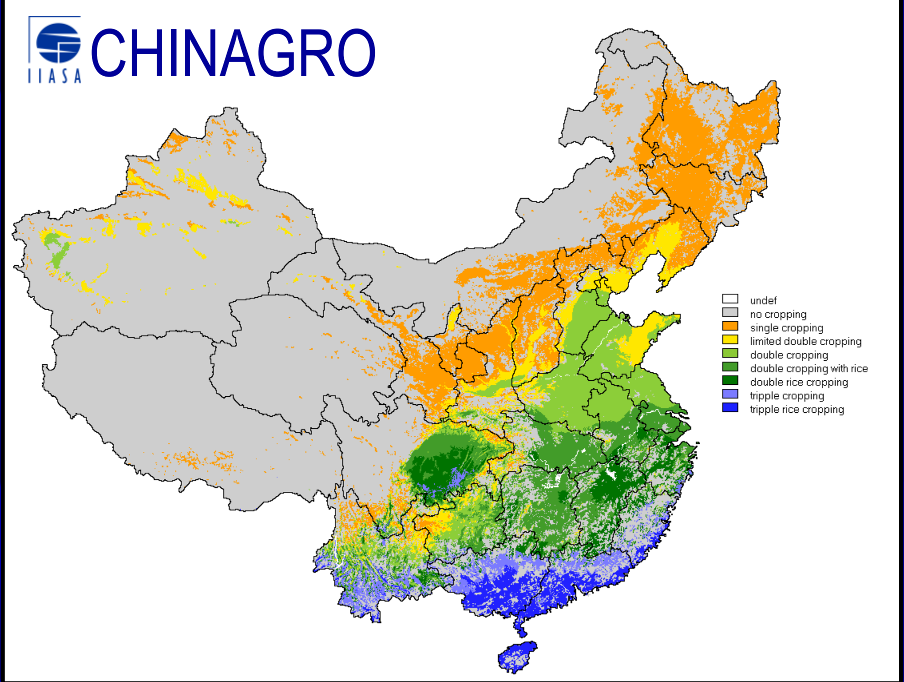
Length of growing period (LGP)

The agro-climatic potential productivity of land depends largely on the number of days during the year when temperature regime and moisture supply are conducive to crop growth and development. This period is termed the length of the growing period (LGP).

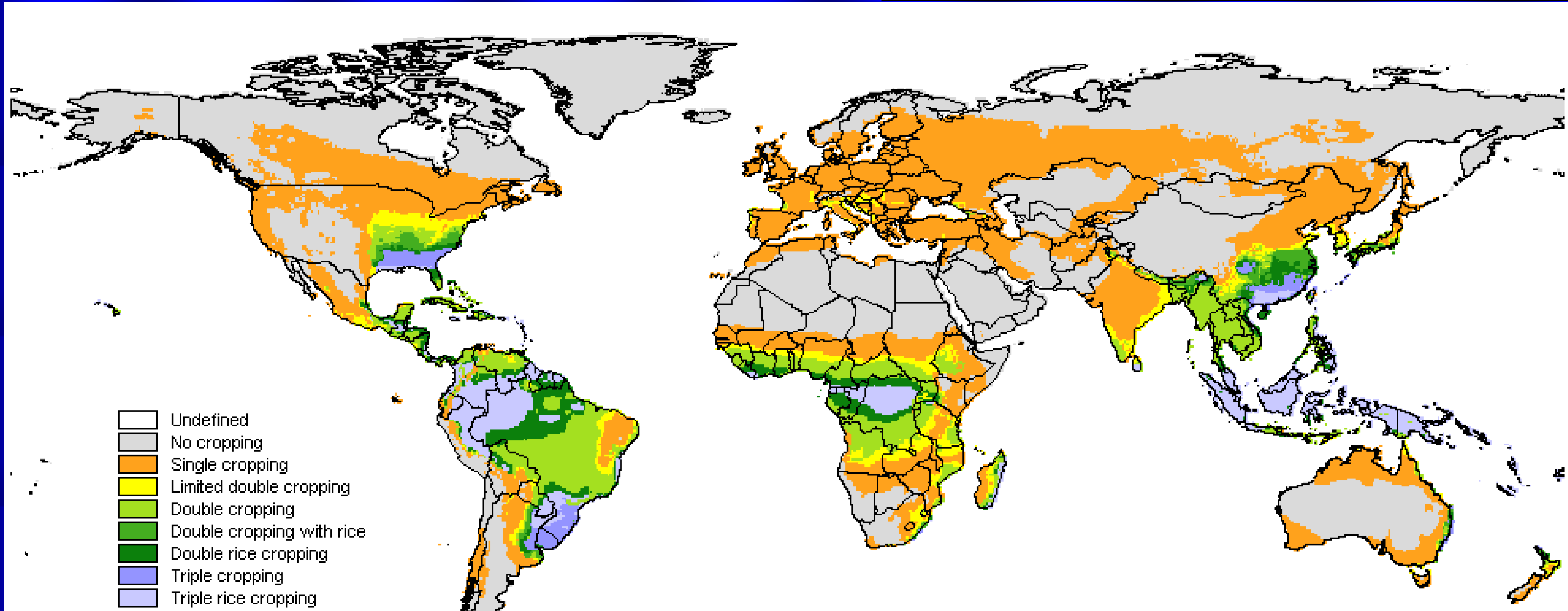


Multiple cropping Zones

Rain-fed & irrigated conditions

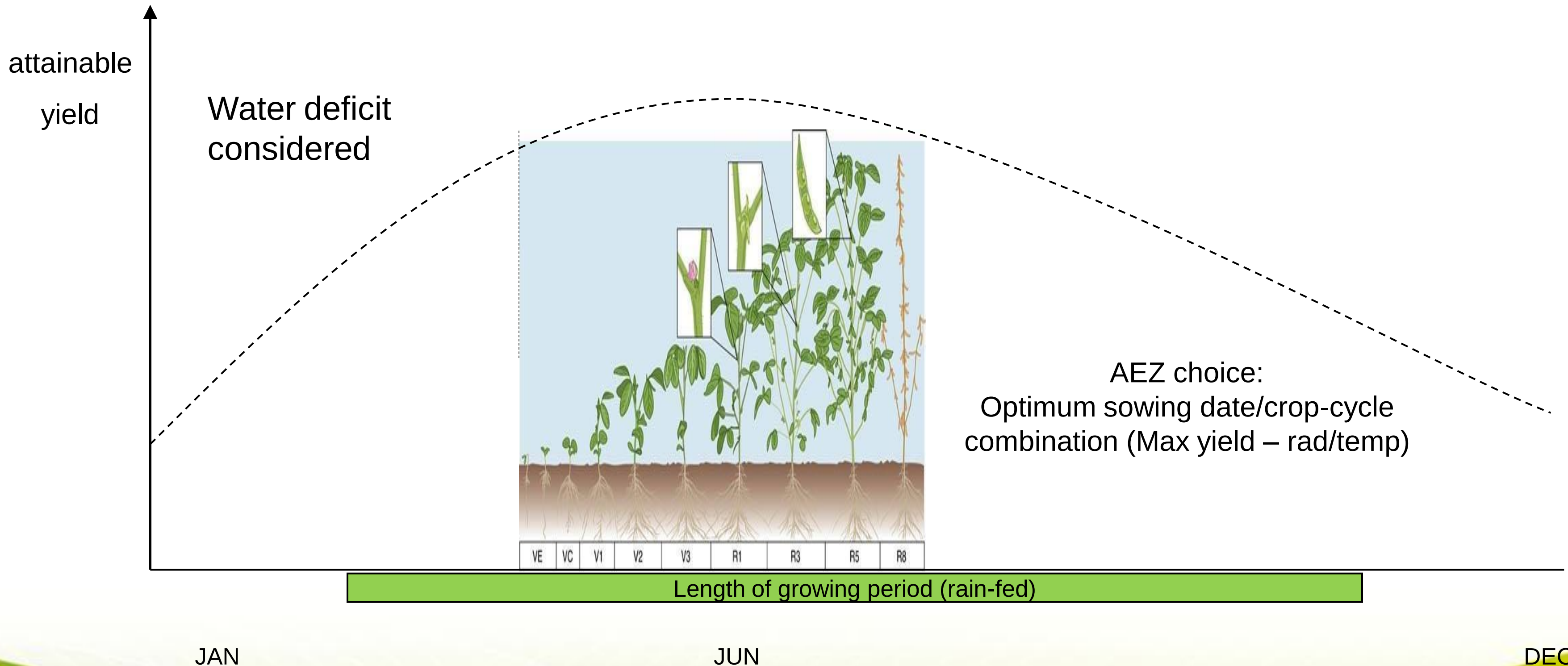


Rain-fed conditions



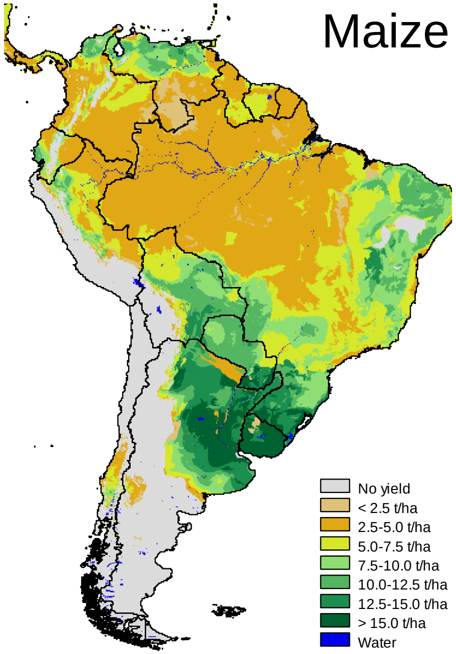
Multiple-cropping zones for rain-fed crop production, reference climate 1961-90

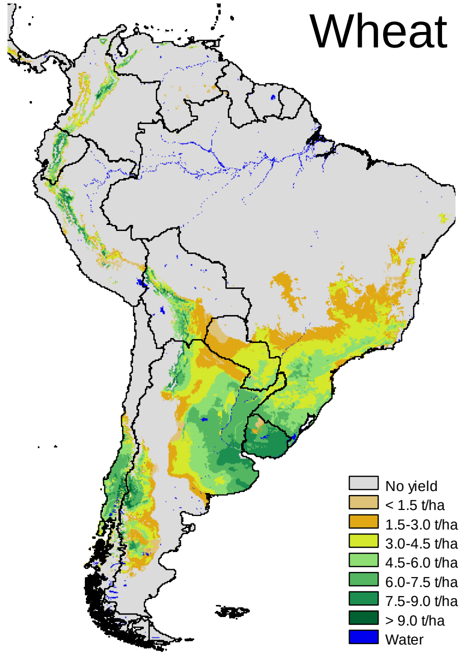
Automatic crop calendar in AEZ

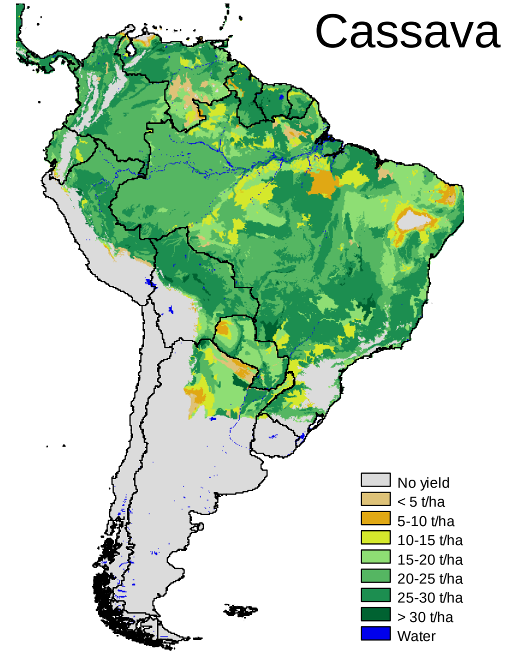


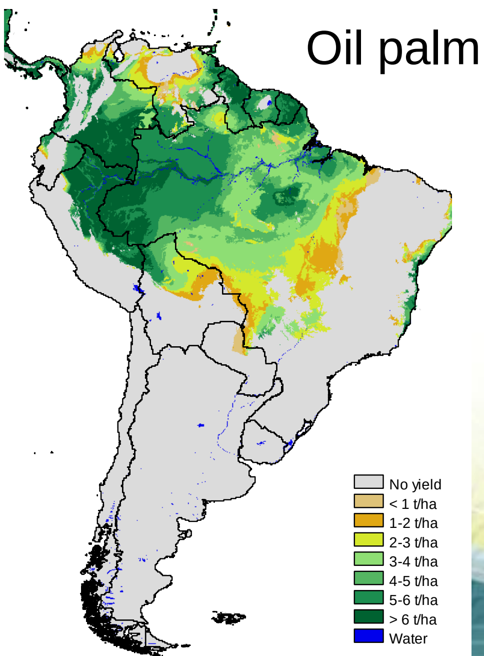
Note: For each grid-cell and LUT the algorithm tests all possible starting dates and determines the highest attainable yield, which then defines the respective outcome for that location .

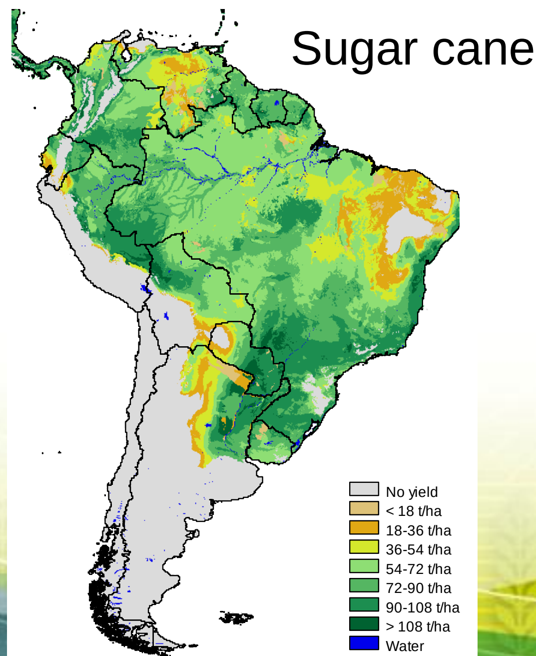
Attainable Rain-fed Yields, high input level

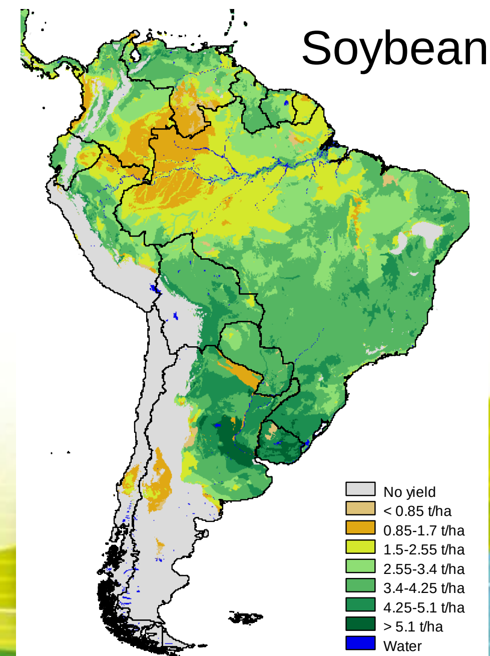




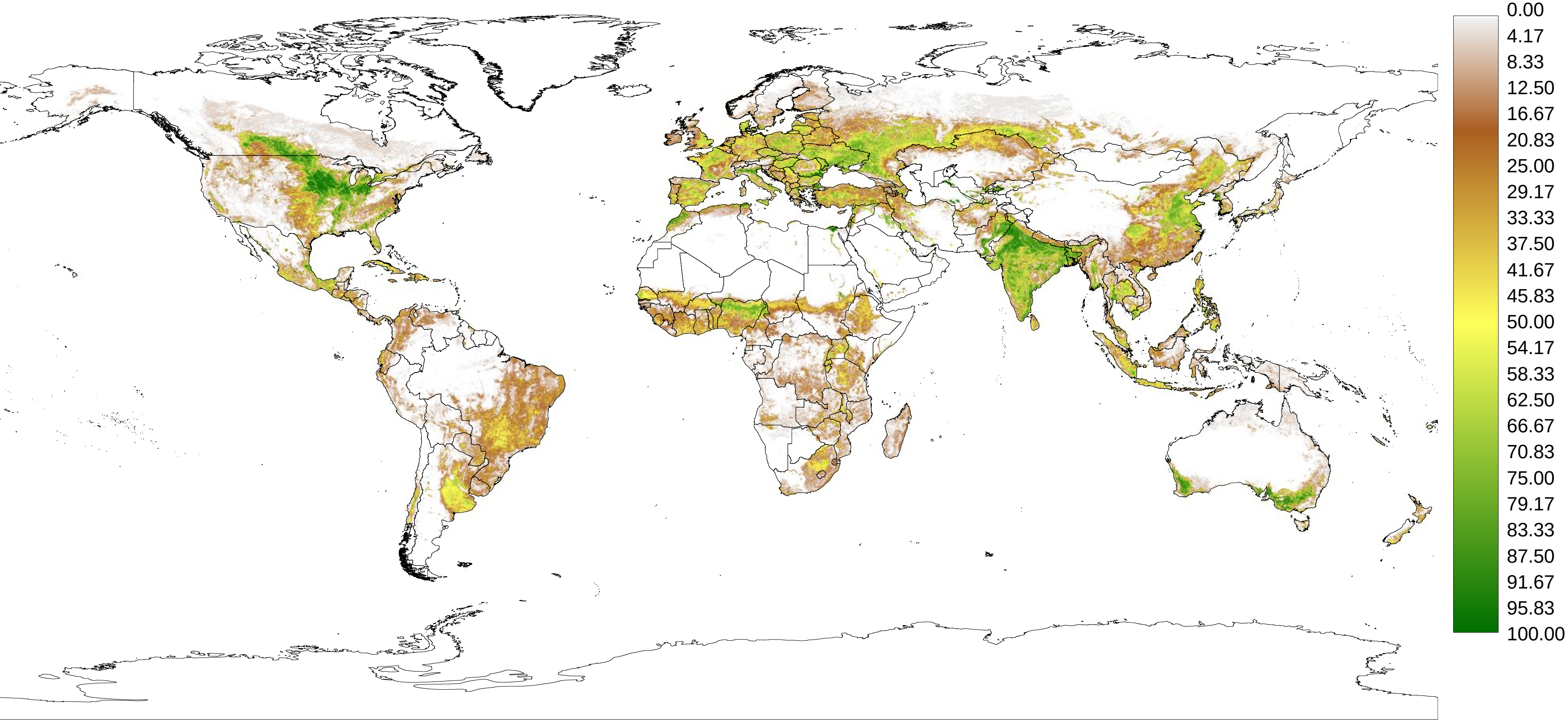




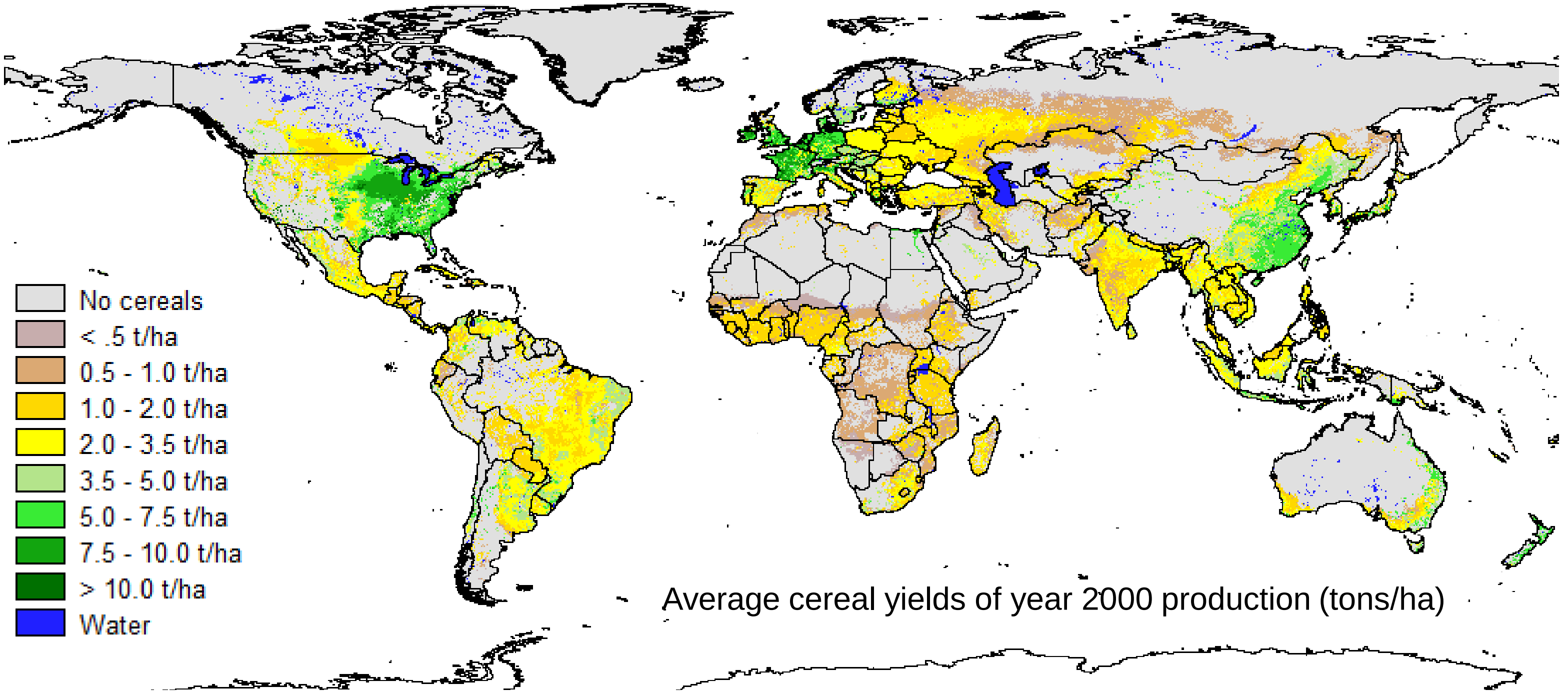




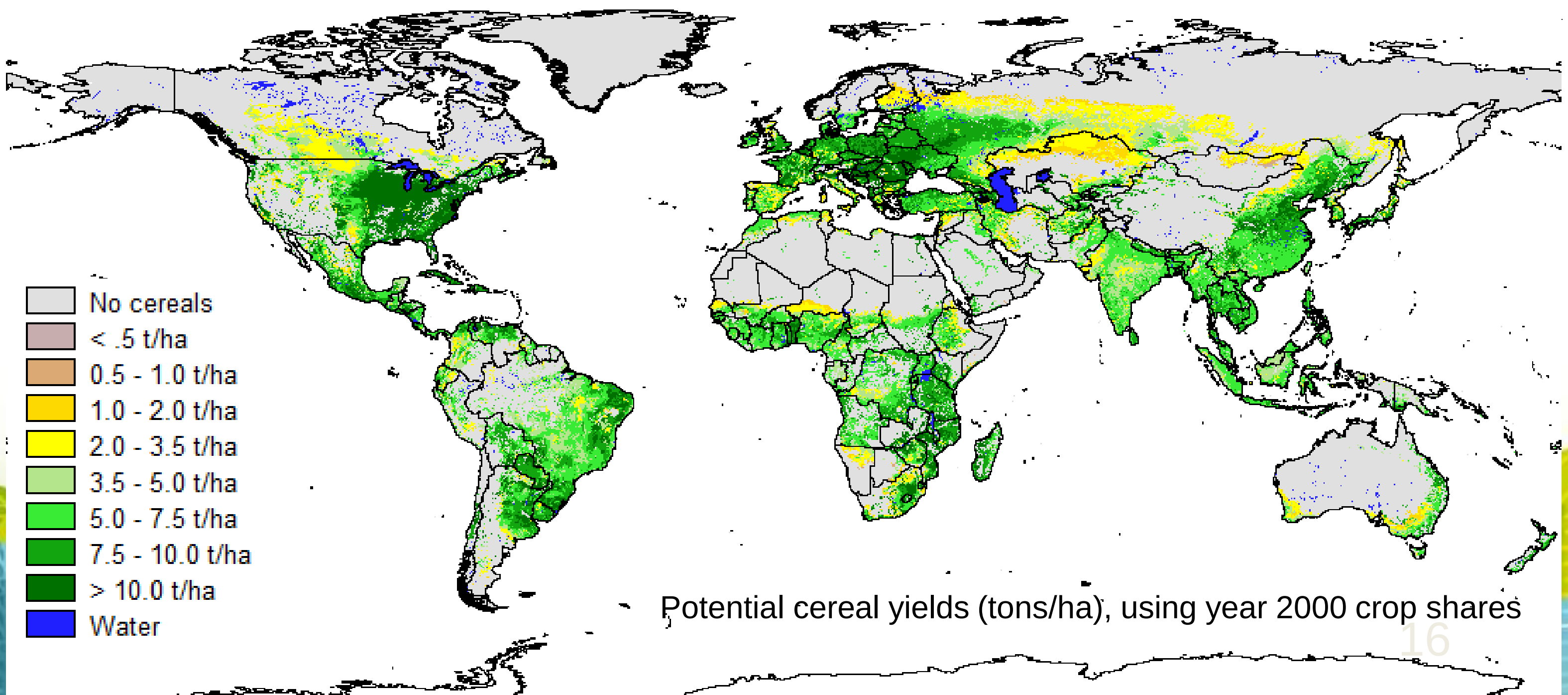
Spatial Distribution and Intensity (percent) of Cultivated Land, year 2000



Note: calibration of GLC2000 class weights starts from estimated reference weights and is based on an iterative scheme to match national / sub-national statistics of year 2000 (FAO AT2015/2030 adjusted cultivated land).

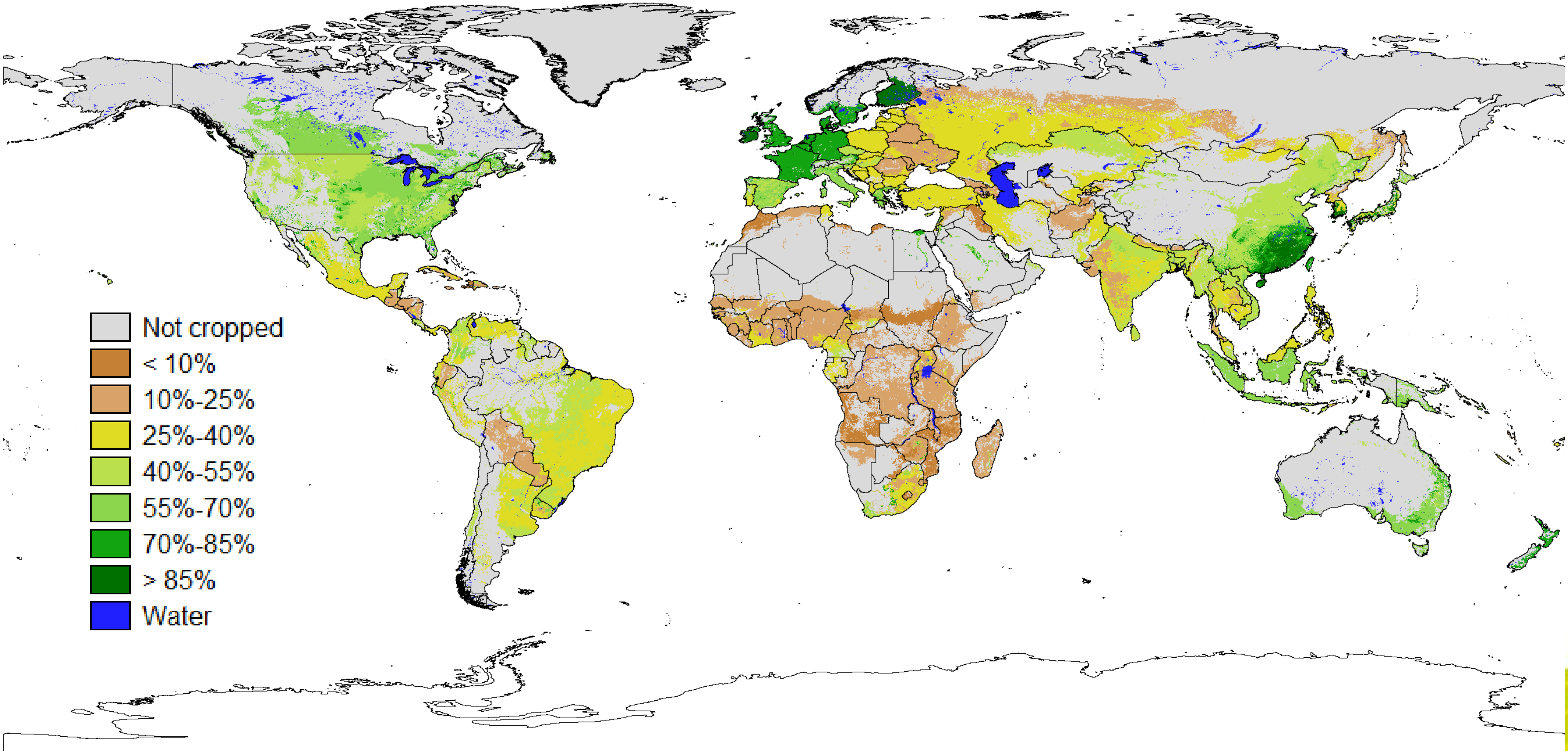


Average cereal yields of year 2000 production (tons/ha)



Potential cereal yields (tons/ha), using year 2000 crop shares

Ratio of Actual to Potential Cereal Output



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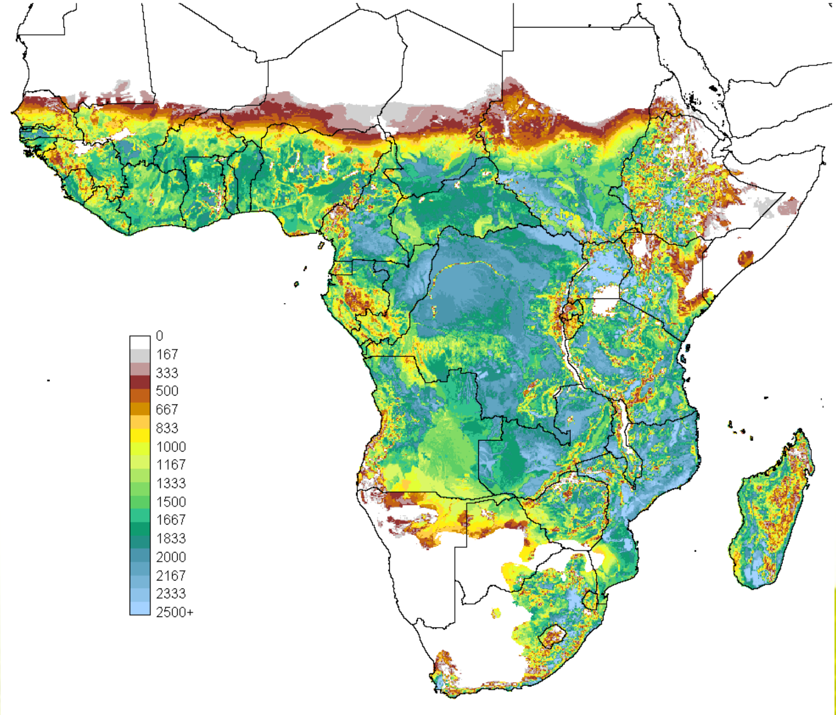
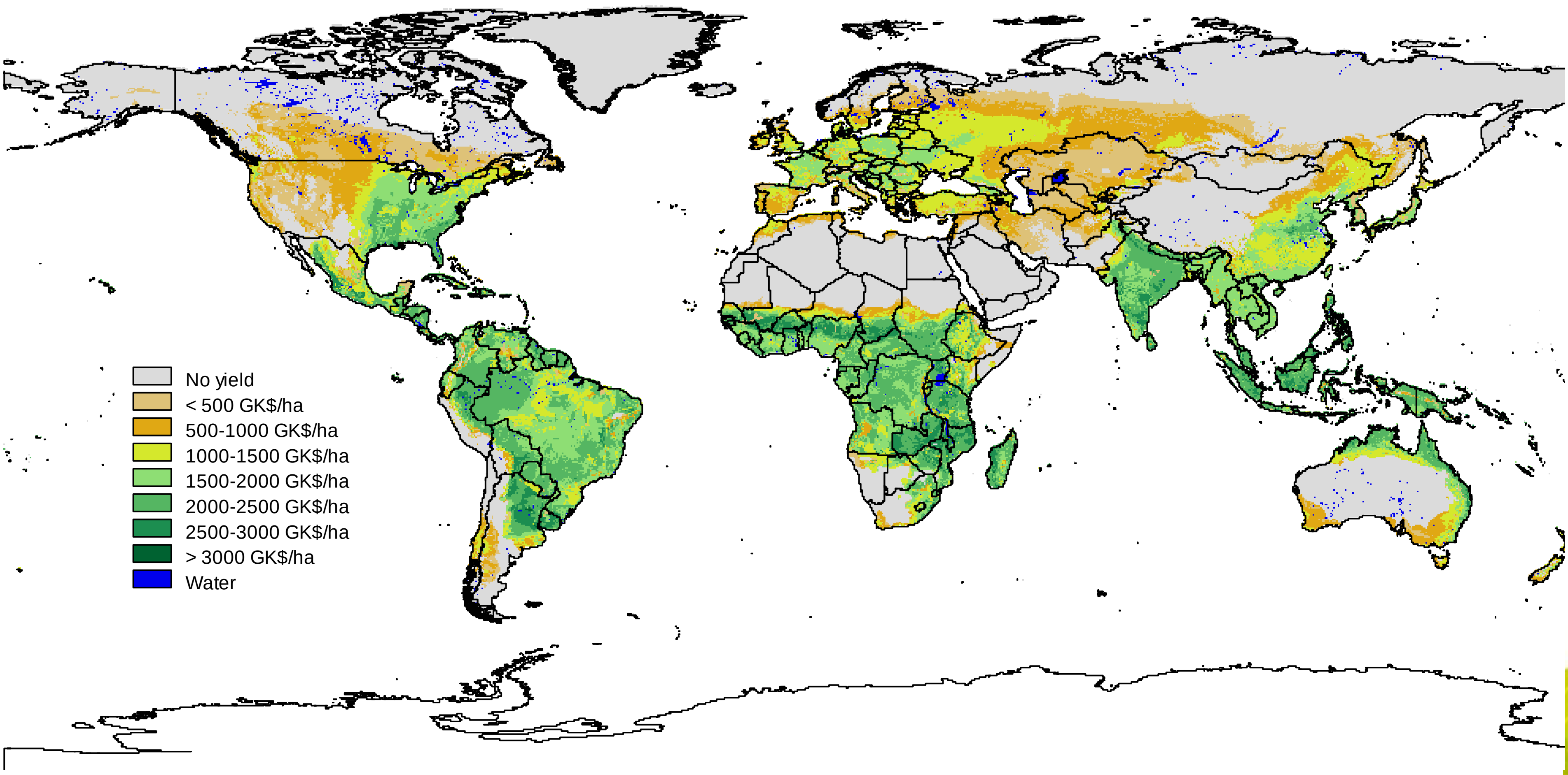
ADDITIONAL LAND SUITABLE FOR CULTIVATION



GAEZ
Global Agro-Ecological Zones

Potential Productivity of 'umbrella' crop under rain-fed conditions (GK$/ha)



Note: The aggregate result shown represents the best of nine major crops (wheat, maize, sorghum, soybean, groundnut, oil palm, sugar cane, cassava, cotton) under rain-fed conditions, assuming good management and high input level.

Comparative Advantage of Sugarcane and Sorghum

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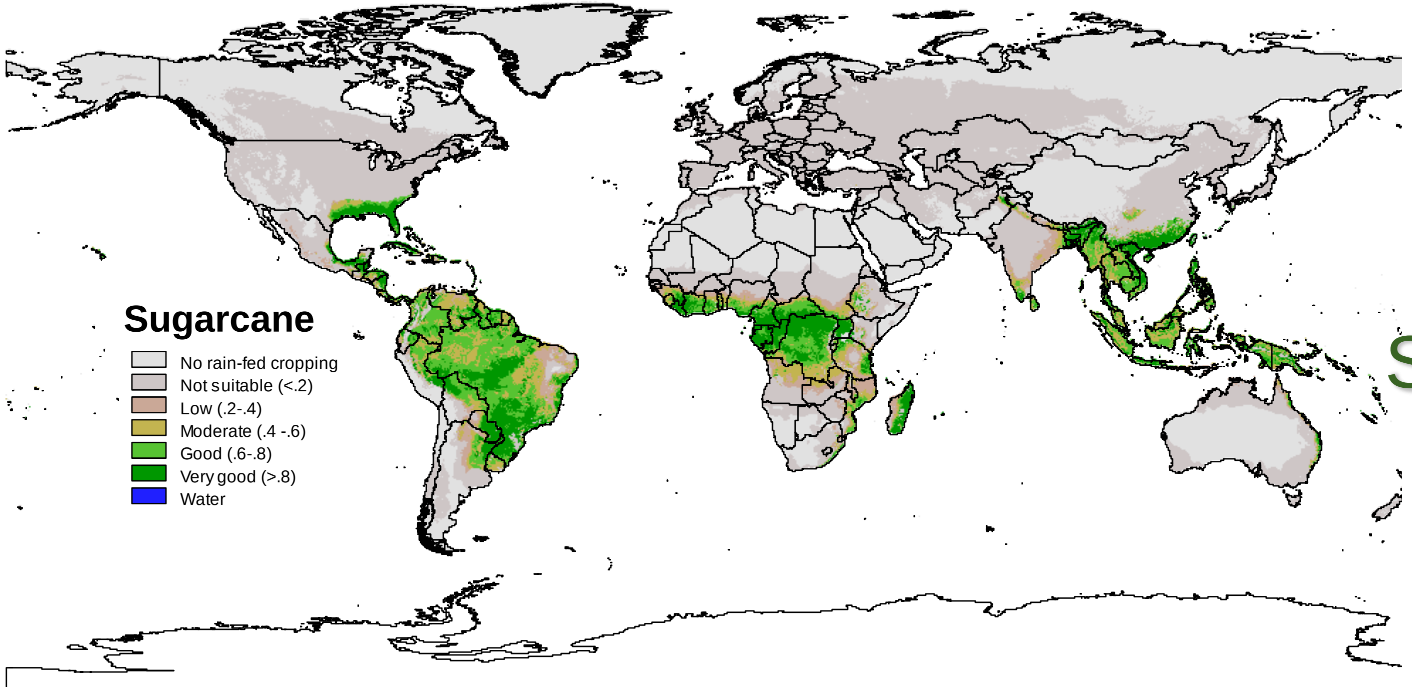
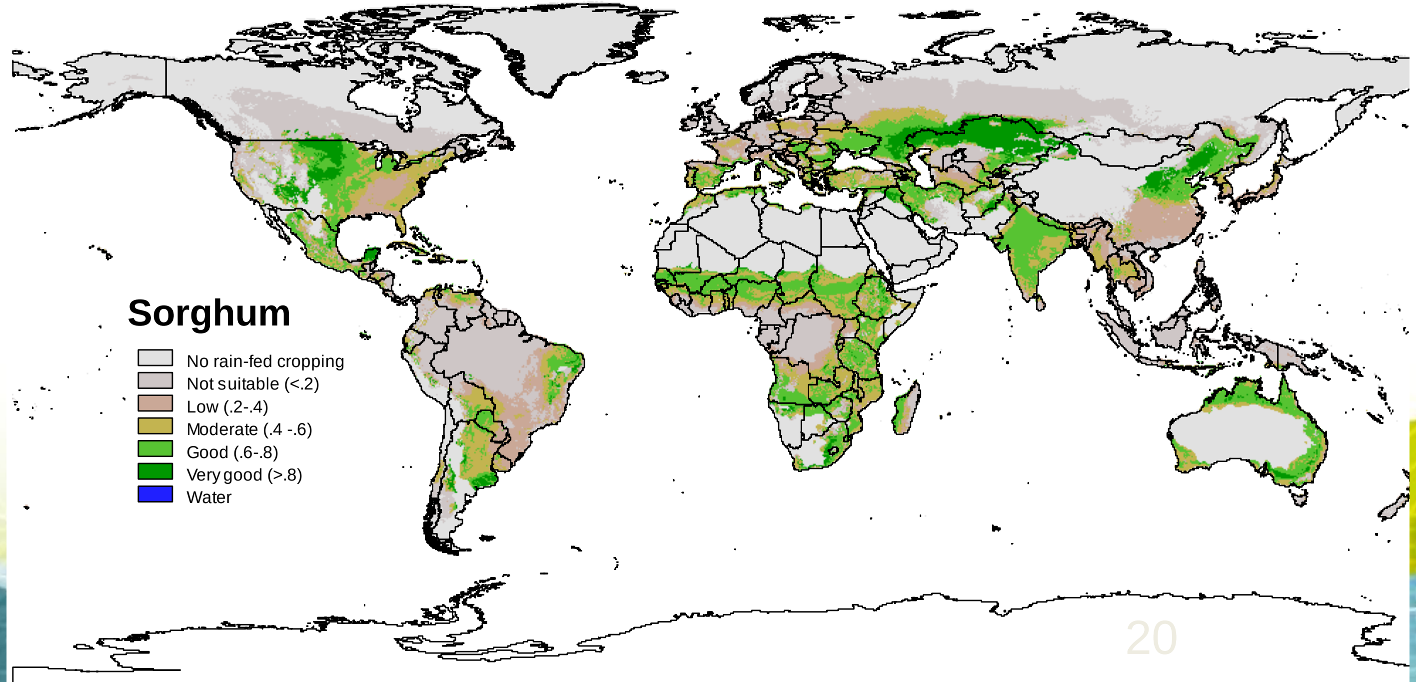


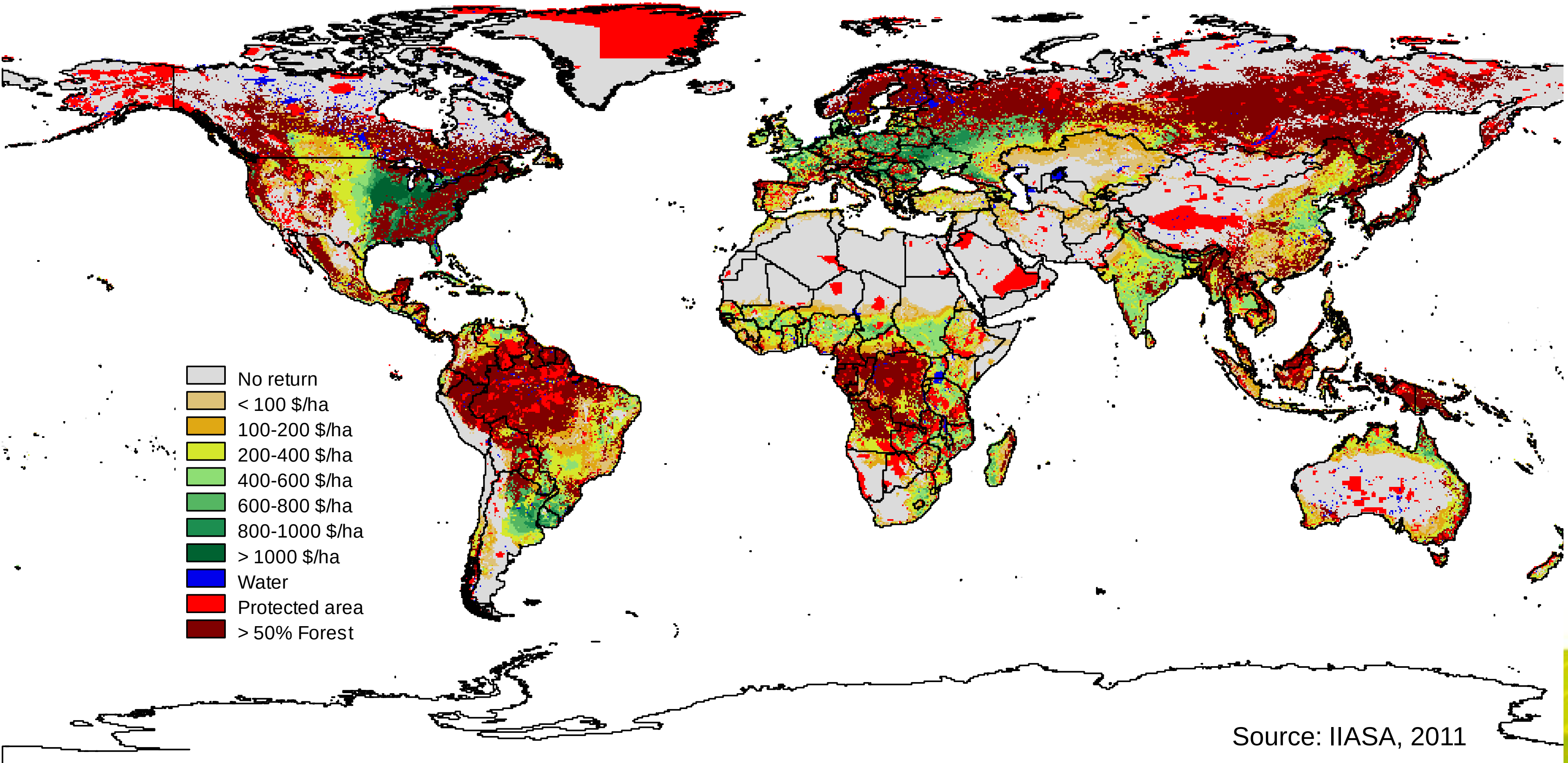


The diagram shows the output value of rain-fed sugarcane and sorghum relative to the 'umbrella' crop (maize, sorghum, wheat, soybean, groundnut, oil palm, sugar cane, cassava, cotton).

Source: IIASA, 2011

GAEZ
Global Agro-Ecological Zones

Potential Net Value of Production of major Cereal Crops under rain-fed Conditions



Note: The aggregate result shown represents the best of three major cereal crops (wheat, maize, sorghum) under rain-fed conditions, assuming good management and high input level.

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Global Agro-Ecological Zones

Grass/Wood Land outside ‘No-go’ areas suitable for ‘umbrella’ crop (mill. ha)

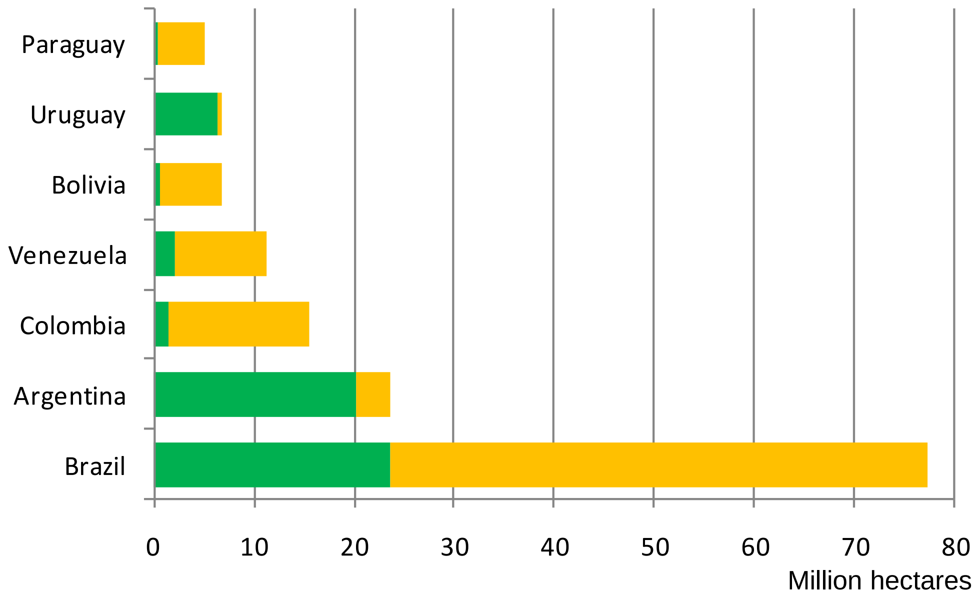
Region	Total Grass/ Wood Land excl. ‘No-Go’	VS+S Grass/Wood Land	NVP > 1000 Grass/Wood Land	NVPT>1000 Grass/Wood Land
Northern America	502	21	5	2
Europe & Russia	512	61	4	1
Australia & N.Zealand	457	29	5	3
Latin America	606	182	152	57
Sub-saharan Africa	855	246	194	85
North Africa & West Asia	87	6	0.0	0
Asia (excl. W.Asia)	563	32	17	8
World Total	3587	578	378	156

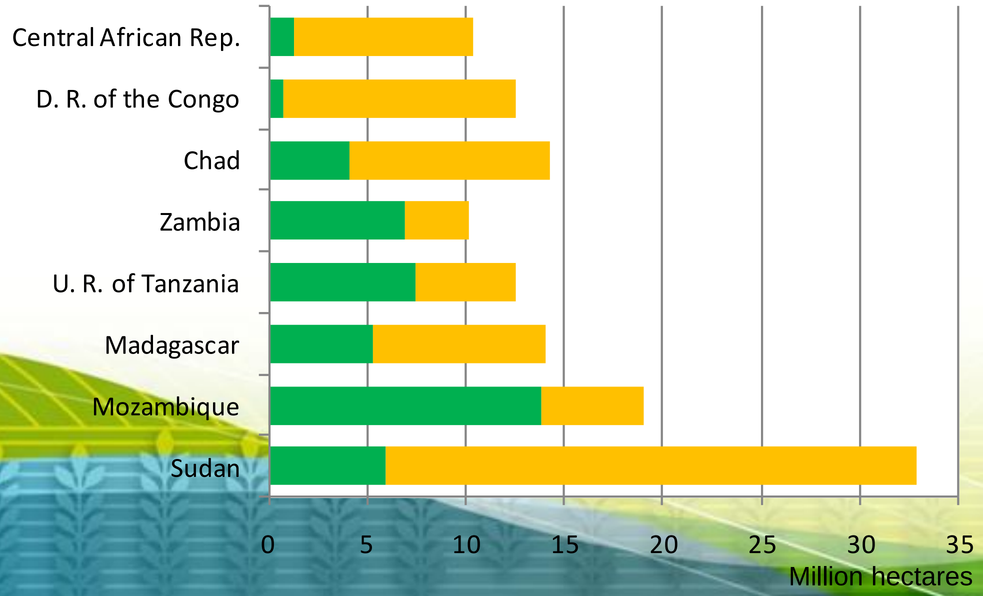
Source: Calculations by authors based on FAO-IIASA GAEZ v3.0 database, 2011

Note: Extents of land currently classified as grass/wood land outside ‘No-Go’ areas. The table shows (i) total extents, (ii) land very suitable and suitable for rain-fed cultivation of at least one of nine major agricultural crops (maize, sorghum, wheat, soybean, groundnut, oil palm, sugar cane, cassava, cotton), (iiI) of which with NVP (excl. transport) > 1000 $/ha, and (iv) NVP (incl. transport) > 1000 $/ha.

GAEZ
Global Agro-Ecological Zones

Countries with large extents of potential highly productive land





Including transport cost to port

Without transport cost to port

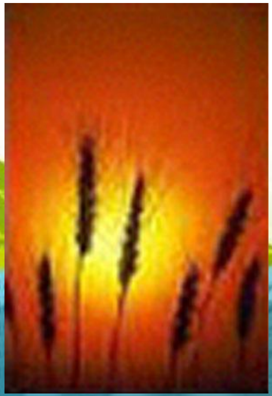
Note: The diagrams show extents of land currently classified as grass/woodland outside 'No-Go' areas and with an estimated NVP exceeding 1000 US$/ha, based on assessment of nine major agricultural crops (maize, sorghum, wheat, soybean, groundnut, oil palm, sugar cane, cassava, cotton).

Source: Calculations by authors based on FAO-IIASA GAEZ v3.0 database, 2011

IMPACTS OF CLIMATE CHANGE ON CROP SUITABILITY, YIELDS AND WATER DEMAND

Agro-ecosystems and Climate Change

- Global warming **+/-**
  - \+ Removal of cold temperature limitations
  - \+ Longer growing season
  - – Faster growing period
  - – Exceedance of temperature thresholds
  - – Increased crop water requirements
  - – Increased incidence of pests and diseases
- Changes in composition of atmosphere **+/-**
  - \+ Yield increases due to CO2 fertilization
  - \+ Increased water-use-efficiency
  - – Pollution (e.g. tropospheric ozone)
- Alterations in precipitation patterns, soil moisture conditions, surface runoff **+/-**
- Increased occurrence of extreme weather events **-**
- Increased climate variability **-**



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Key Topics & Approaches

- Establish a common database of bias-corrected climate projections to 2100 using high resolution RCMs;
- Simulate the spatial and temporal distribution of China's agro-meteorological resources, such as cumulative temperature sums, moisture index, length of growing period and multi-cropping conditions under different future climate projections.

1. Characterize ***climate and agro-meteorological resource change of China*** with IPCC SRES Projection, two Regional Models

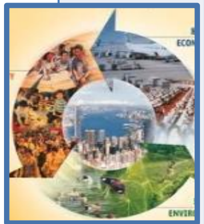
- Apply new data-model fusion method to up-scale the site specific crop model (DSSAT), providing a site-informed "micro foundation" for AEZ model.
- Assess the climate change impact on the production potential of main crops.

2. Establish an ***integrated multi-scale data-modeling fusion framework*** for agro-ecosystem analysis.

- Quantify the influence of population growth and changes in domestic diet structure on food demand and supply;
- Simulate land-use changes, rural labor supply and possible adaptations to climate change;
- Assess their combined impacts on the supply potential of China's agro-ecosystems.

3. Project ***land use changes and population dynamics*** consistent with future climatic and socio-economic trends.

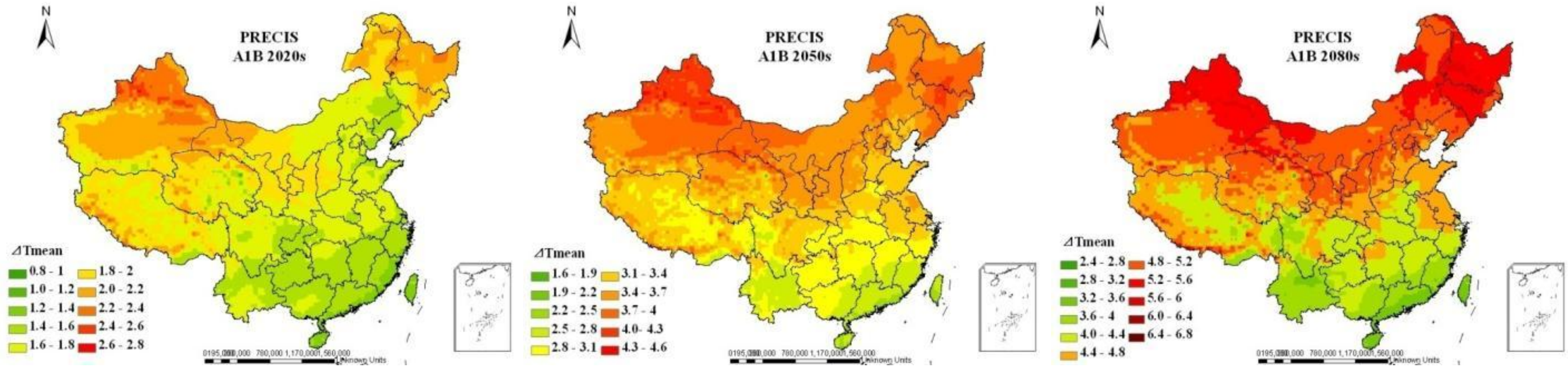
- Develop and apply policy assessment tools to simulate input and output management options for sustainable development of Chinese agriculture in general and the climate change issue in particular.

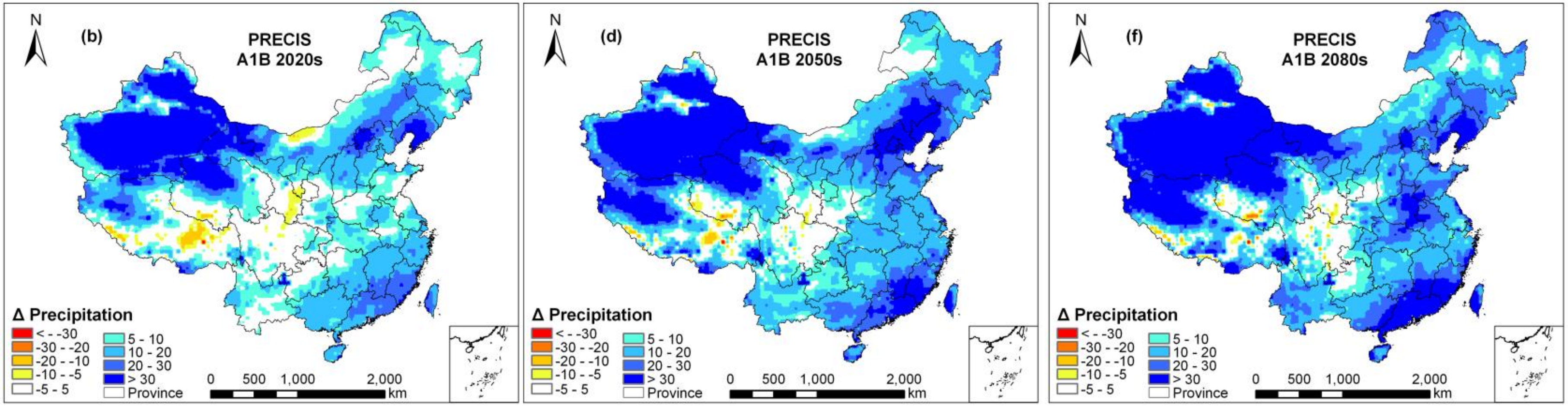


4. Assess different policy issues: ***climate change impacts*** on China's food economy; feeding ***China's livestock***.

Climate Change Scenario Projected by PRECIS

(30 year average annual temperature & precipitation, Baseline (1961-1990) vs 2020s(2011-2040), 2050s(2041-2070), 2080s(2071-2100) A1B scenario)





High resolution (50x50km) PRECIS has provided 90 years scenario projections for future climate change. Among them, the A1B scenario shows the projection under the relatively high CO2 emission scenario. The comparison of the A1B baseline (1961-1990) with projections for 2020s-2080s shows the changes. For example, average temperature in *Northeastern China and Northern Xinjiang province* may *increase by 5 ℃*, and *precipitation* may increase significantly in the *Northwestern China, probably by 30%.*

Framework for the DSSAT-AEZ coupling

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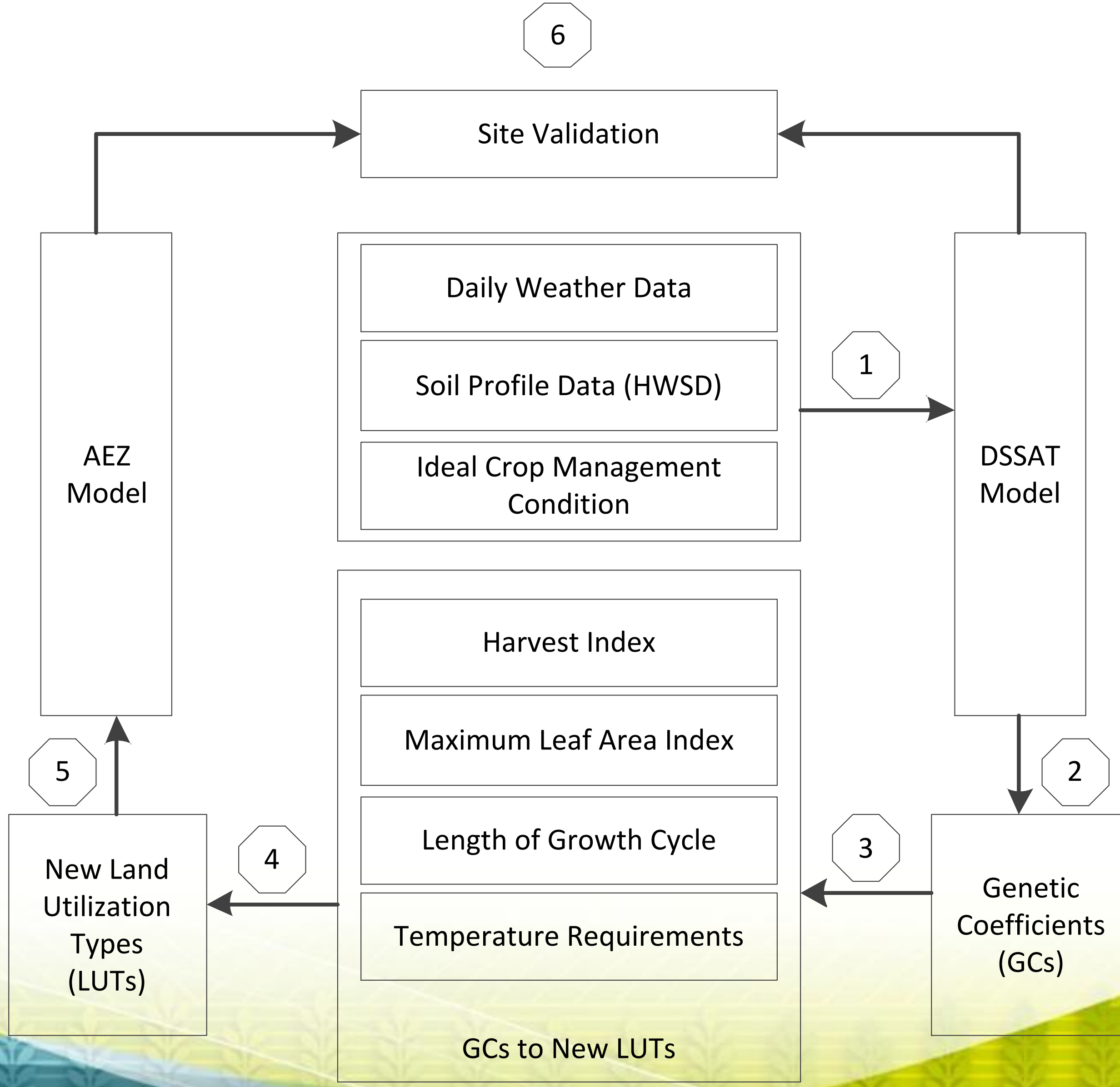
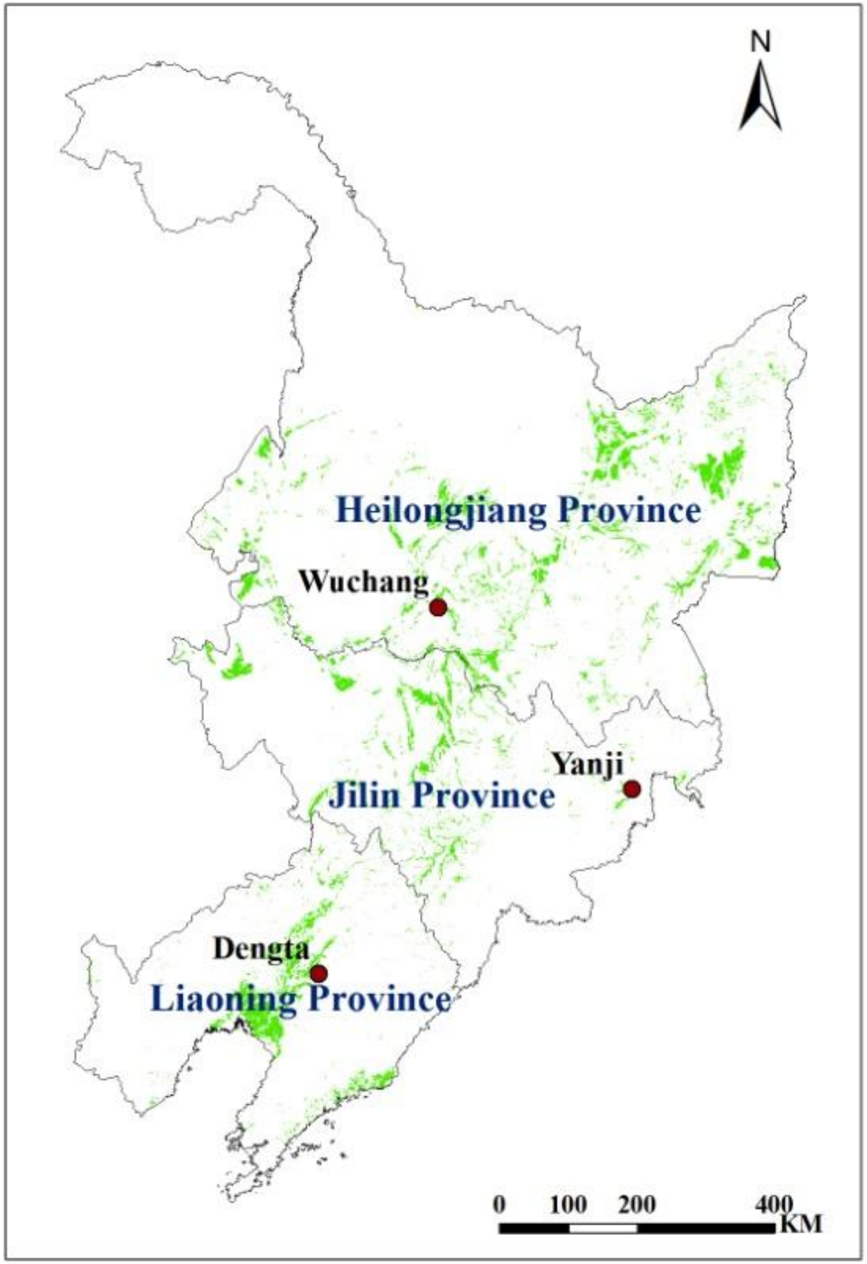
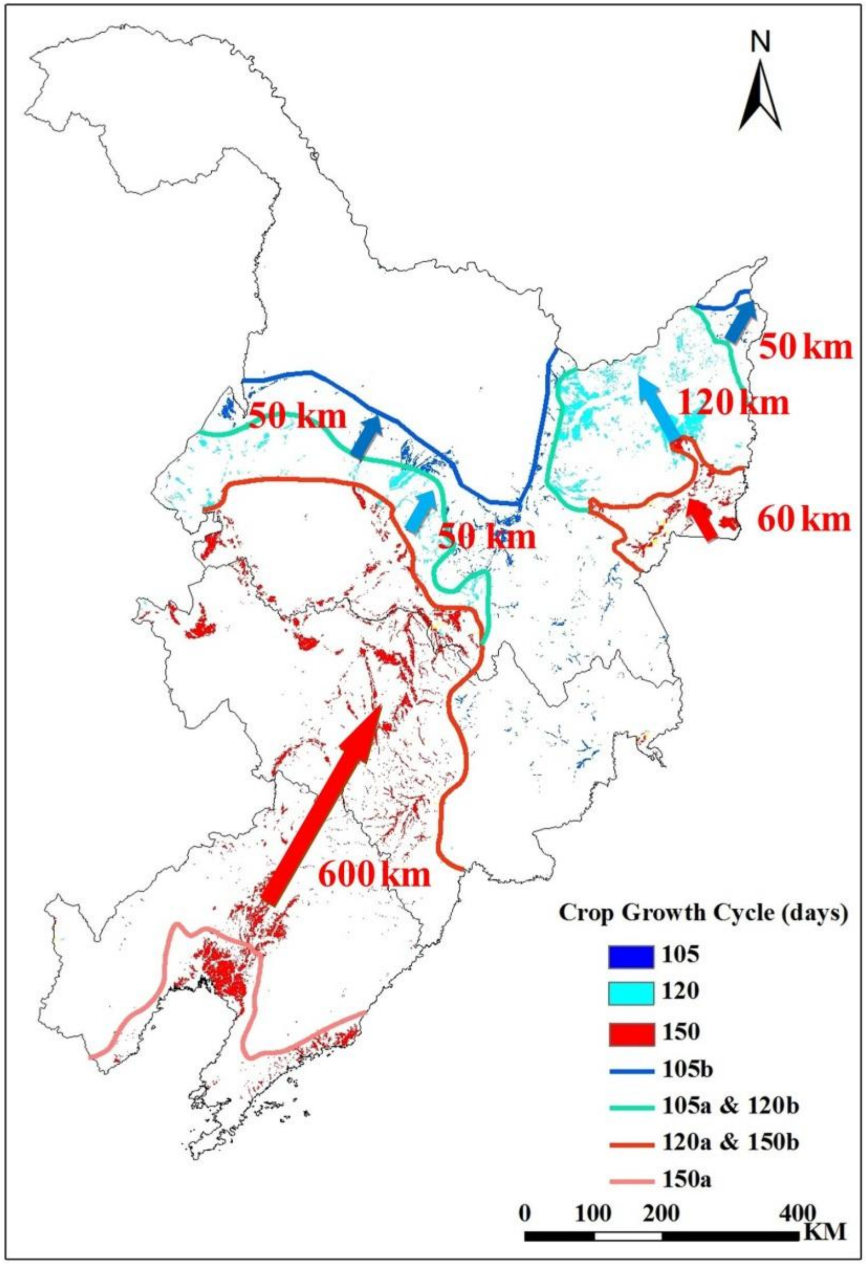


Paddy fields in Northeast China (2000) and location of agro-meteorological observation sites



Shift of rice planting boundary from original LUTs (marked as 105a, 120a, 150a) to new LUTs (marked 105b, 120b and 150b)



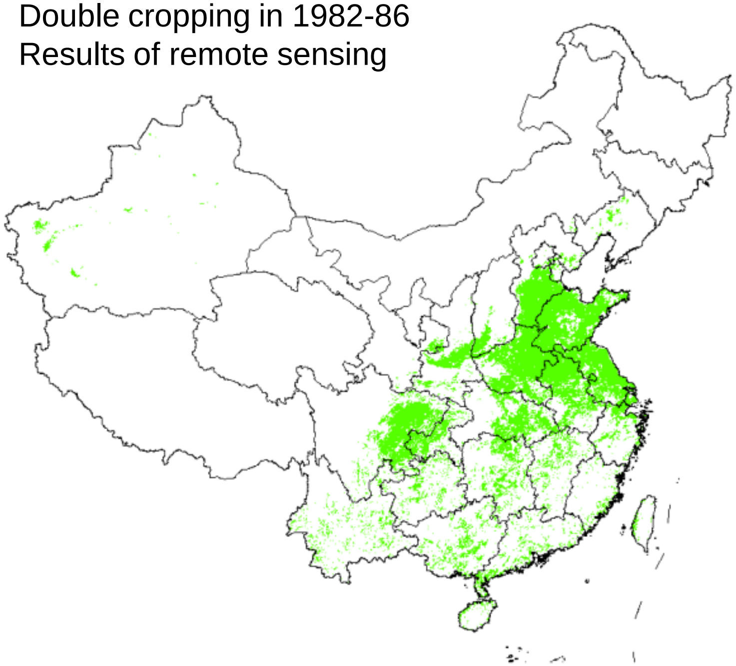
Production potential under climate change

- Climate change assessments have typically focused on single crops only and have neglected the emerging multi-cropping opportunities induced by global warming, thus tending to over-estimate the adverse impacts of climate change on crop production.
- Representative results for China indicate that without the mechanism of CO2 fertilization, effect of which is still debated, climate-induced yield reductions are 4-14% for rice, 2-20% for wheat and 0-23% for maize by the 2050s, suggesting quite adverse implications for China's food security which would imply a growing dependence of China on world food market.

Multi-cropping zones: Comparing Remote Sensing vs AEZ

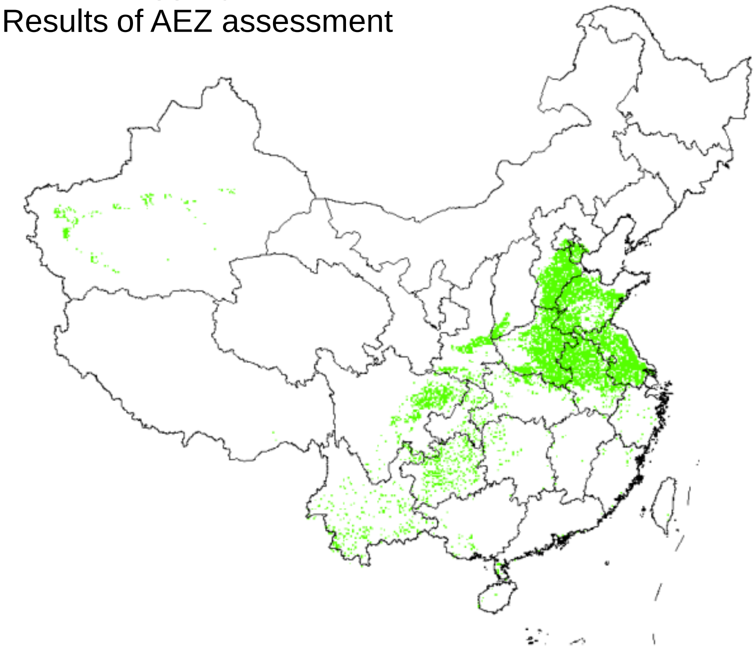
- *Remote sensing* was used to derive a spatial dataset of multi-cropping conditions in the 1990s.

Double cropping in 1982-86
Results of remote sensing



- *AEZ* simulated multi-cropping classification under average climate condition in 1990s.

Double cropping in PRECIS baseline
Results of AEZ assessment



The ***multi-cropping classification*** produced by the AEZ simulation is ***very similar*** to the multi-cropping system derived from the remote sensing data of the 1990s. The comparison indicates that ***the established multi-cropping system utilizes the agro-meteorological potential well.***

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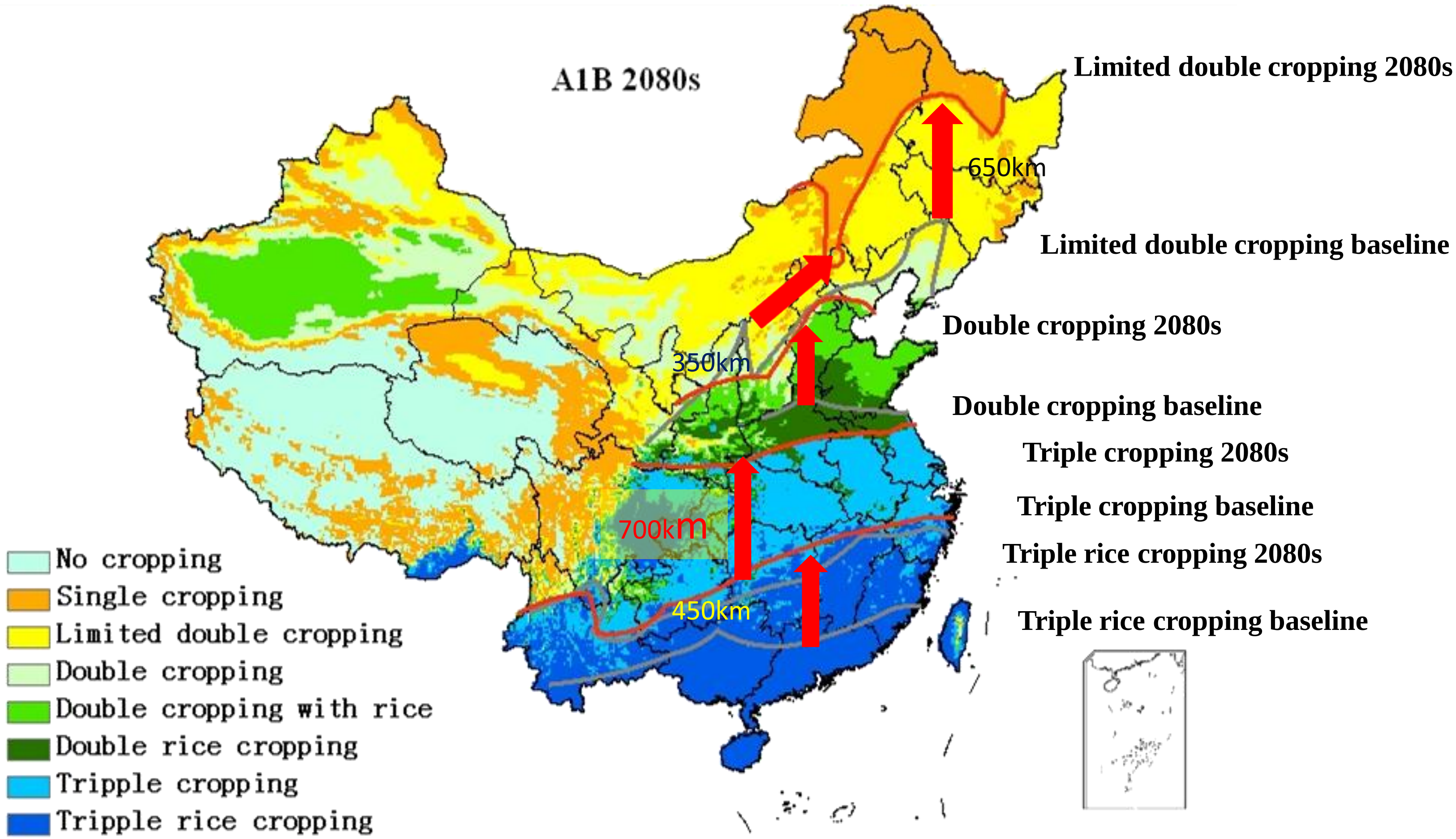
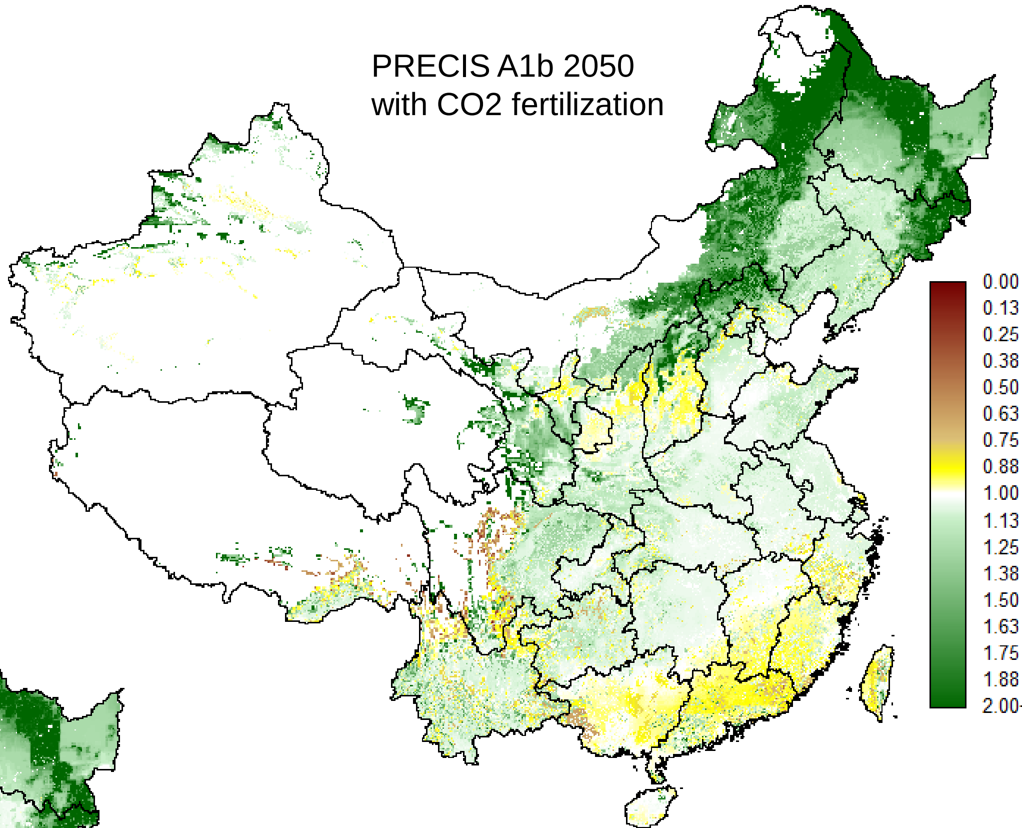
Cropping Systems under Irrigated Conditions

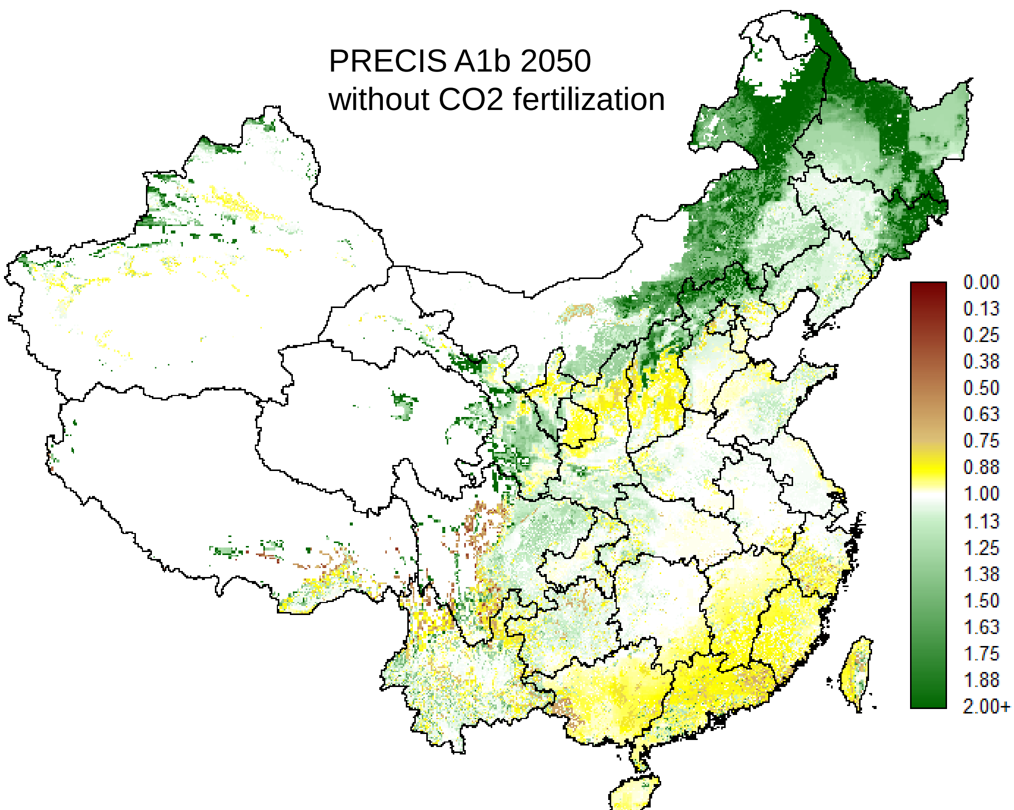
(2080s, PRECIS, A1B)



Under the A1B scenario in 2080s, the ***cropping systems will move northwards***, increasing potential multi-cropping and sown area. This could ***increase the potential crop production in especially in Northeast and Northwest China***. The AEZ analysis demonstrates that the cropping system may change significantly and multi-cropping zones will shift by several hundred kilometers.

Potential Single-crop Yields relative to Baseline Yields

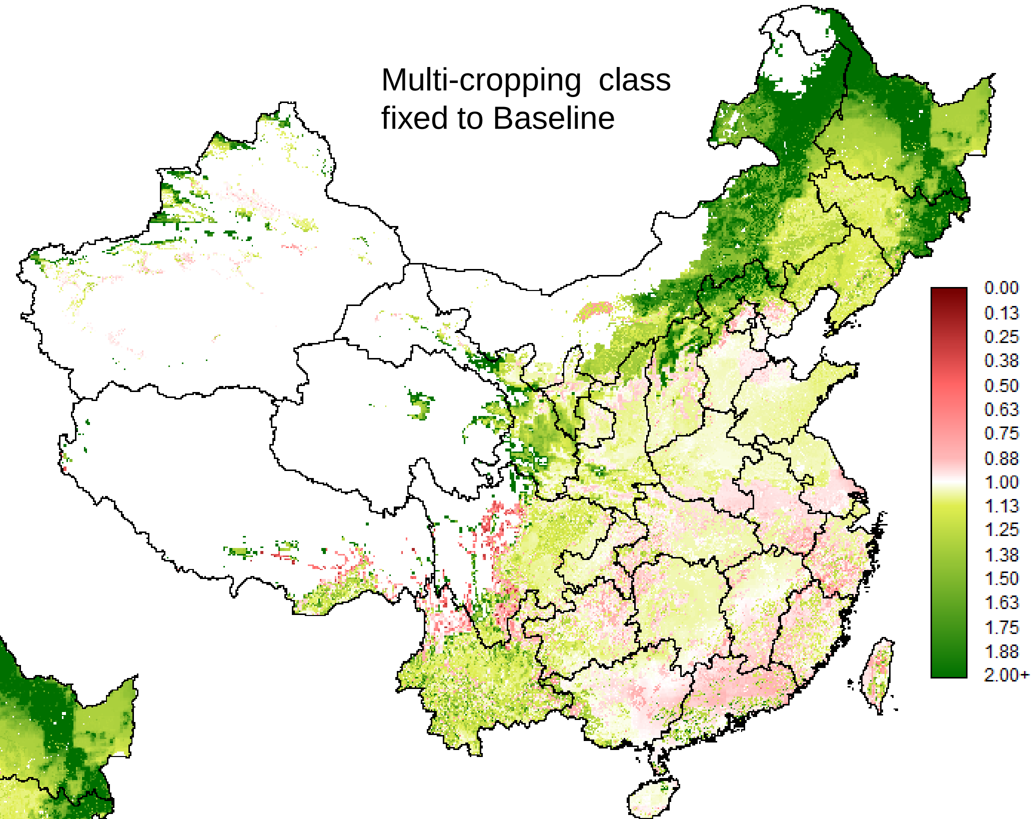




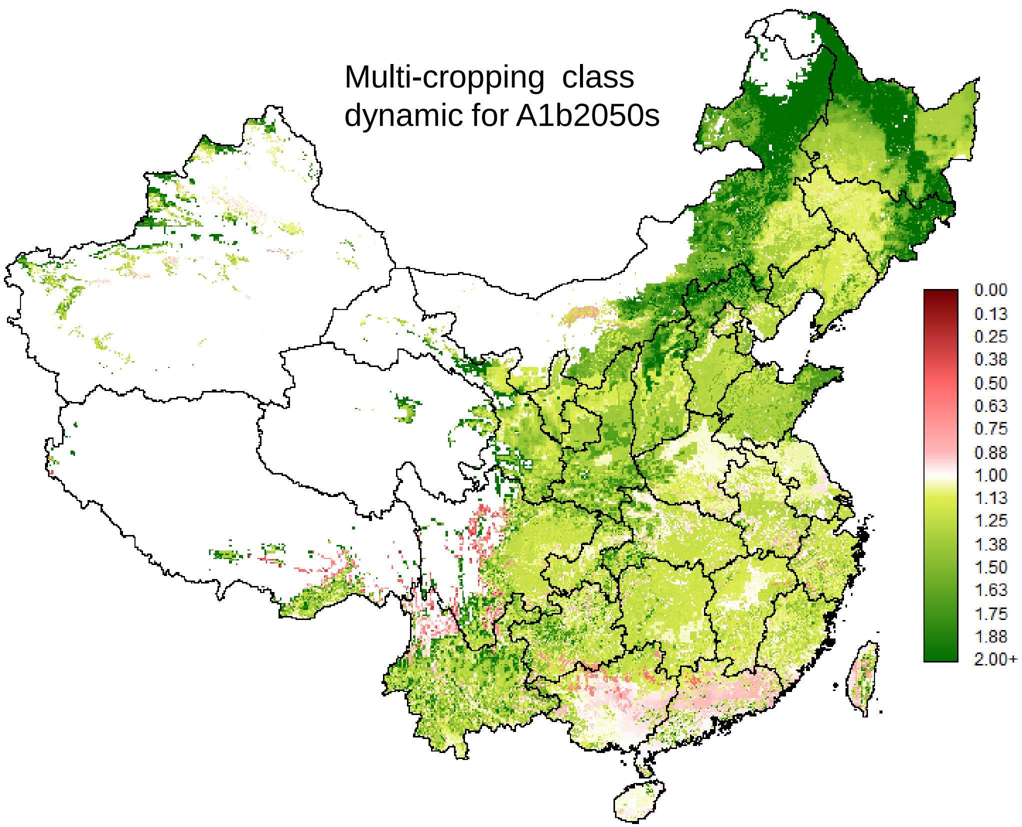
Shown are the ratios of best single-crop yields in PRECIS A1b 2050s climate relative to the best single-crop yield under Baseline. Values range from 0 to 2.

Multi-cropping Potential Cereal Yield Changes from Baseline to PRECIS A1b 2050s (ratio)

Multi-cropping class fixed to Baseline

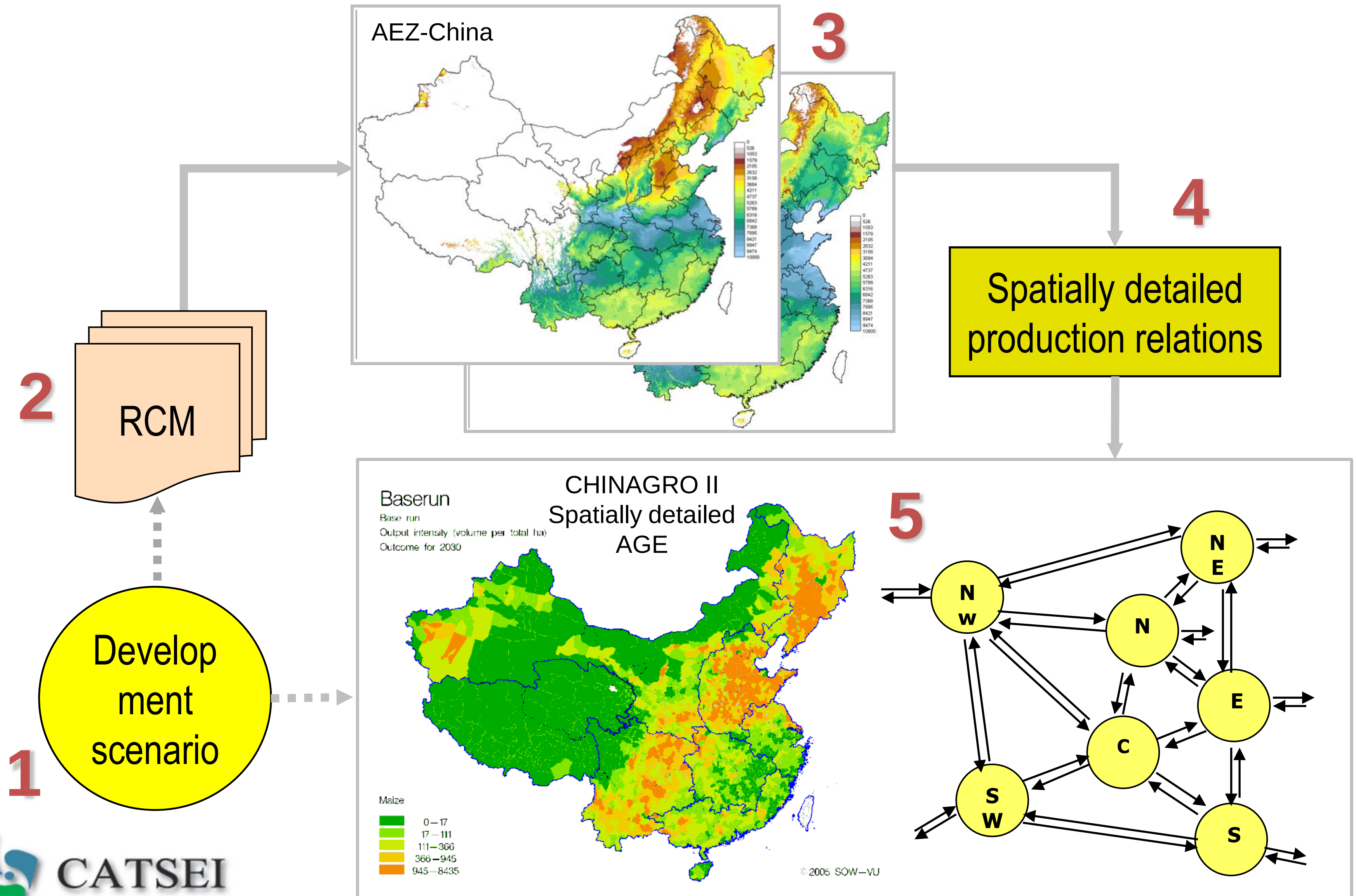


Multi-cropping class dynamic for A1b2050s



For PRECIS A1B climate in 2050s, the maximum potential multi-cropping cereal yield is estimated to be lower than for Baseline in ***southern China***. This will be more than compensated by increased multi-cropping yield potential in ***North and Northeast China*** .

CHINAGRO – A Spatially Detailed National Food System Assessment Framework



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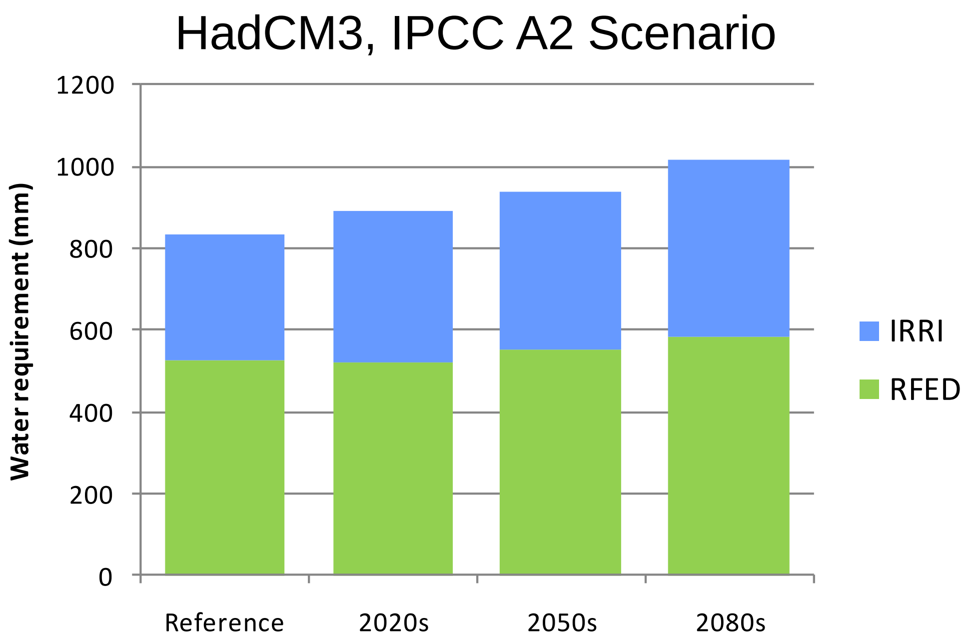
CHINAGRO Model: Main Characteristics and Drivers

- ***CHINAGRO is a General equilibrium model representing consumer and producer behavior, government policies and markets.***
- Main Characteristics:
  - Focus on agriculture (non-agriculture largely given via scenarios)
  - Spatial detail: agricultural supply by county (~2800); commodity detail:
    - 17 tradable commodities (explicit trade flows across regions and from/to abroad)
    - 8 farm types/production activities competing for land and stable capacity in every county
  - Demand more aggregated: 8 regions with 3 rural and 3 urban classes
- Main Drivers:
  - Income growth and urbanization leading to rising meat and feed demand
  - Constraints on agricultural expansion due to environment (land use pollution, water) and industrialization
  - Steady trade liberalization in agriculture
  - Rural and regional development policies
  - Climate change impacts on yields and water requirements
- ***CHINAGRO is the most detailed agro- economic model of Chinese agriculture available.***

China: Climate Change Impacts on Crop Yields and Water Requirements



With climate change the share of irrigation in total crop water requirements as well as the total amount of water to be supplemented by irrigation increases, varying with scenario/ climate model.

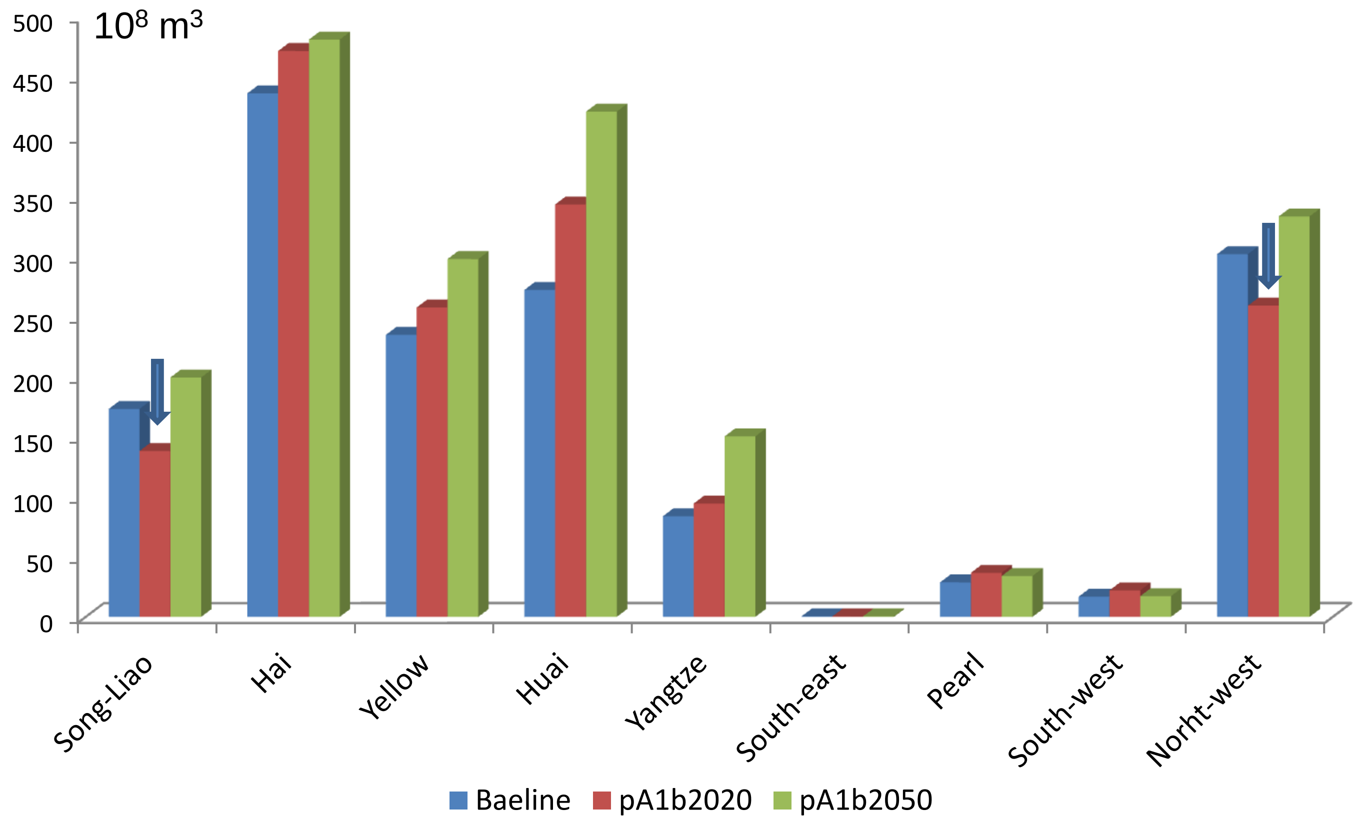
Policy relevant findings:

- Climate change requires substantial adaptation of cropping systems in China's regions;
- Crop production potential is shifting northwards with climate change;
- Positive temperature effects may be limited by soil moisture deficits and more frequent extreme event;
- Crop water requirements projected to increase more than10% by 2050; a growing fraction to be supplied by irrigation;
- High risk that water stress will increase with climate change. Magnitude of effects varies with GCM and scenario.

The impacts of climate change on China's agriculture will largely depend on the consequences for regional water resources.

Balance of Irrigation Water Requirements and Supply

Estimated Irrigation Water Requirements



The Northern basins like Yellow, Huai, Hai & North-west basin have large requirements for irrigation water. In Song-Liao and North-west basins the irrigation need may decrease in 2020s. In 2050s the irrigation requirements will be greater than Baseline in all 9 major river basins. Total net irrigation water requirements will increase **5%** in A1B 2020s and **25%** in A1B 2050s.

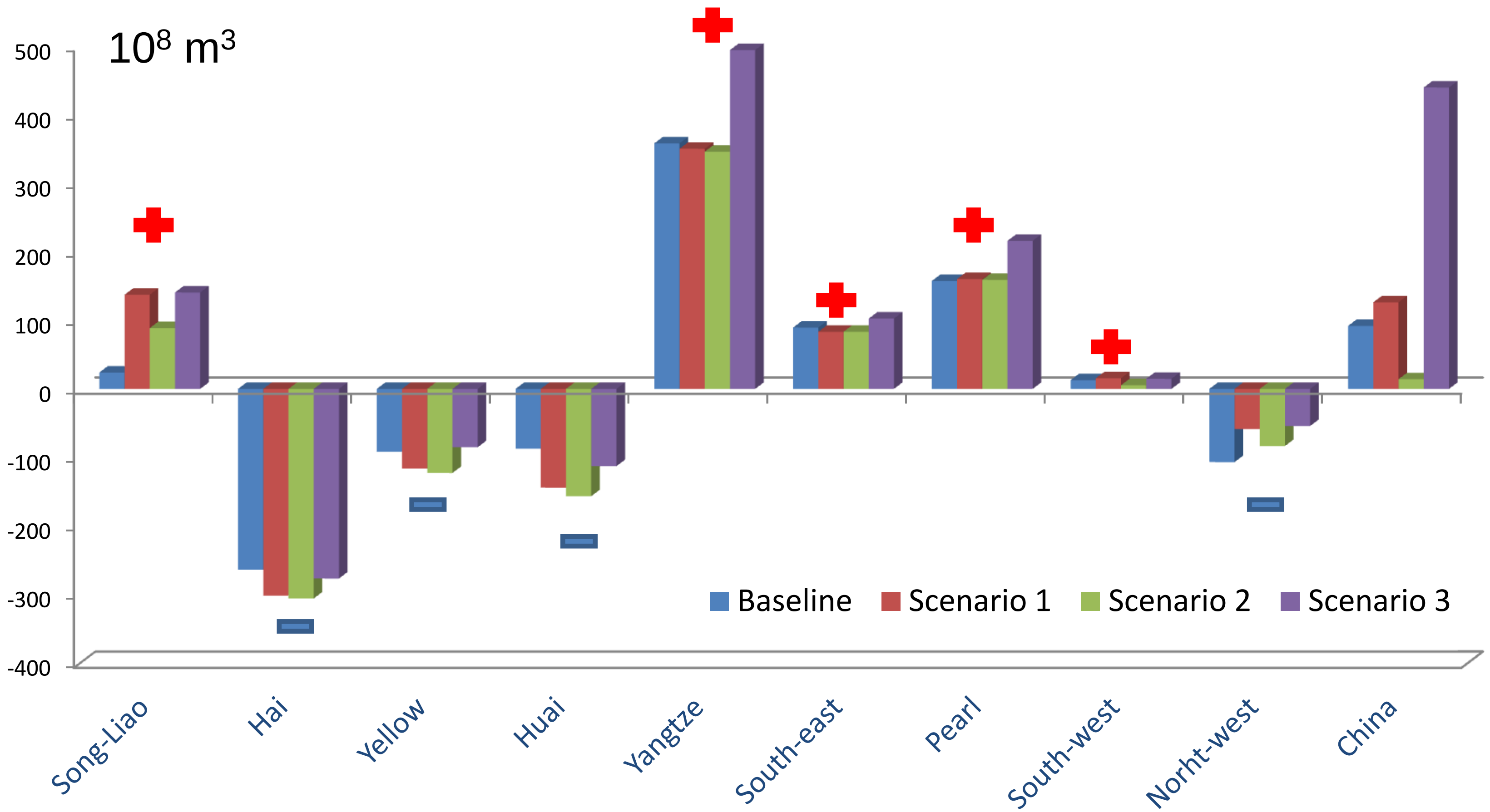
Irrigation Water Demand-Supply Gap, 2030

- Scenarios 1 : The effective irrigation area does not change and the rate of irrigation efficiency does not change
- Scenarios 2 : The effective irrigation area increases but the farmland irrigation efficiency rate does not change
- Scenarios 3 : The effective irrigation area and the farmland irrigation efficiency rate both increase

$$Wb = Ws \times Re - Wr$$

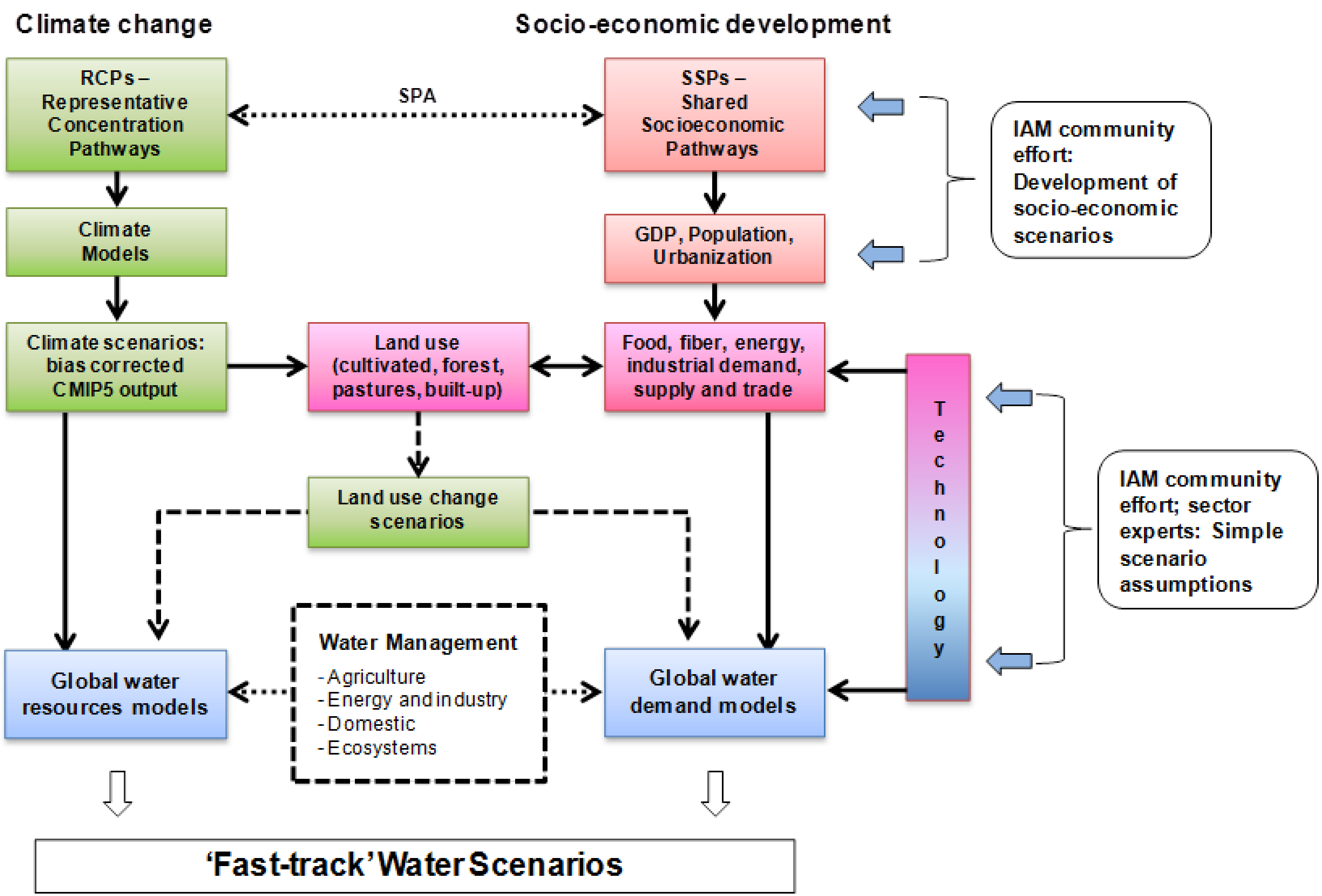
Wb	water resource budget for each basin
Ws	total irrigation water supply for each basin (from statistical data and IWRP)
Re	water use efficiency for each basin(from statistical data and IWRP)
Wr	irrigation water requirement (from AEZ water balance calculation)

Water Resources Budget in the Nine River Basins

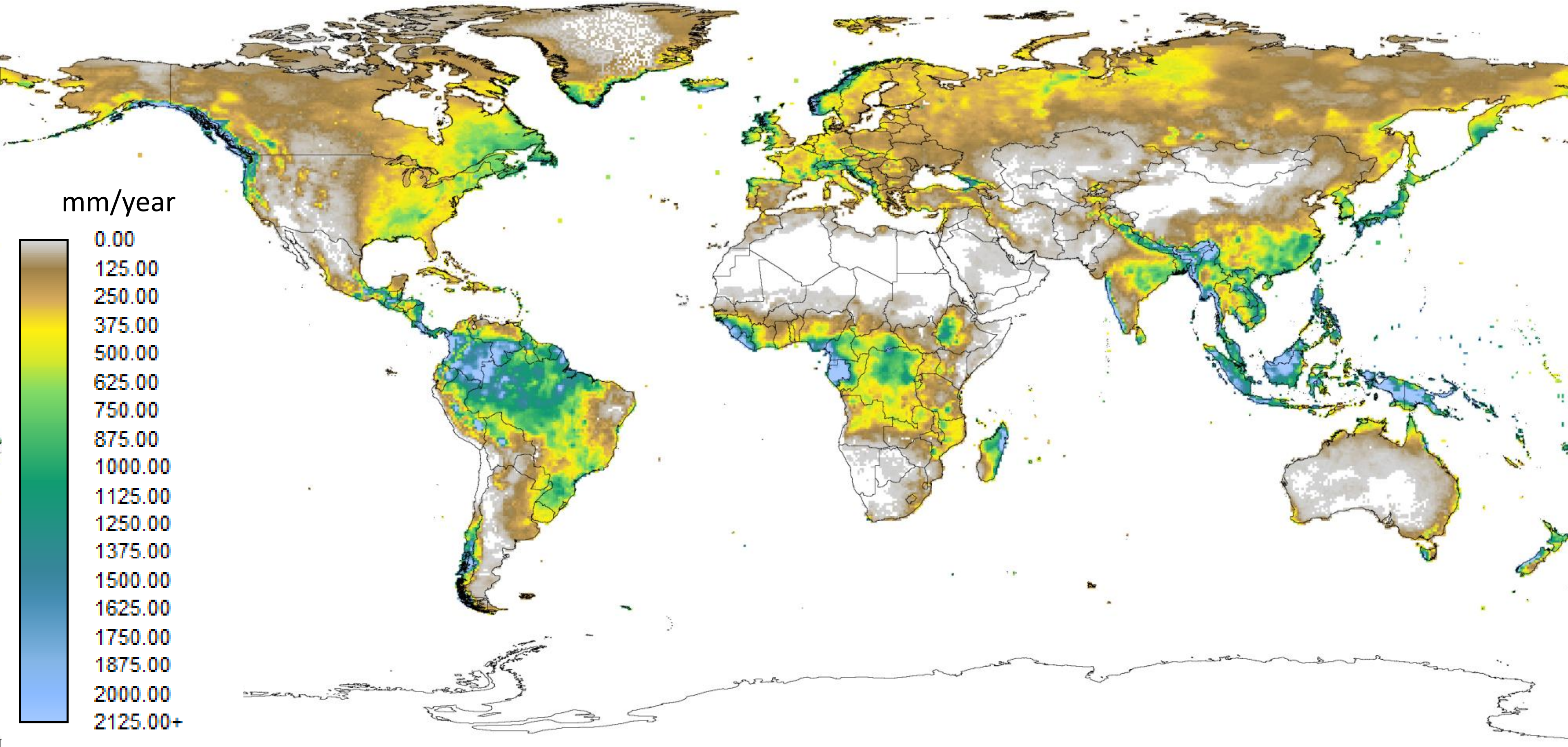


unit:10^8m^3	Scenario 1	Scenario 2	Scenario 3	Diversion in 2030
Hai basin	-301.9	-306.0	-276.9	163.4
Yellow basin	-116.2	-122.8	-85.2	97.6
Huai basin	-144.2	-156.7	-112.8	218.6

Multi-model assessment framework applied in the global water analysis

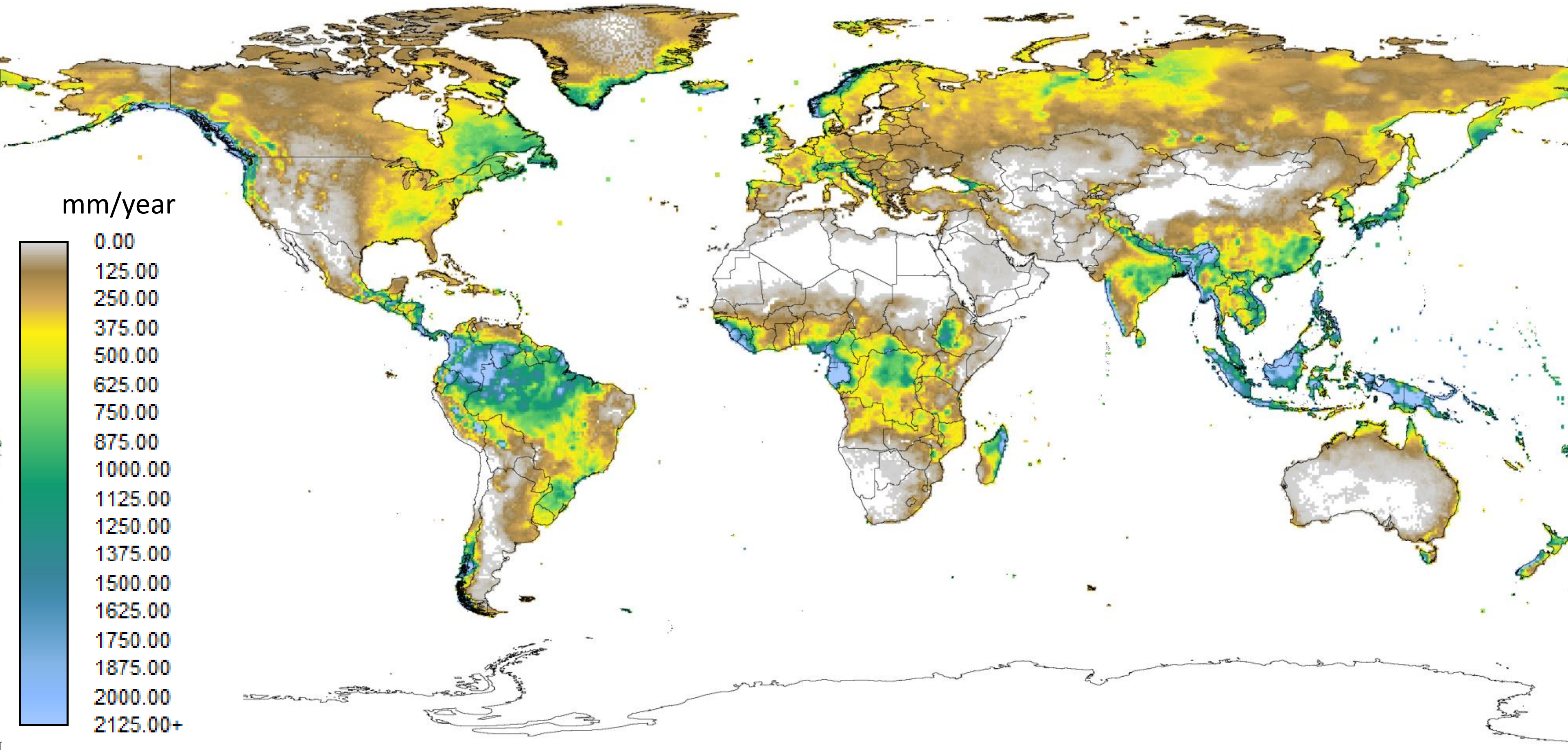


Mean Annual Runoff, 1971-2000



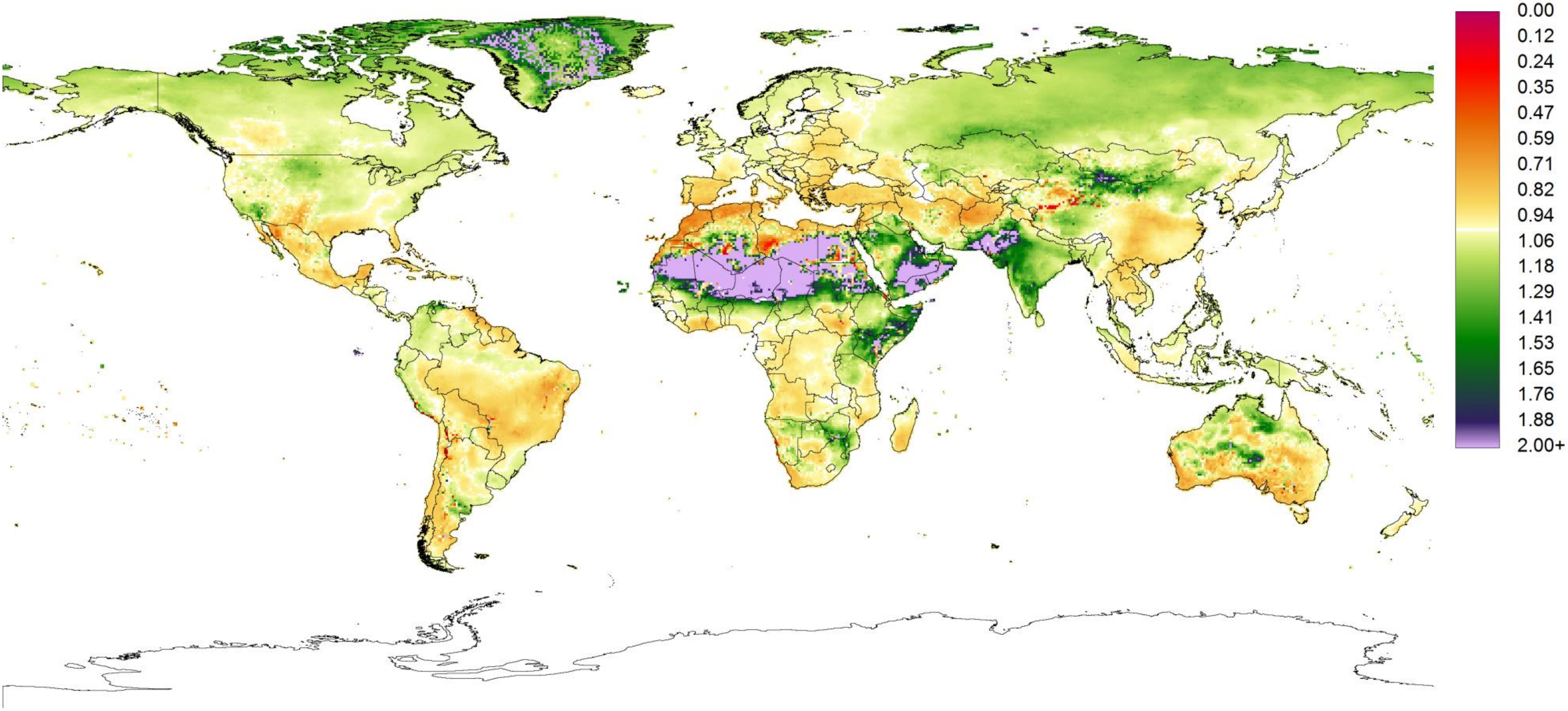
Note: The map shows the multi-model ensemble mean of annual runoff calculated over a 30-year period 1971-2000 using outputs of six hydrological models and five CMIP5 climate models at 30 arcmin latitude/longitude, bias-corrected for impact and adaptation analysis by the ISI-MIP project.

Mean Annual Runoff, 2050s, RCP 8.5



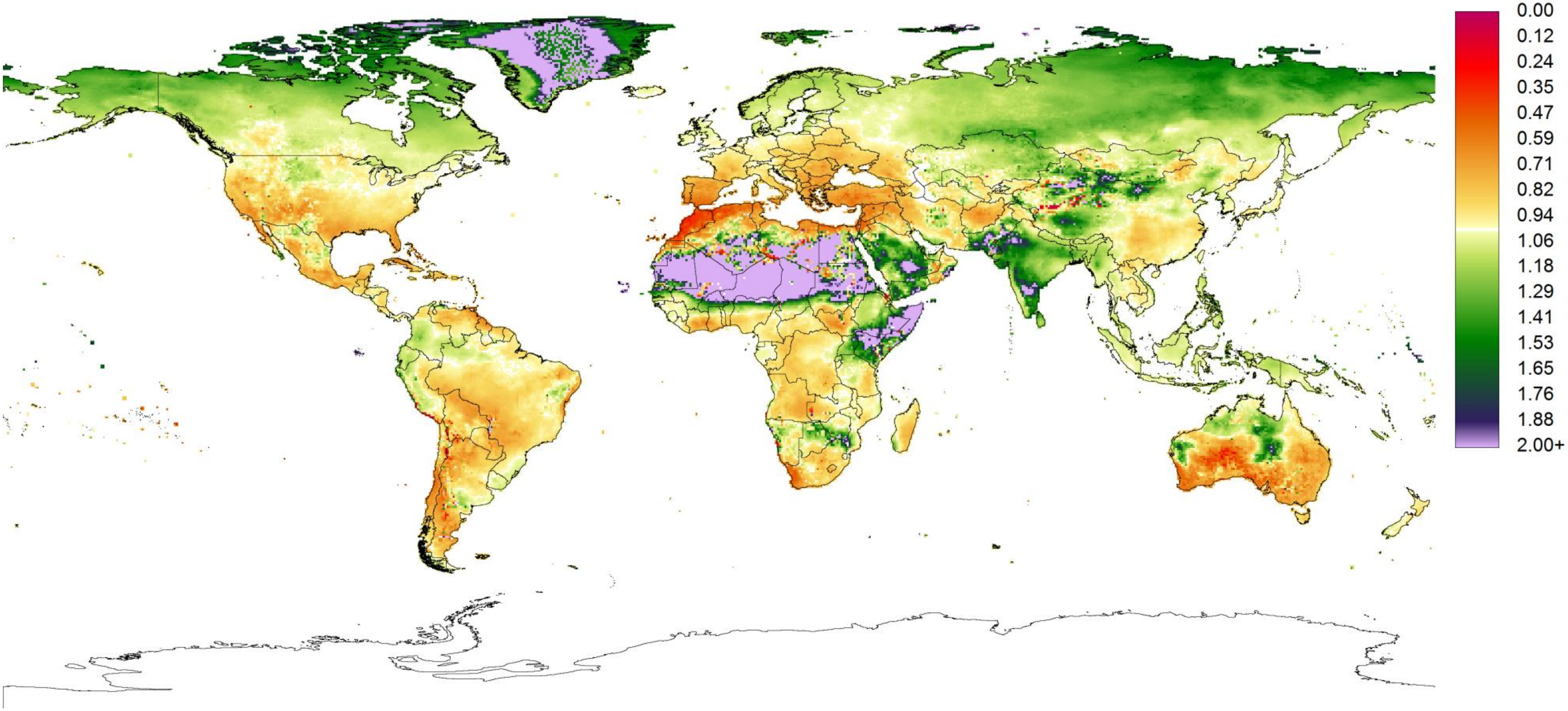
Note: The map shows the multi-model ensemble mean of annual runoff calculated over a 30-year period 2041-2070 using outputs of six hydrological models and five CMIP5 climate models (for RCP8p5) at 30 arcmin latitude/longitude, bias-corrected and interpolated for impact and adaptation analysis by the ISI-MIP project.

Change of Mean Annual Runoff, 2000-2025, RCP 8.5



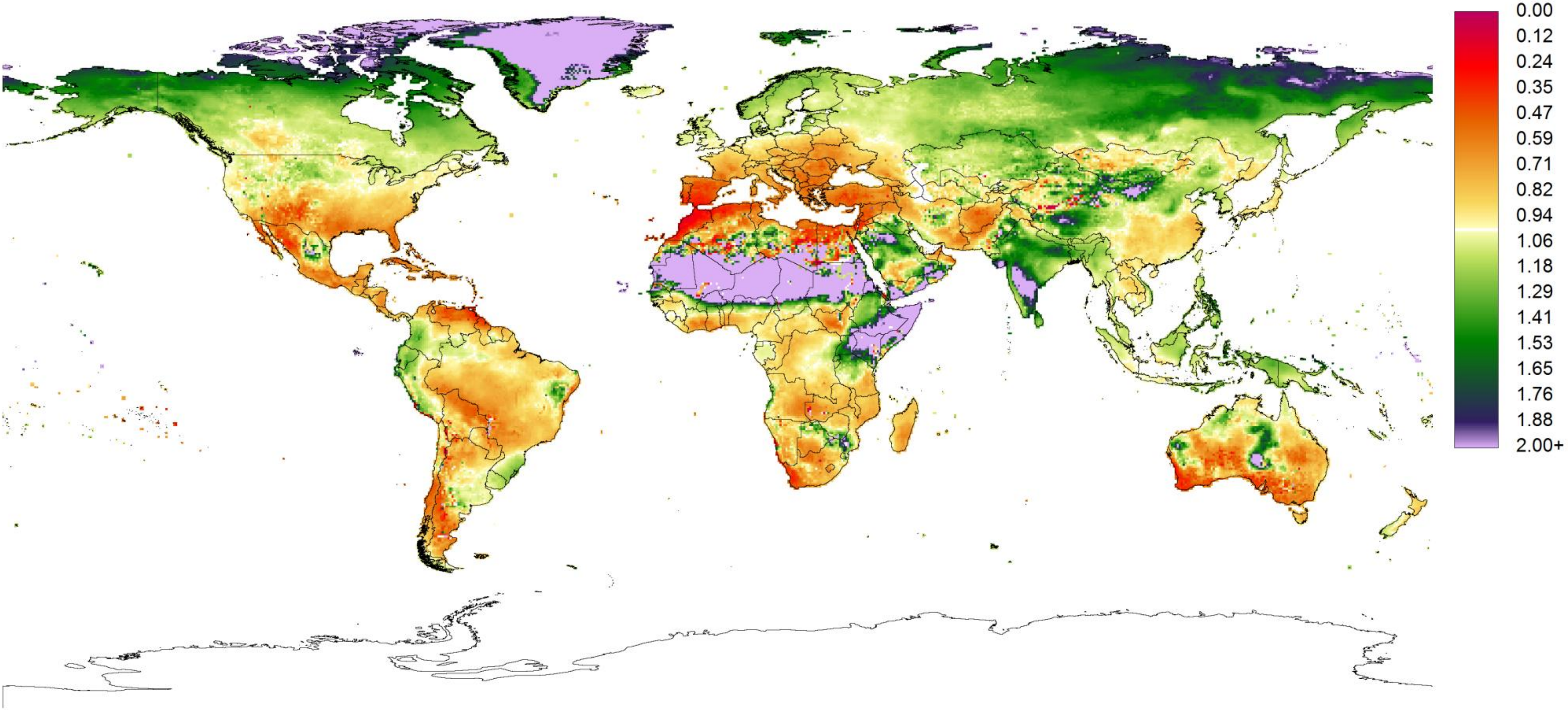
Note: The map shows the ratio of multi-model ensemble mean annual runoff calculated over a 30-year period respectively for 2011-2040 and 1971-2000 using outputs of six hydrological models and five CMIP5 climate models (for RCP8.5) at 30 arcmin latitude/longitude, bias-corrected for impact and adaptation analysis by the ISI-MIP project.

Change of Mean Annual Runoff, 2000-2050, RCP 8.5



Note: The map shows the ratio of multi-model ensemble mean annual runoff calculated over a 30-year period respectively for 2041-2070 and 1971-2000 using outputs of six hydrological models and five CMIP5 climate models (for RCP8.5) at 30 arcmin latitude7longitude, bias-corrected and interpolated for impact and adaptation analysis by the ISI-MIP project.

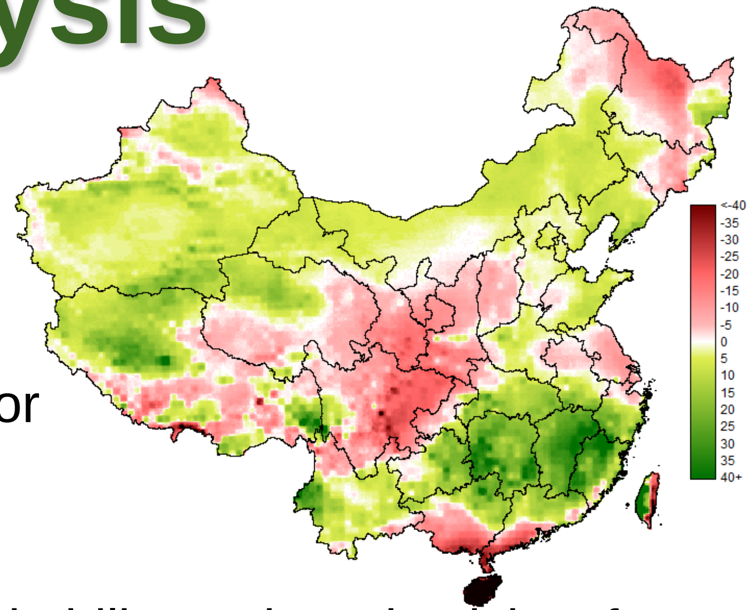
Change of Mean Annual Runoff, 2000-2080, RCP 8.5



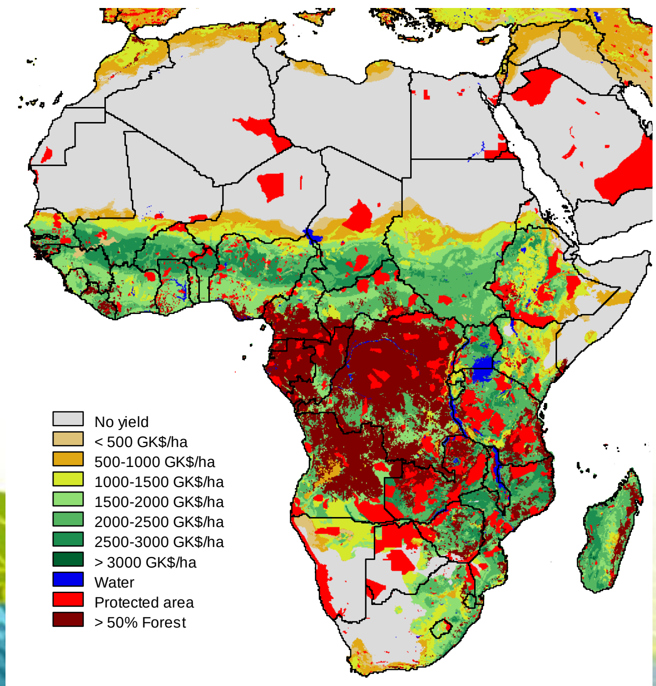
Note: The map shows the ratio of multi-model ensemble mean annual runoff calculated over a 30-year period respectively for 2070-2099 and 1971-2000 using outputs of six hydrological models and five CMIP5 climate models (for RCP8.5) at 30 arcmin latitude/longitude, bias-corrected for impact and adaptation analysis by the ISI-MIP project.

AEZ Analysis

GAEZ Global Agro-Ecological Zones



- Provides standardized framework and database for land resources appraisal and for analyzing alternatives of land and water resources use.
- Contains an automatic crop calendar search for assessing historical variability and enabling simulations for adaptation to climate change.



- Estimates land suitability and productivity of a large number of food, feed and energy crops across a wide range of environmental settings.
- Computes crop water requirements and irrigation demand and indicates trade-offs among crops and between rain-fed and irrigated uses.
- Produces comprehensive resource accounts for current land use, reveals apparent yield gaps and resource limitations, and can identify hot-spots for land use change and intensification.

Thank you!

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