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A global perspective on agricultural irrigation

- Introduction
- Direct impacts of irrigation on land, water and atmosphere
- Combined impacts of the use of different resources or management practices on environment and socio-economy
- The need for a new generation of global data products

Data needed to understand tradeoffs between agriculture and the environment

Resources:

- Climate
- Population
- Land (soil)
- Water
- Cultivars
- Livestock
- Energy
- Other assets

Economic and institutional factors:

- Market access
- Land tenure
- Credit availability

Environmental and socio-economic variables:

- Poverty
- Greenhouse gas fluxes
- Biodiversity
- Water quality
- Soil degradation

Agriculture and Forestry sectors

Management:

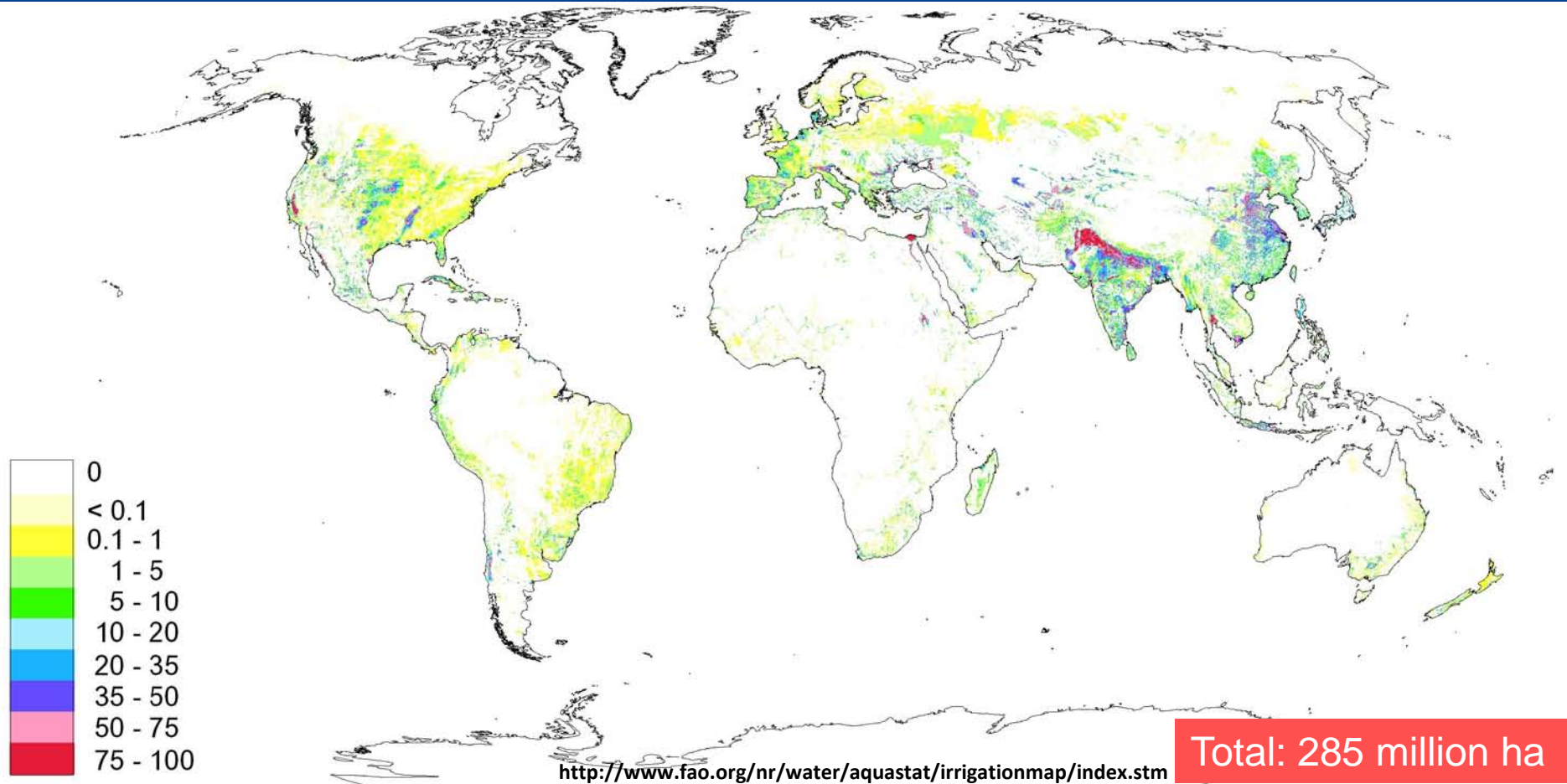
- Planting/harvest dates/cropping intensity
- Irrigation
- Fertilization
- Plant protection
- Labor
- Other management practices

Marketed products:

- Food
- Fiber
- Fuel
- Timber
- Carbon credits

Irrigated land in year 2000

GMIA 4 (Siebert et al., 2006)

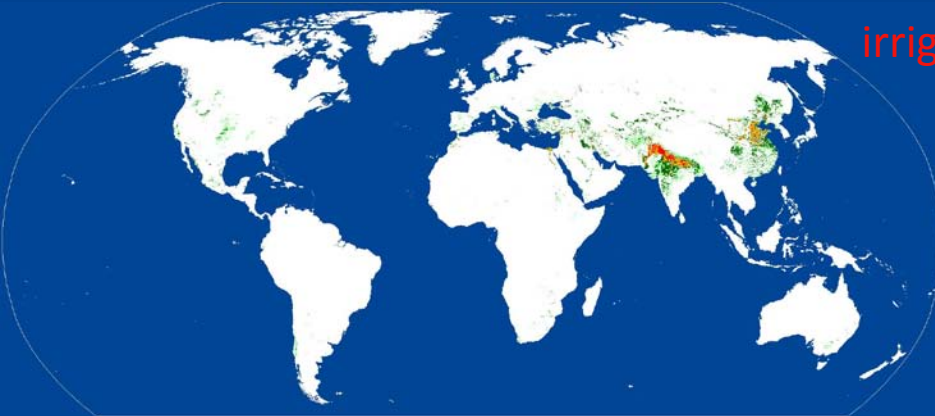


Irrigated and rainfed crop areas around year 2000 (harvested area)

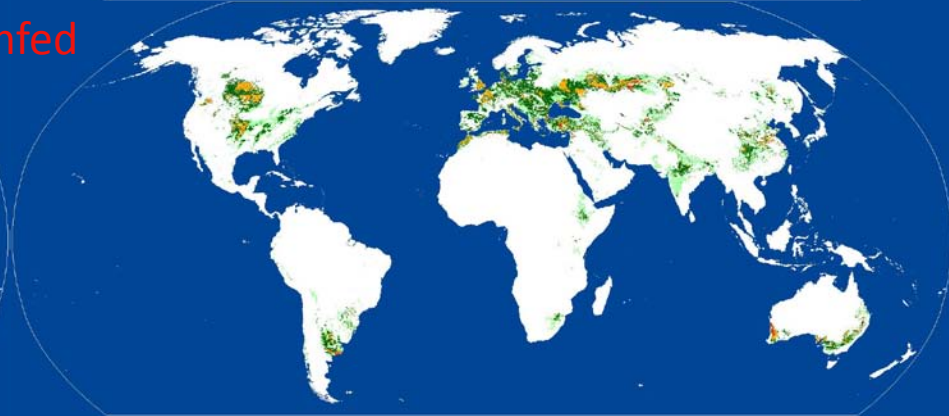
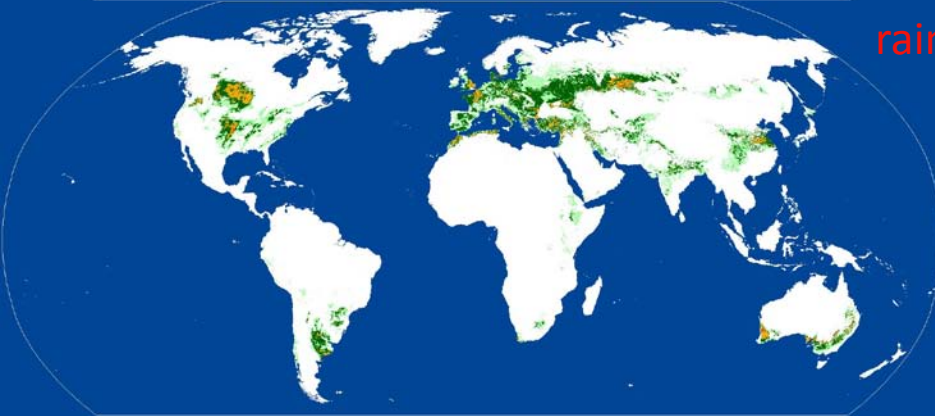
MIRCA2000 (Portmann et al., 2010)

Wheat
irrigated

IFPRI SPAM (You et al., 2006)



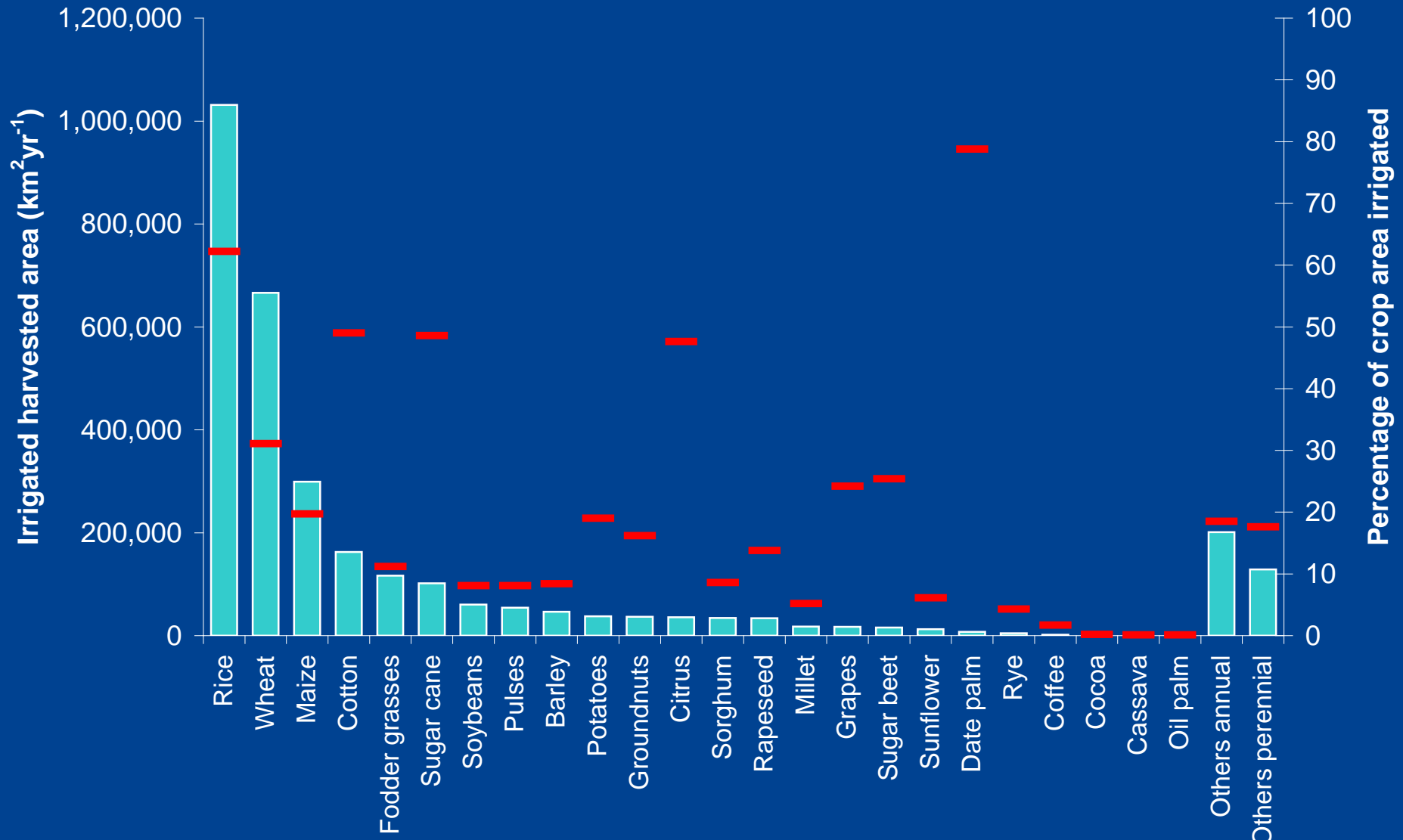
rainfed



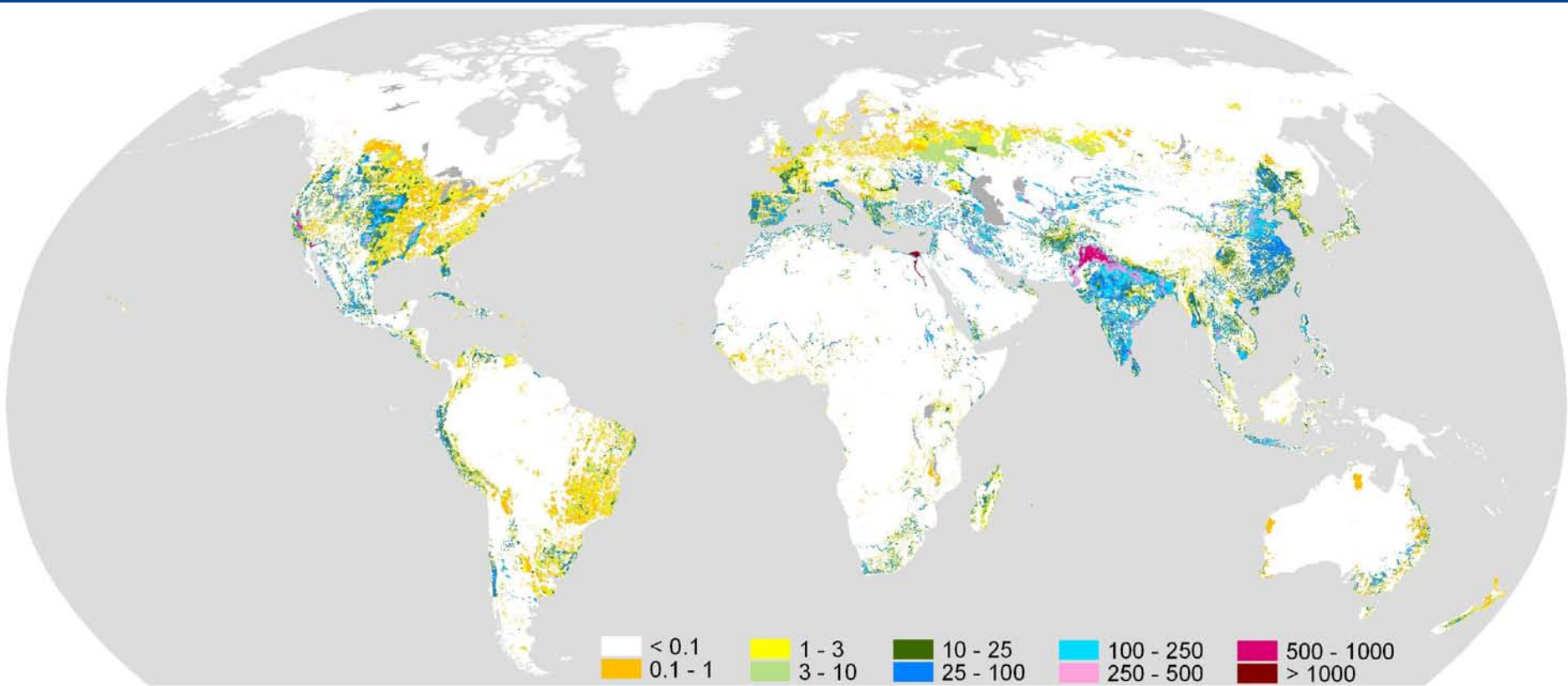
Harvested area as percentage of 5 arc-minute cell area



Harvested area of irrigated crops (MIRCA2000, Portmann et al., 2010)



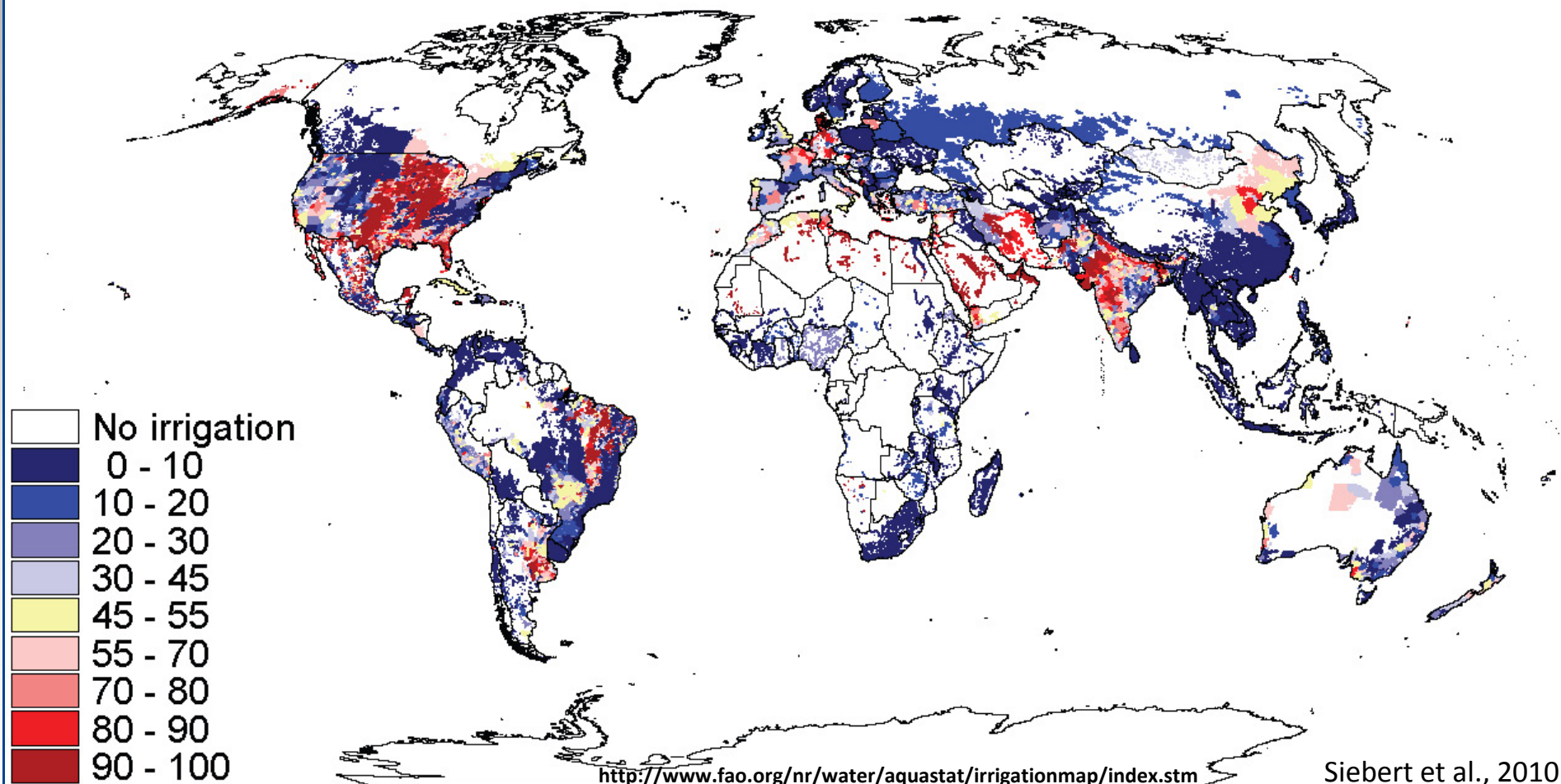
Irrigation water requirement (mm yr⁻¹)



Siebert and Döll, 2010

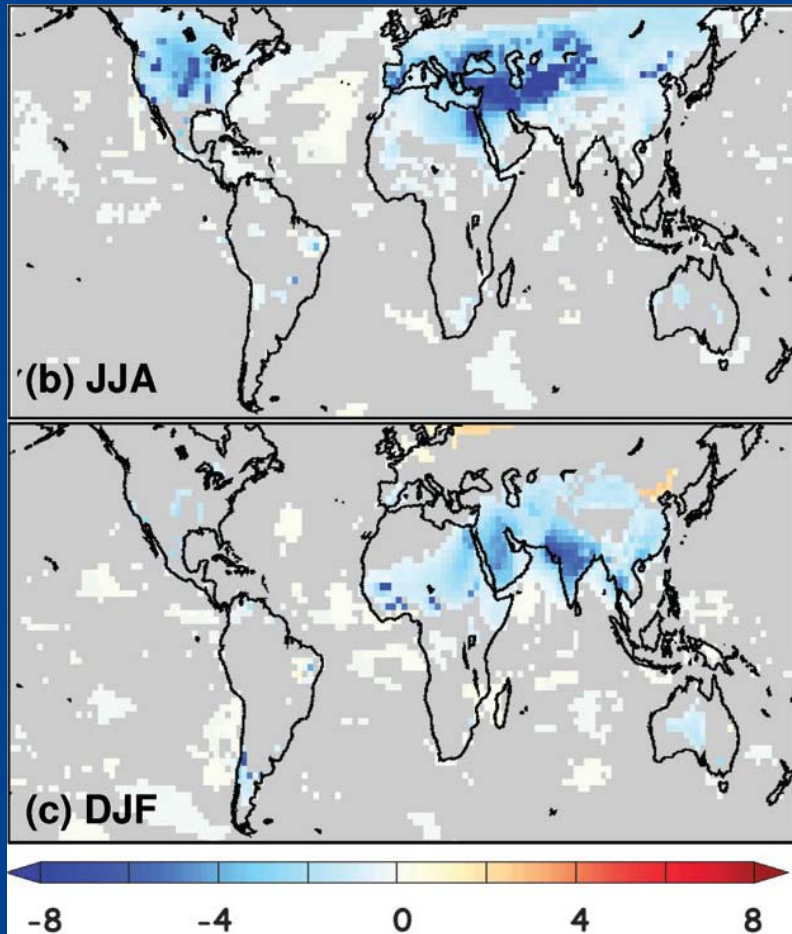
Consumptive irrigation water use about 1180 km³ yr⁻¹ in year 2000, of which 307 km³ yr⁻¹ was for rice and 207 km³ yr⁻¹ for wheat

Areas irrigated with groundwater (percentage of total irrigated land)



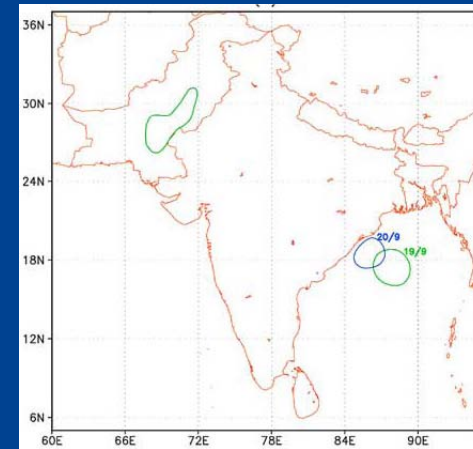
43% of total irrigation consumptive water use ($545 \text{ km}^3 \text{ yr}^{-1}$) is from groundwater

Surface cooling up to 10°C in densely irrigated regions

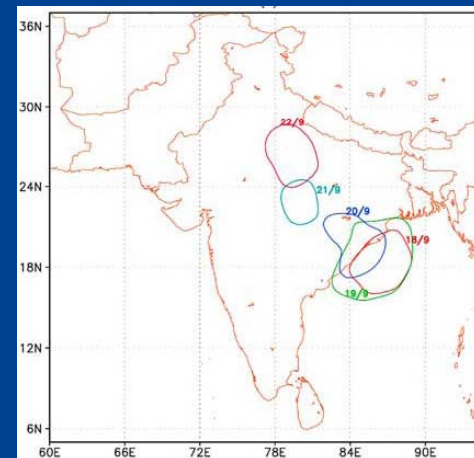


Lobell et al. (2009)

Impacts of irrigation on the South-Asian Summer Monsoon



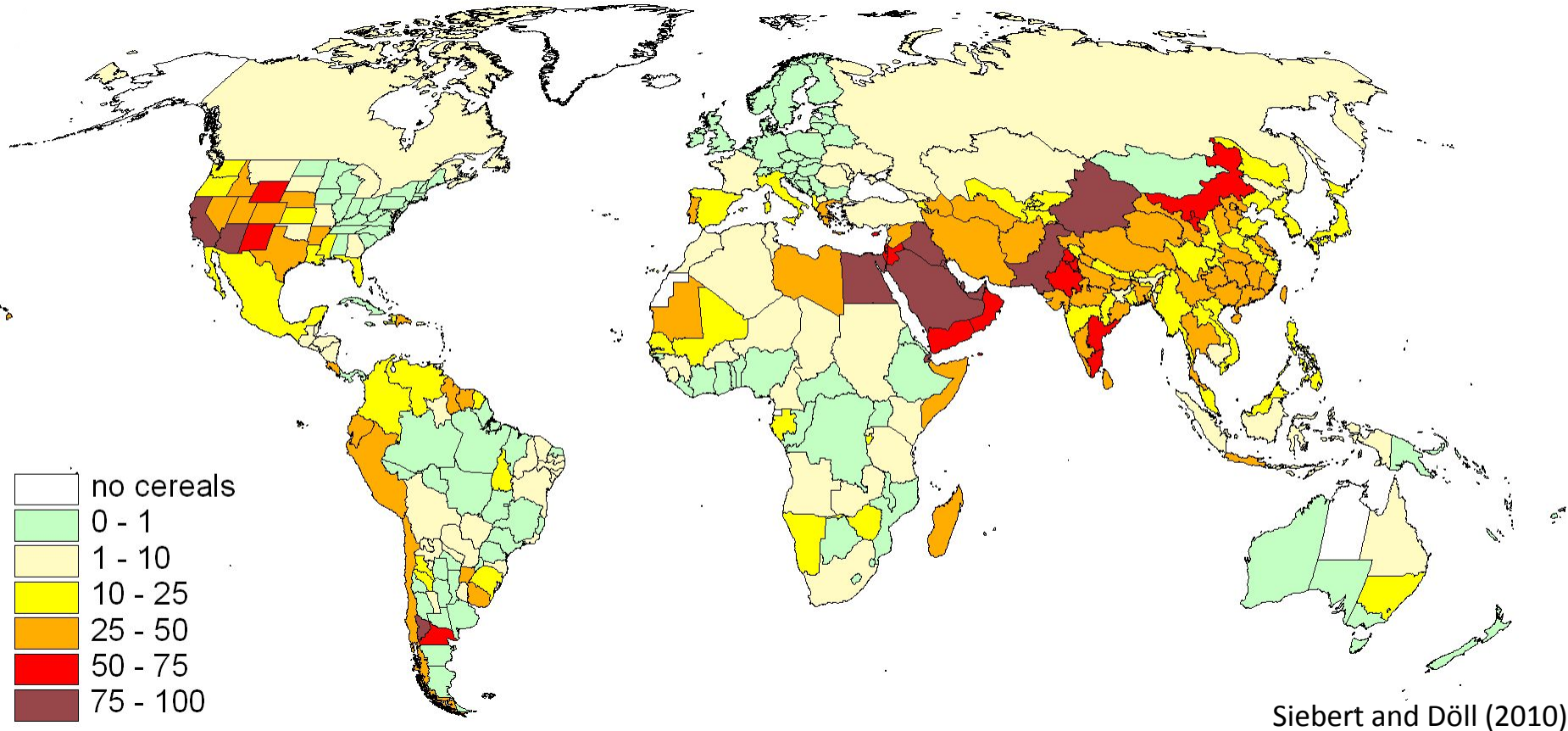
model run without irrigation



model run with irrigation

Saeed et al. (2009)

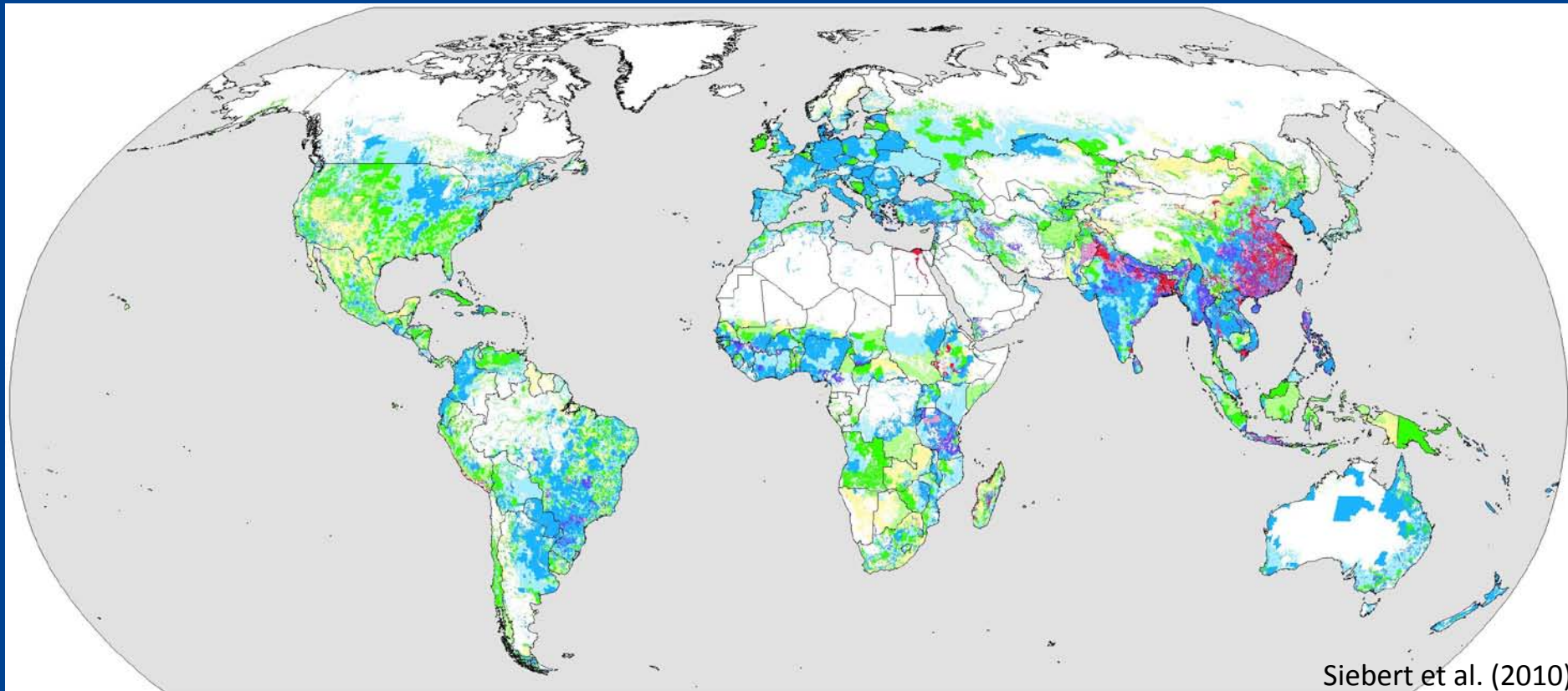
20.3% decline in global cereal production when not using irrigation



=> 4623 m³ water replace 1 ha of cereals growing area

In multi-cropping regions cropping intensity is larger in irrigated agriculture as compared to rainfed agriculture => better radiation use efficiency on cropland

Cropping intensity (including fallow)



Siebert et al. (2010)

| | | |
|-------------|-----------|-----------|
| No cropland | 0.4 - 0.6 | 1.1 - 1.3 |
| < 0.2 | 0.6 - 0.9 | 1.3 - 1.5 |
| 0.2 - 0.4 | 0.9 - 1.1 | > 1.5 |

Salinization and water logging are implications of poor land and water management.

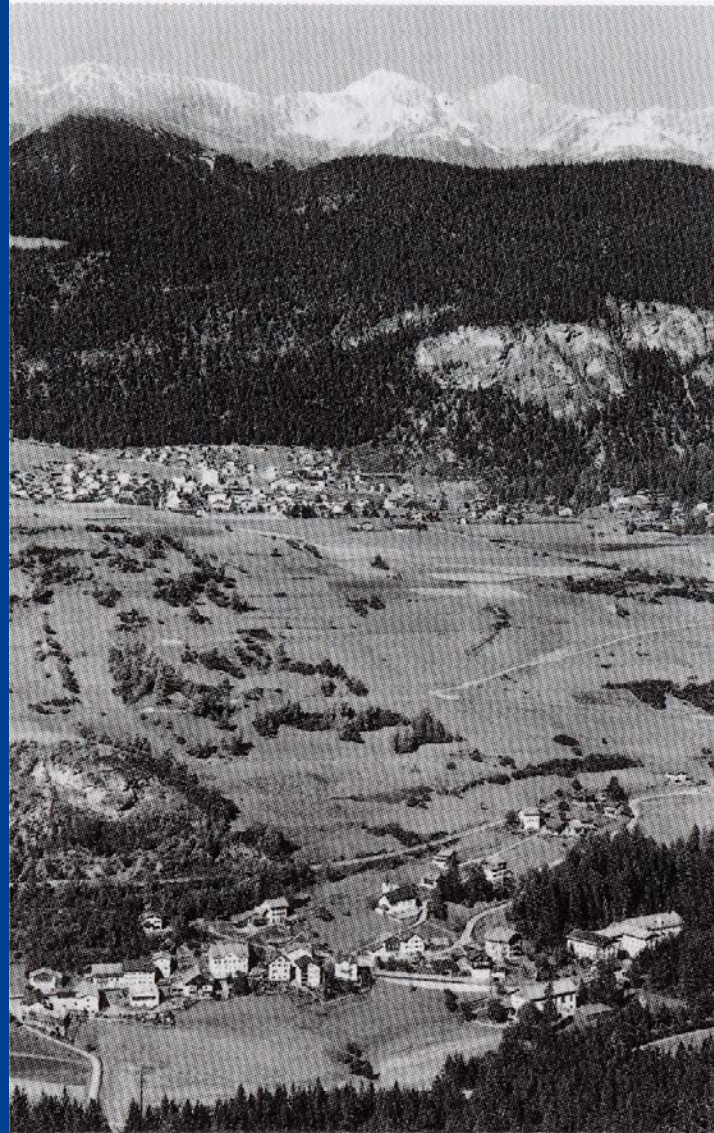
| Country | Irrigated area salinized (Million ha) |
|--------------|---------------------------------------|
| Pakistan | 7.0 (35%) |
| China | 6.7 (11%) |
| India | 3.3 (5%) |
| Uzbekistan | 2.1 (50%) |
| Iran | 2.1 (26%) |
| Turkey | 1.5 (31%) |
| World | > 30.0 (> 10%) |

Data source: FAO AQUASTAT
<http://www.fao.org/nr/water/aquastat/main/index.stm>

Artificial drainage of irrigated land and conjunctive management of ground and surface water at the basin scale are required for sustainable management of irrigated land



1931

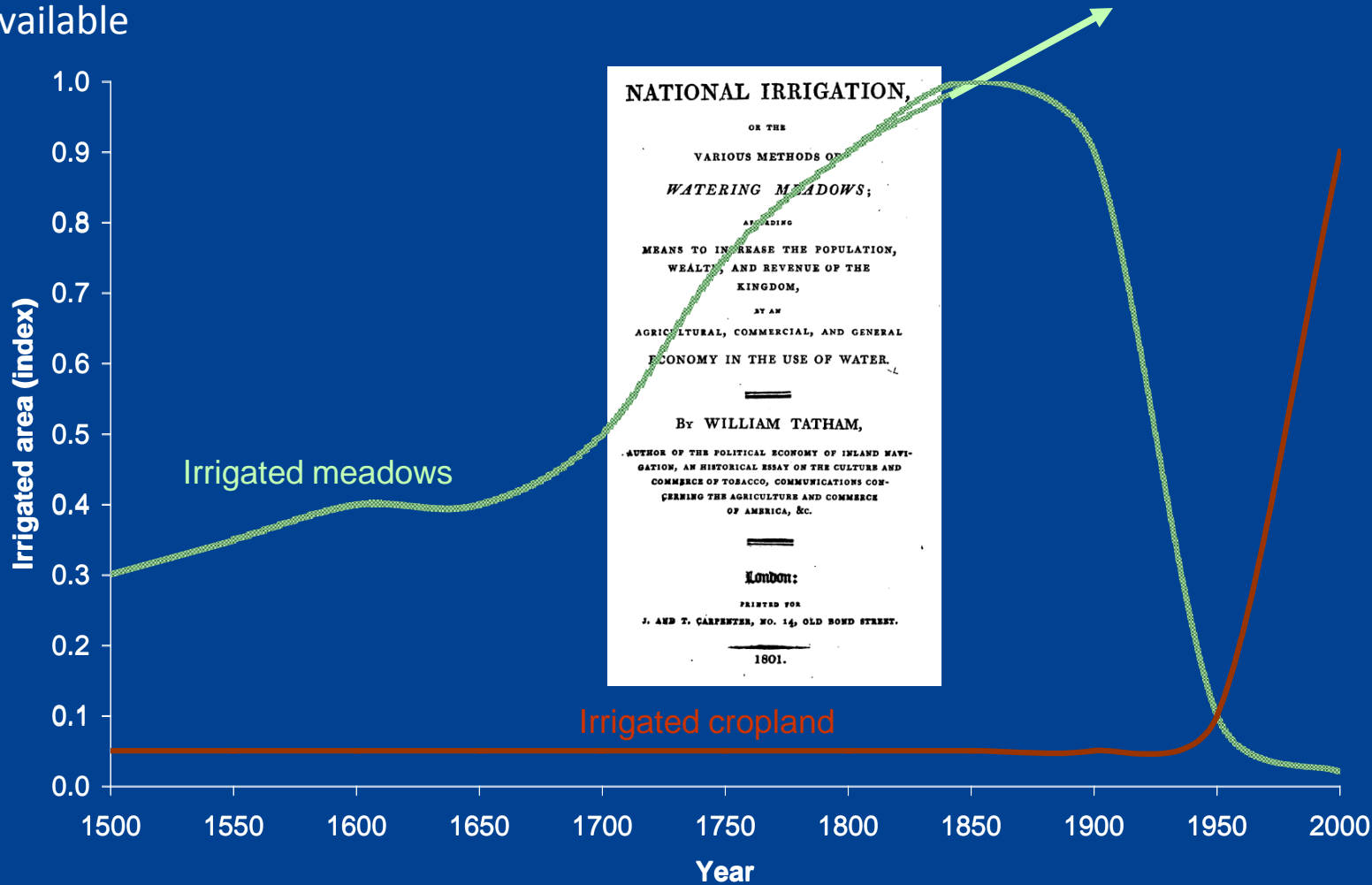


1991

Irrigated (1931) and
rainfed (1991)
meadows in
Alvaneu, Switzerland

Source: Romedo Guler,
documenta natura, Bern

Irrigated meadows were common in Northern, Western and Central Europe until mid of last century while irrigated cropland was exceptional. The main reason for irrigating meadows was to recycle crop nutrients => irrigation of meadows stopped when synthetic fertilizers became available



The main reason for flooding paddy rice is to suppress weed growth. In many regions is it possible to save a lot of irrigation **water** and to achieve similar rice yields without flooding

BUT: this will require additional inputs of **labor** and/or **pesticides**

Flooded paddy rice



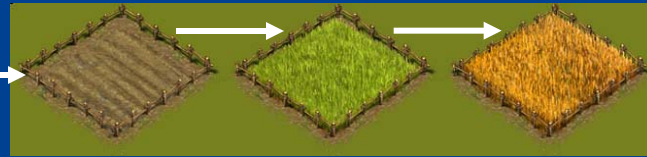
Non-flooded irrigated rice





Inputs

- Fertilizer
- Pesticides
- Irrigation
- Machinery
- ...



crop yield

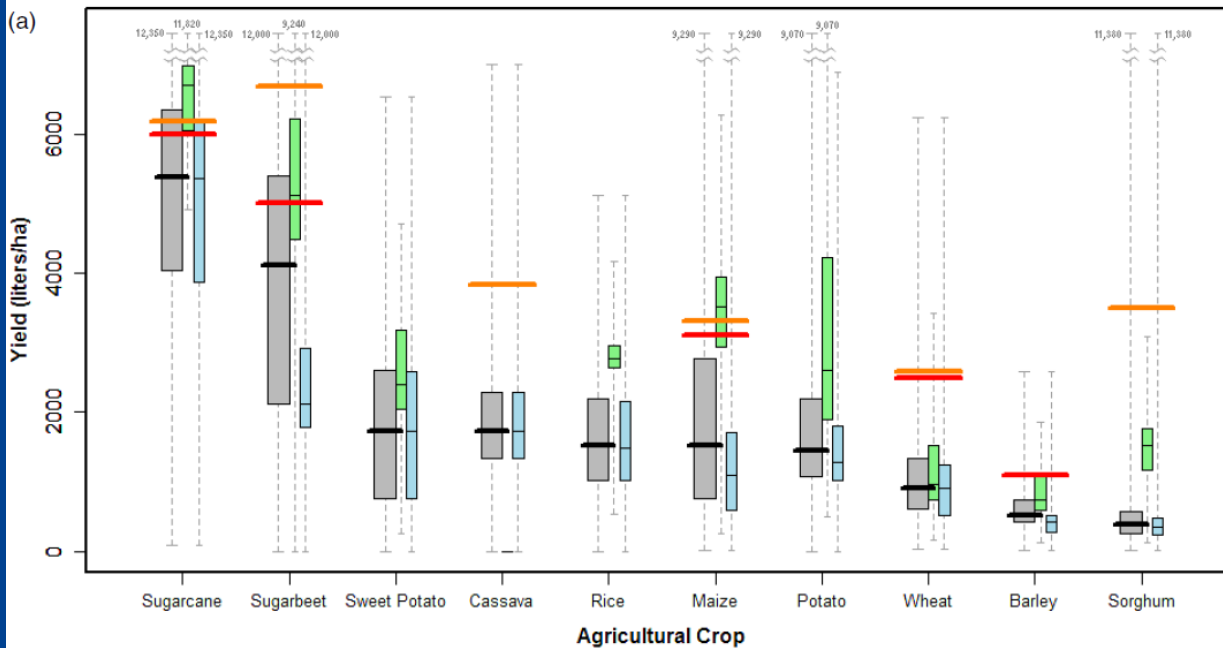


crop production



bio-fuel

Global Ethanol Yields

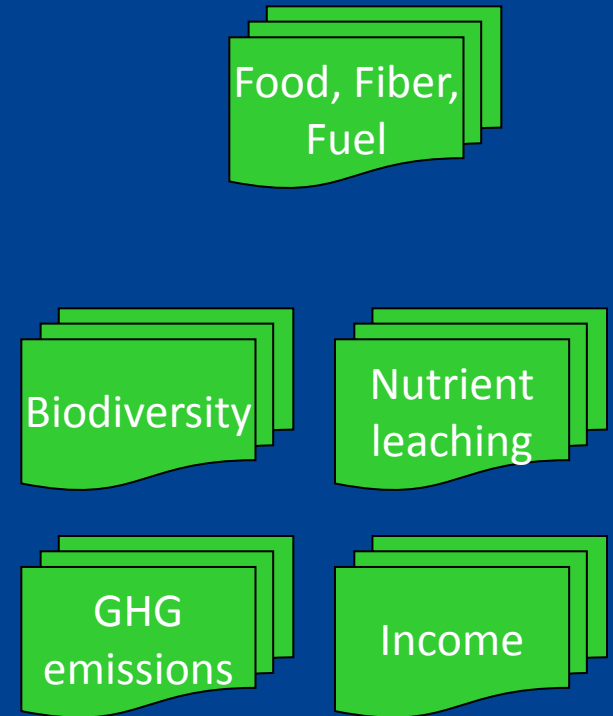
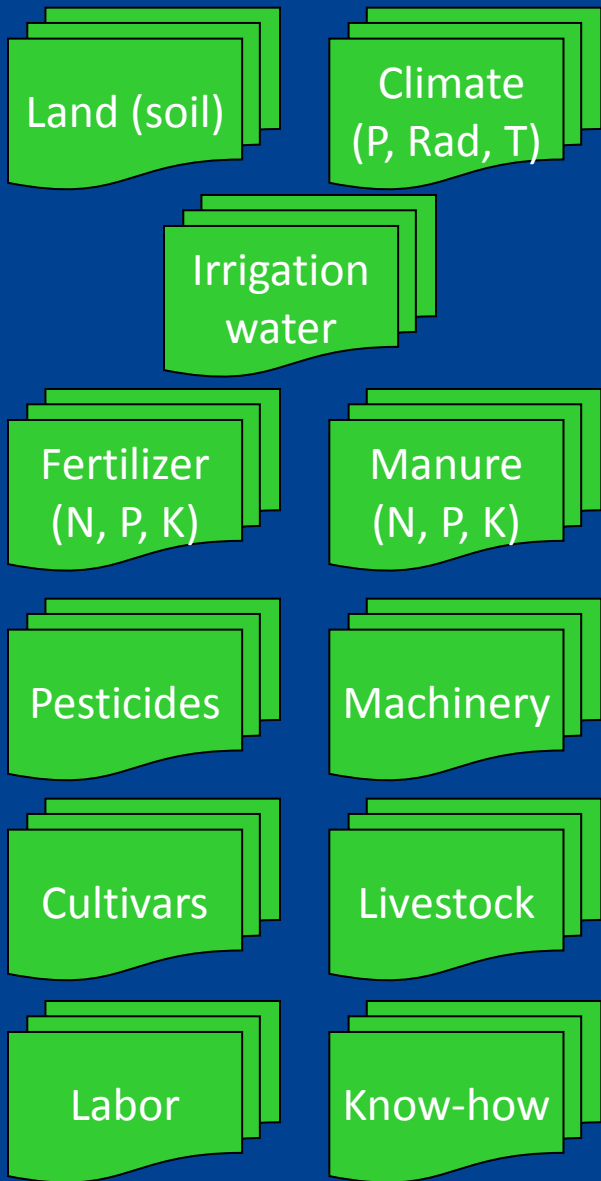


~~Maximizing of bio-fuel yield~~



Maximizing of energy balance

Global ethanol yield potential of different crops (Johnston et al., 2009)



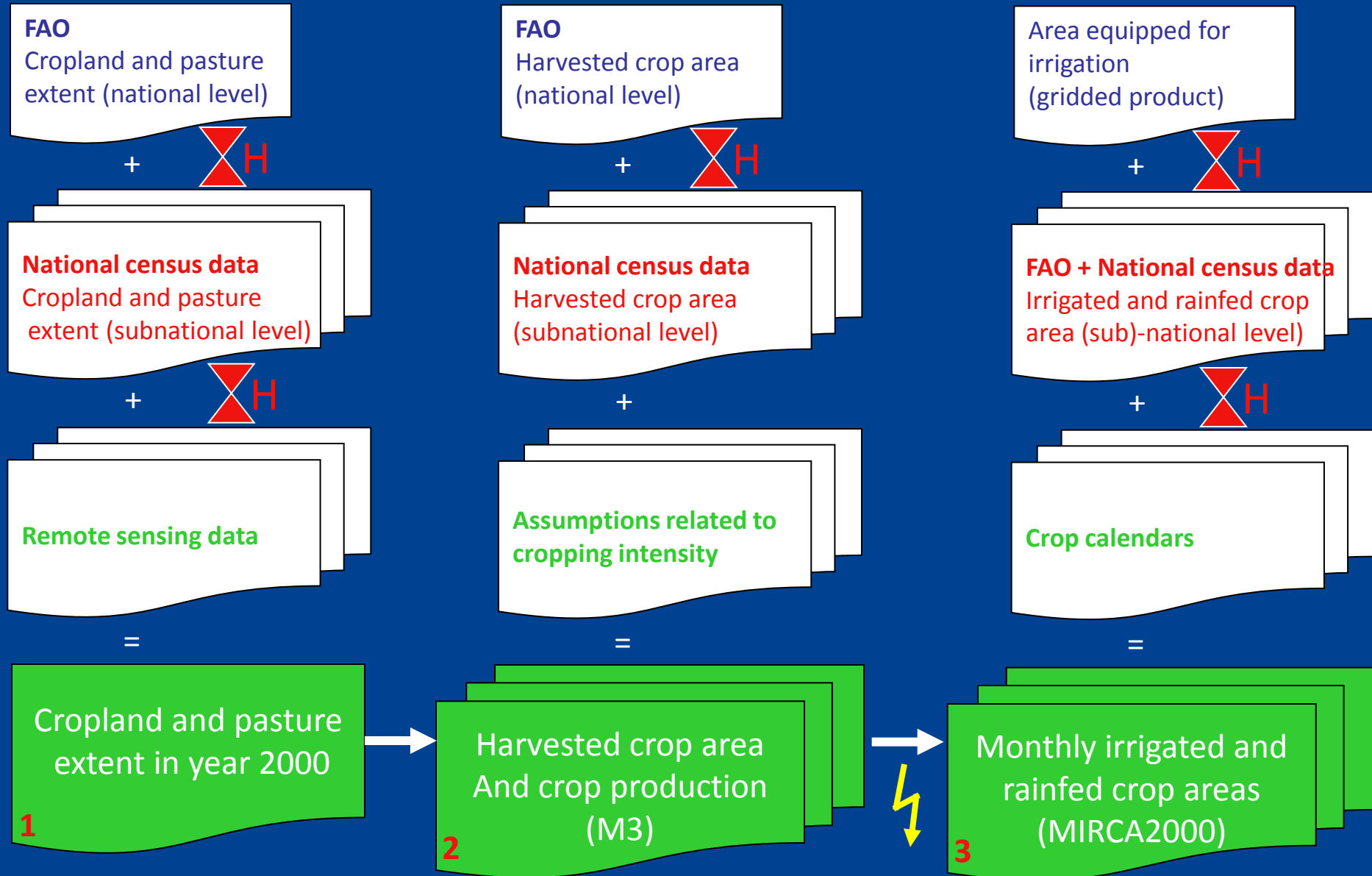
Complex spatio-temporal patterns of resources use
Resources can replace to some extent each other

To analyze resources use in agriculture we need
input data layers consistent at the grid cell level!

Need for layers of consistent data products

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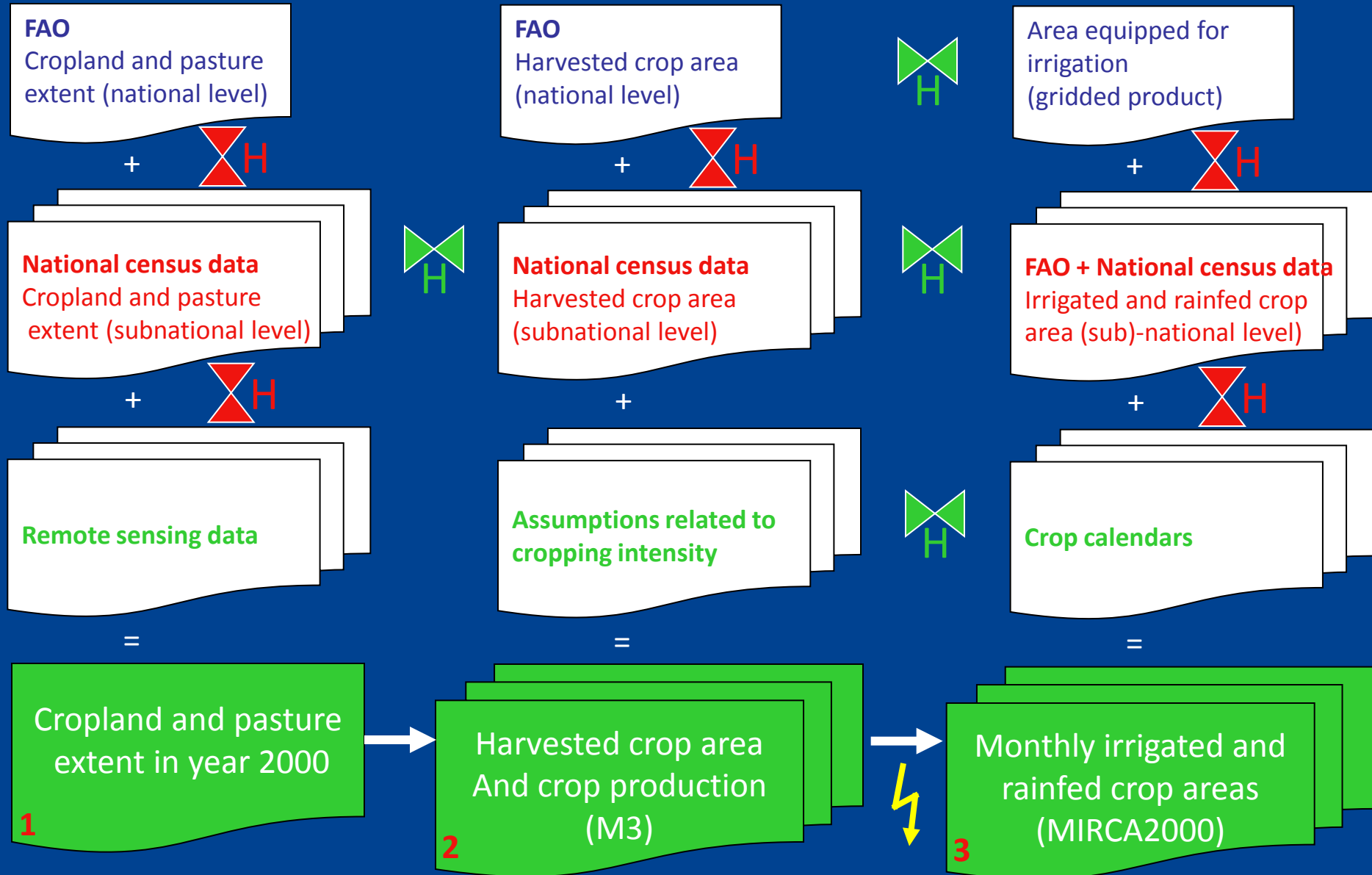
GEOSHARE kickoff meeting,
Purdue University, May 2011



Need for layers of consistent data products

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GEOSHARE kickoff meeting,
Purdue University, May 2011



Census data

Historical irrigation maps

Publications

Historical irrigation data base

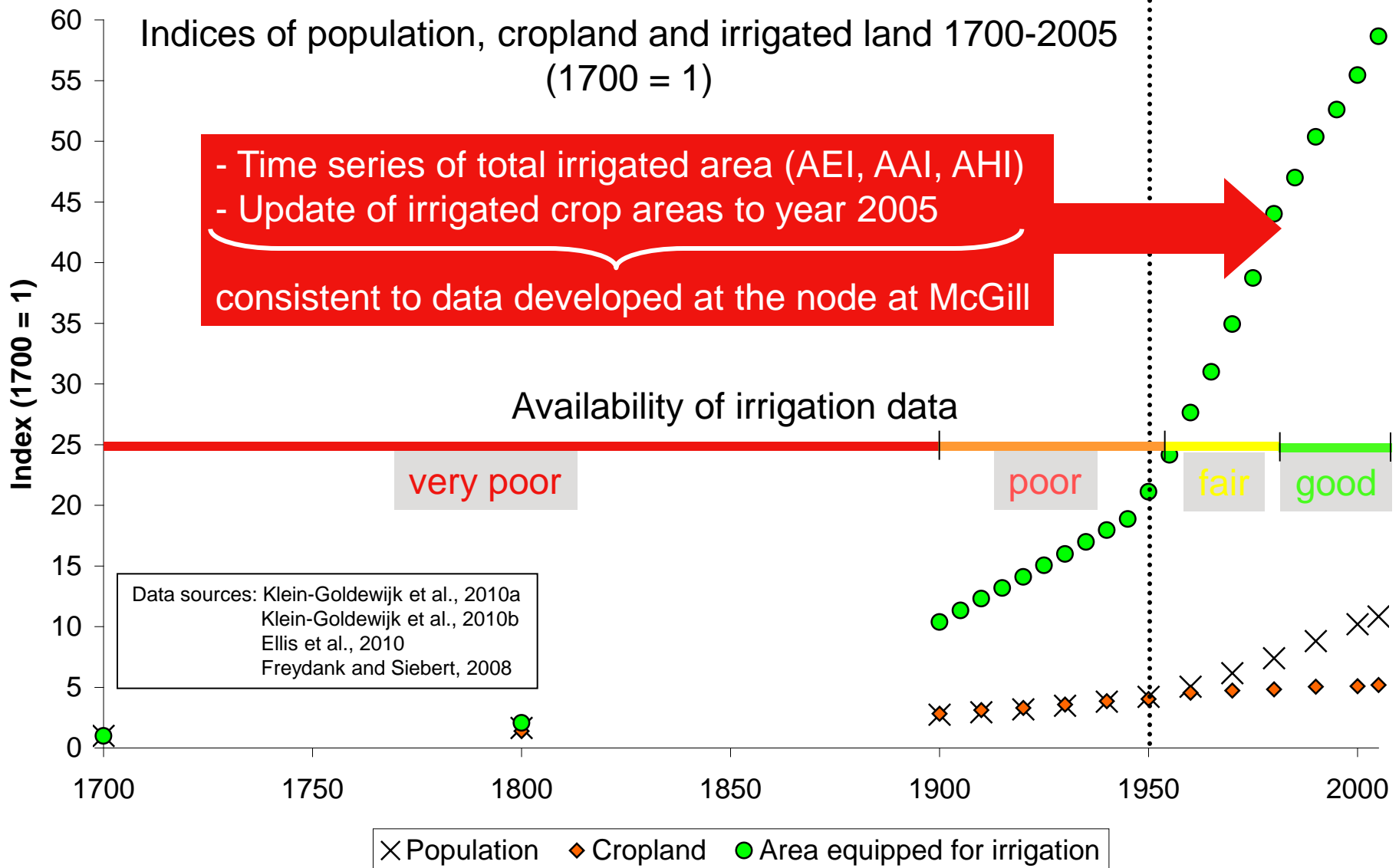
- Harmonization of input data
- Filling of data gaps
- Downscaling of statistics to grid cell level

Historical cropland and
pasture extent

Time series of harvested crop
area and crop production

Indices of population, cropland and irrigated land 1700-2005 (1700 = 1)

- Time series of total irrigated area (AEI, AAI, AHI)
- Update of irrigated crop areas to year 2005
consistent to data developed at the node at McGill



Data sources: Klein-Goldewijk et al., 2010a
Klein-Goldewijk et al., 2010b
Ellis et al., 2010
Freydank and Siebert, 2008

× Population ♦ Cropland ● Area equipped for irrigation

Thank you!



Qui cresce il primo riso svizzero
Hier wächst der erste Schweizer Reis
Ici pousse le premier riz suisse

Varietà: **Loto** - rice prodotto da risi, di alta qualità
 Italiano: **Arborio** / Schweizer Reissorten
 Varietà: **Loto** - un riz précoc de haute qualité, idéal pour le rizotto
 Semina / Ansaad / sowing: **mai** / maggio / early May / début mai
 Maturità / Ernte / harvest: **ottobre** / Oktober / en octobre

Valori nutrizionali / Nährwert / values nutritives
 energia / Energiewert / valeur énergétique: **per 100g / per 100 g / pour 100g**
 Proteine / Eiweiß / protéines: **355 kcal / 1475 kJ**
 Carboidrati / Kohlenhydrate / glucides: **2 g**
 Grassi / Fett / lipides: **78 g**
 Fibre / Ballaststoffe / fibres: **1 g**

Cotturazione:
 in acqua, senza ammollo, con irrigazione a pioggia e quindi grande risparmio di acqua (fino al 60%), cottura secondo le regole della produzione integrata (PI).

Raccolta e raffinazione:
 Trattata con una mietitrebbia convenzionale da erede, sbornata dal fieno di acciuga con macchinari discaricati e (stranisci), erede sbornata a livello presso le risaie di Lavagna di Bonnan.

Qui si sa cosa è energia.

Autore:
 System Treckenbau mit Berggang, Dabach, bis 60° senkrech Wasserleitbauch, IP-Produktion.

Verpackung:
 Eine mit hochmodernen Getreidemähdreschern, Schälern mit herkömmlichen Separatortrommeln, Sortieren, schwingeln, wägen, schälmaschinen in den Reismühlen von Lavagna und Bonnan.

Die besten Reisarten sind hier.

Coltivazione:
 in culture non submergite, campo irrigato per overflow con una grande economia di acqua (fino al 60%), coltivazione selon les règles de la production intégrée (PI).

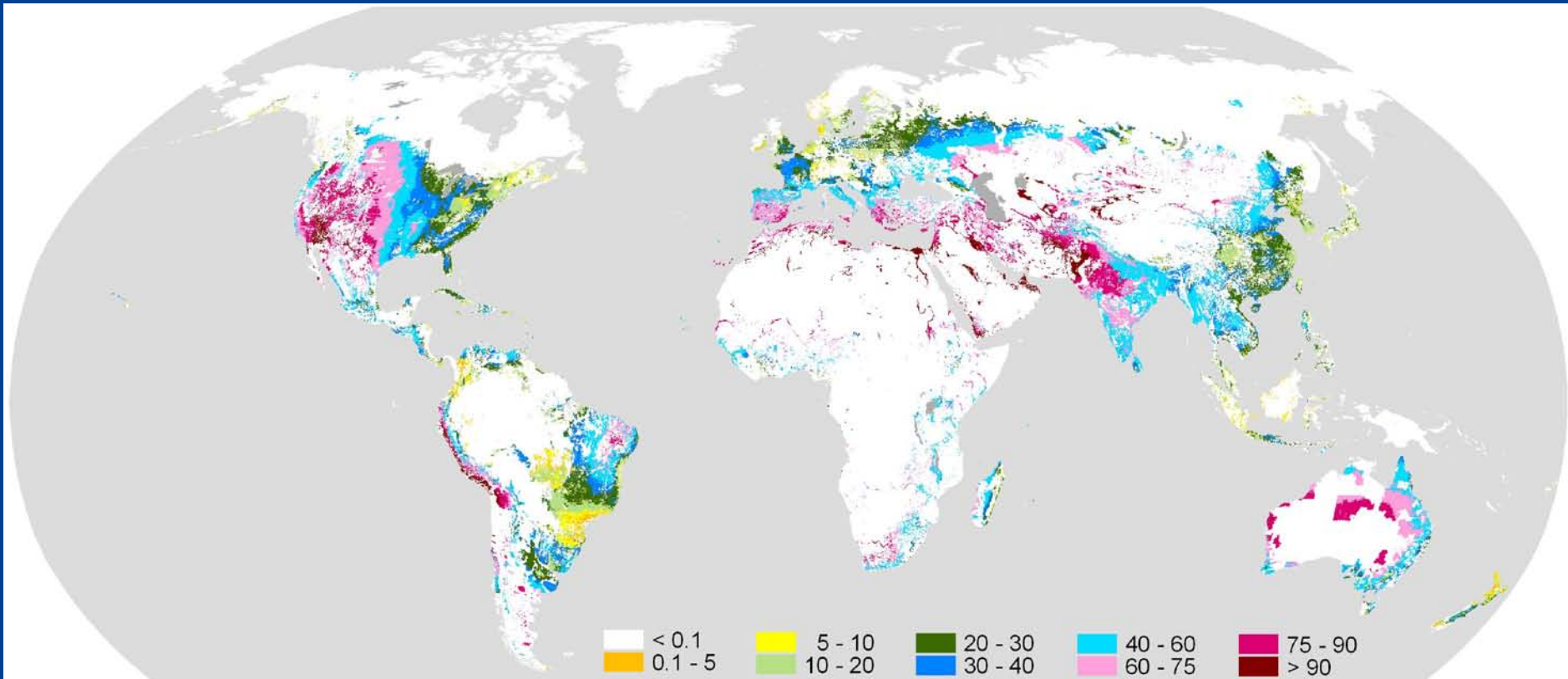
Raccolta et raffinazione:
 traité avec une moissonneuse - batteuse à cylindre conventionnelle, épiéage de riz avec le foin, en épiéage d'une manière conventionnelle, affinement du riz en - foin et criblage auprès des moulins de Lavagna et de Bonnan.

Les riz sont en riz à sec.

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Irrigation water use (percentage of total water use of irrigated crops)



Siebert and Döll, 2010

Globally averaged, 56% of the total water requirement of irrigated crops is from irrigation and 44% from precipitation stored in the soil

Many high yield varieties require optimal growing conditions including irrigation in order to realize their full yield potential. Therefore traditional varieties (risk management as main objective) are less frequent in irrigated high input systems => **loss of biodiversity**

BUT

In many irrigation oases in very arid regions we find endemic varieties => **increase of biodiversity**

=> overall impact of irrigation on biodiversity differs in space and time

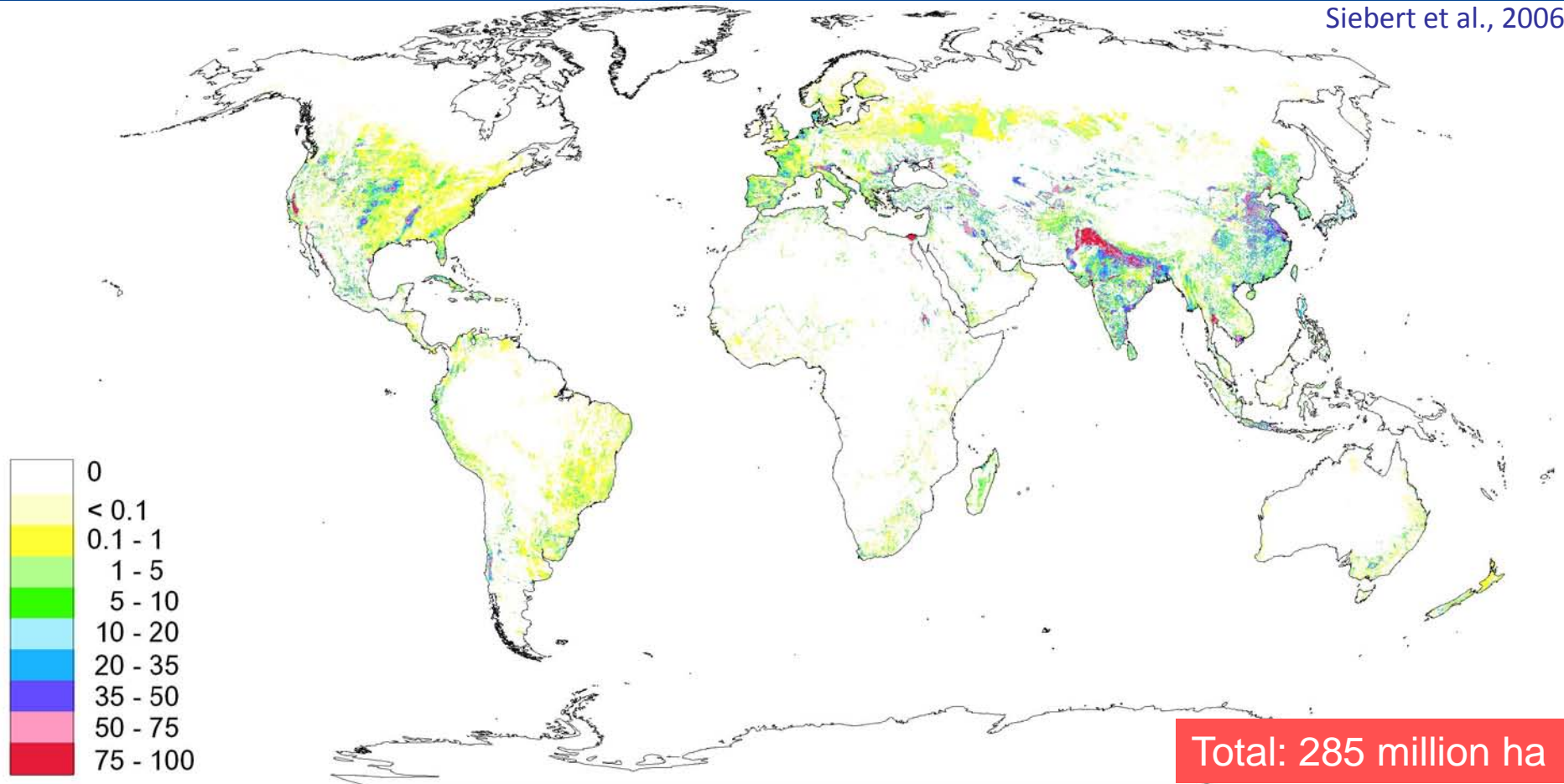


Wheat cultivation in mountain oases of the Sultanate Oman, new botanical wheat variety described first in 2003

Photographs: S. Alkhanjari and A. Buerkert, University of Kassel

Area equipped for irrigation in year 2000 (as percentage of total 5 arc-minute grid cell area)

Siebert et al., 2006



Area equipped for irrigation in year 1900 (as percentage of total 5 arc-minute grid cell area)

Ellis et al., 2010

