Water Research Horizon Conference
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GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN



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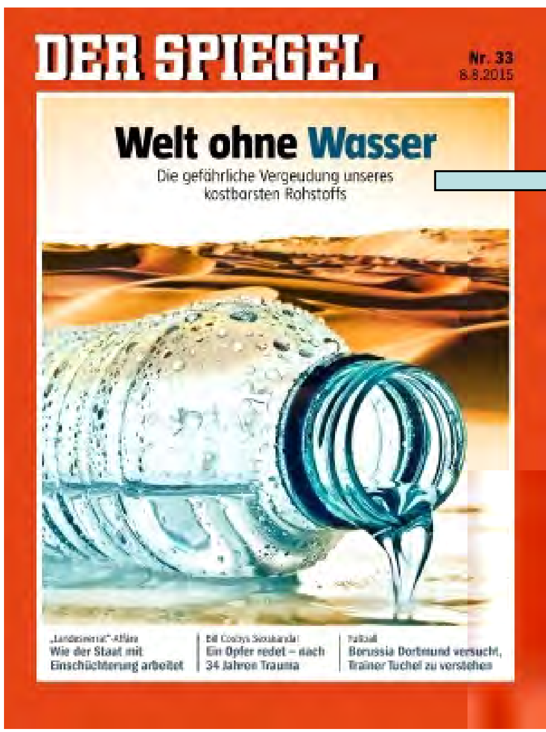
Dynamics and trends in water requirements for agriculture

- *Perspective for session: Balancing Water Quantity and Quality for Agriculture (A1)*

Guidelines for presenters:

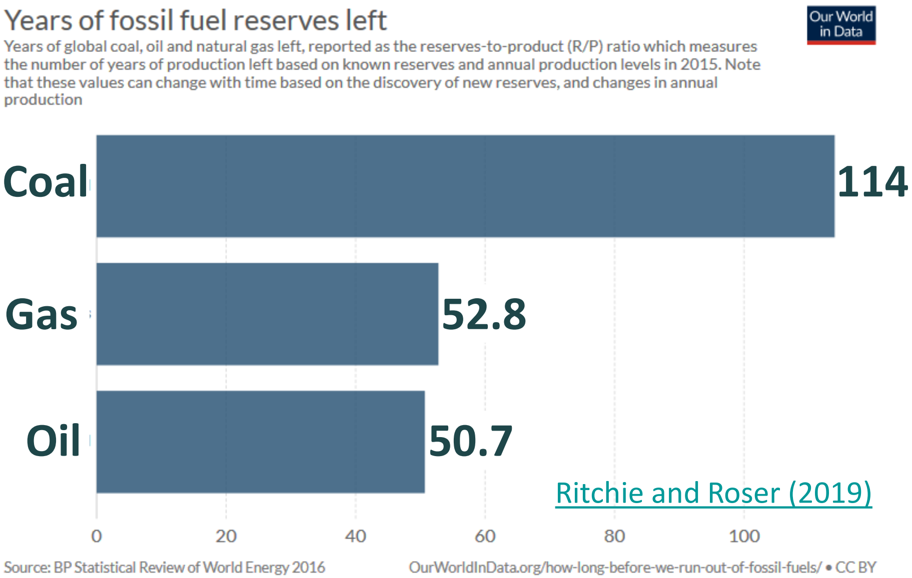
- seek the conference participants a new perspective to **open questions or missing links as well as** to **new research approaches**
- present new ideas supporting **novel interdisciplinary approaches to support bridge-building between** scientific groups with different disciplinary backgrounds,
- step stones that may promote a strengthening of the community by pushing forward cooperation in fields that up to date lack interaction and knowledge about each other.



World without water
The dangerous waste of our most valuable resource

Structure of the talk:

- Challenges with quantifying water availability
- Challenges with quantifying trends in water use
- Challenges with quantifying dynamics in water use

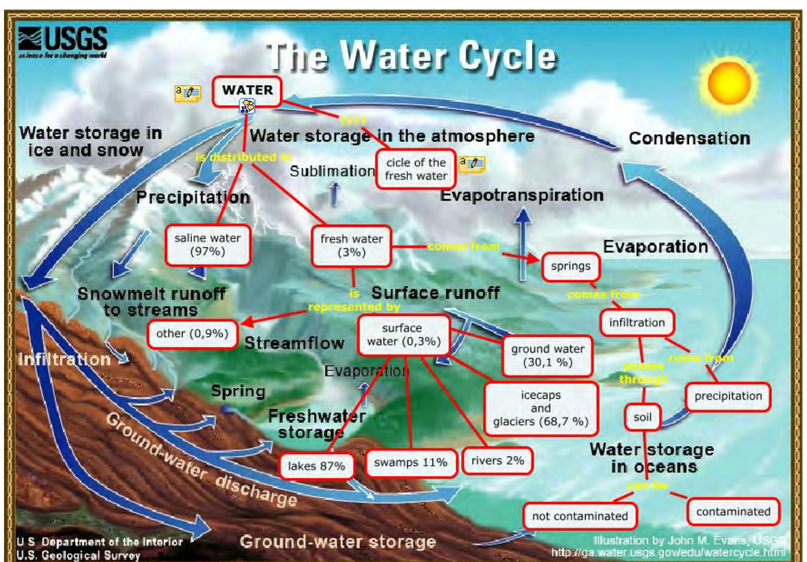


Fossil fuel reserves:

Non-renewable resource

=> Consumption is reducing the remaining reserves and the years left until the reserve is used up

=> Process can only be delayed by exploration of new reserves and reduced consumption



Water:

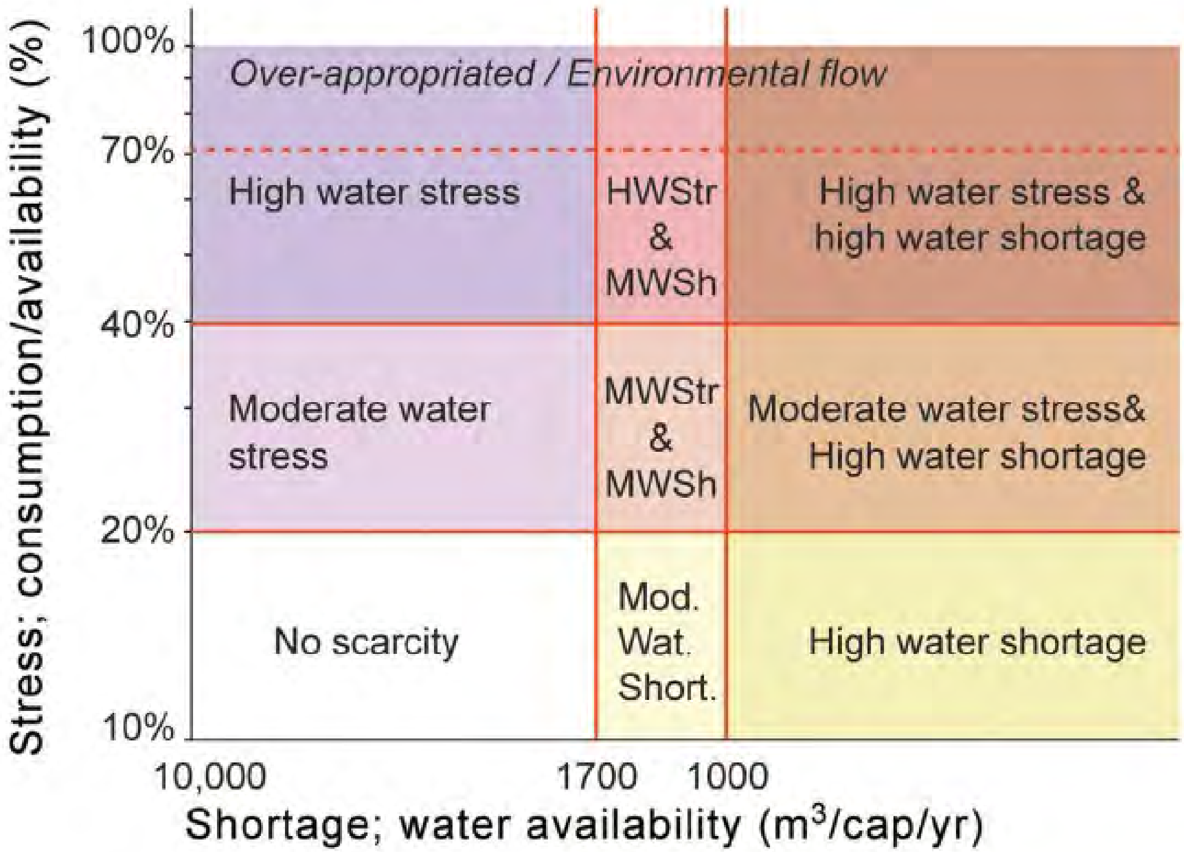
Renewable resource (except fossil groundwater)

=> Little change in total storage volumes

=> Can never be used up

=> Scarcity is caused by **spatial and temporal imbalances** between water availability and water demand

Determining water scarcity – the Falkenmark water scarcity matrix



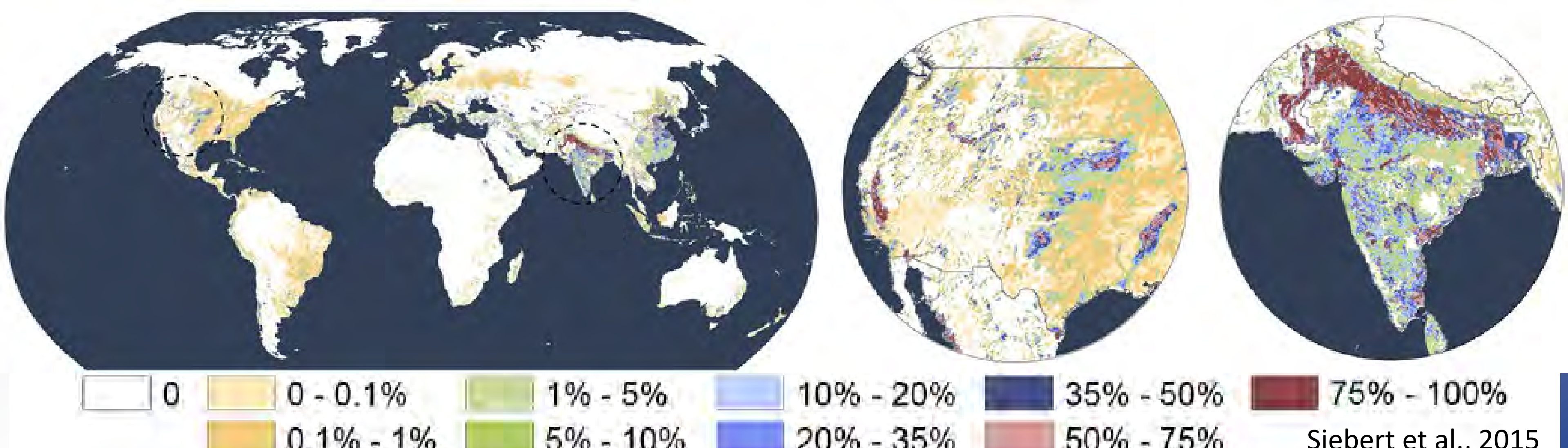
Kummu et al. (2016)

$$\frac{\text{water use}}{\text{population}} = \frac{\text{water use}}{\text{water availability}} \times \frac{\text{water availability}}{\text{population}}$$

$$\text{i. e. per capita water use} = \text{stress indicator} \times \text{shortage indicator}$$

- **90%** of consumptive water use is for irrigation (Döll et al., 2012)
- **43%** of cereal production on irrigated land, >**20%** decline in total cereal production without irrigation (Siebert and Döll, 2010)
- **17 million** reservoirs with a surface > **50 million ha** have been used for water supply and energy production and result in increased evapotranspiration and flow regulation (Lehner et al., 2011)
- **42%** of the freshwater use for irrigation is extracted from **groundwater** => declining groundwater tables in many irrigation areas (Döll et al., 2012)
- > **13%** of the sea level rise in period 2000-2008 can be attributed to groundwater depletion (Konikow, 2011)

2005: 306 Millionen ha

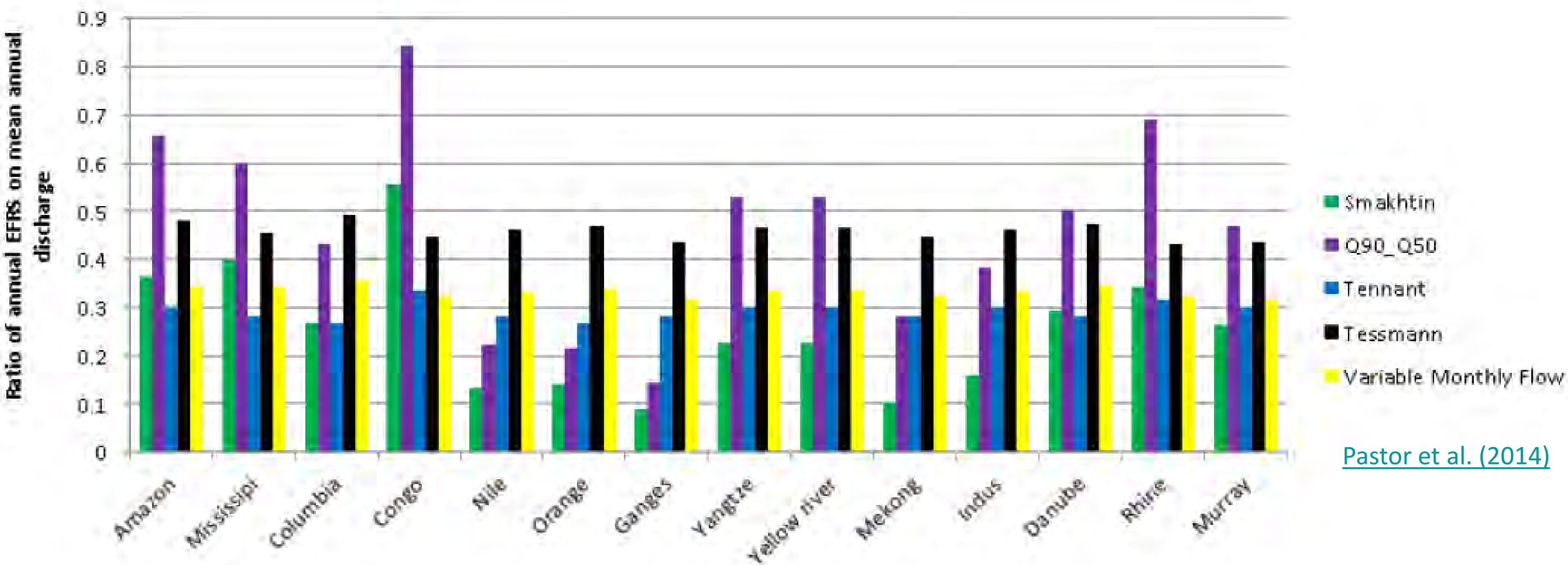


Siebert et al., 2015

Challenges in determining water availability

Challenges in determining water availability for agriculture **– surface water resources**

Water available for human use = river discharge – **environmental flow requirement**

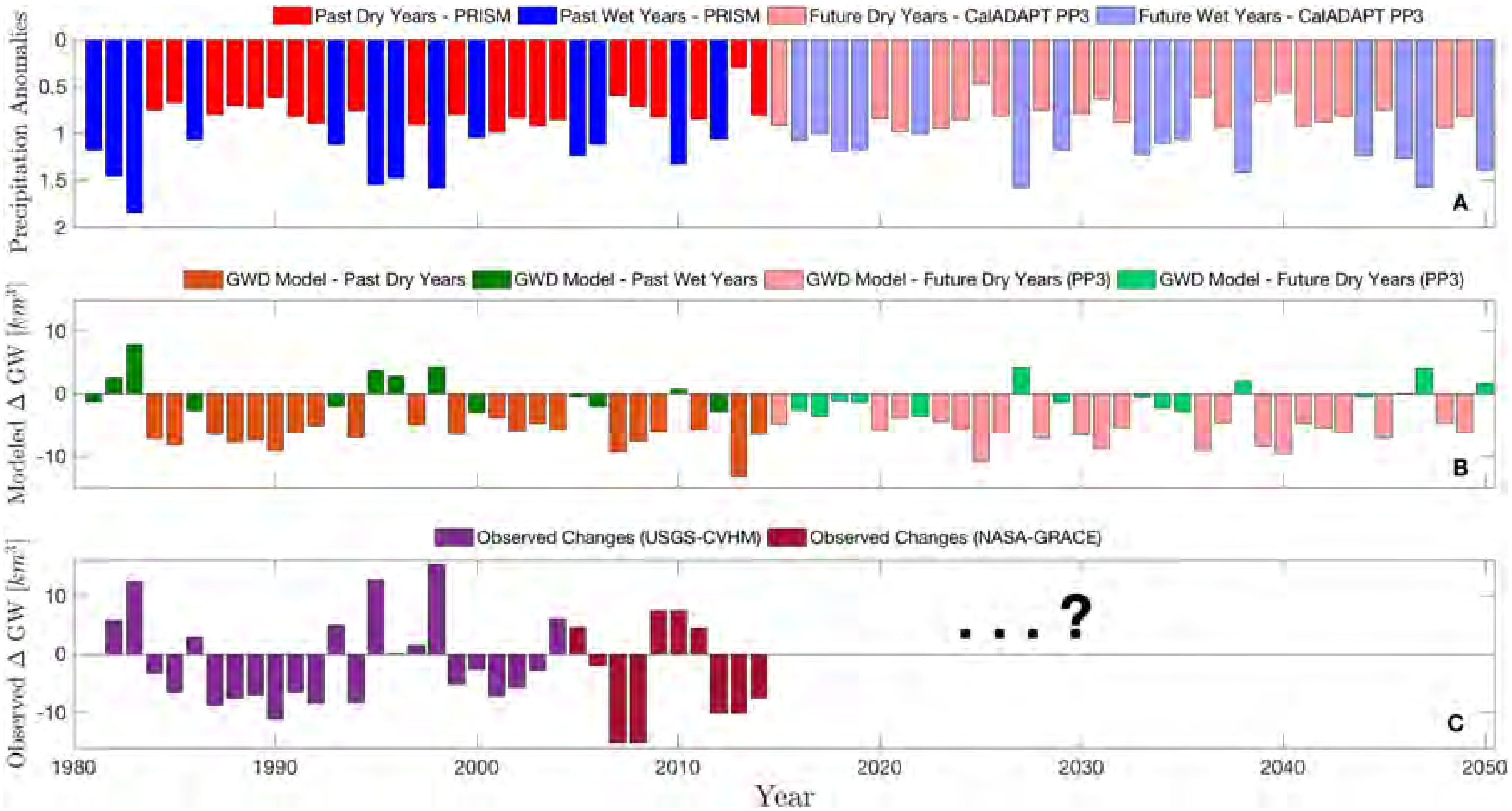


Pastor et al. (2014)

- Estimates of environmental flow requirements differ considerably depending on the method used and on the basin and period (high flow, low flow) when the method is applied!
- All methods are based on river discharges that would be observed under “pristine” conditions. There are big uncertainties in calculating these pristine baseline conditions.

Challenges in determining water availability for agriculture – **groundwater resources**

Water available for human use = long-term mean groundwater recharge



Massoud et al., 2018

Which time period should be considered to balance groundwater extractions and groundwater recharge?

Challenges in estimating trends in water use

1) Water use statistics

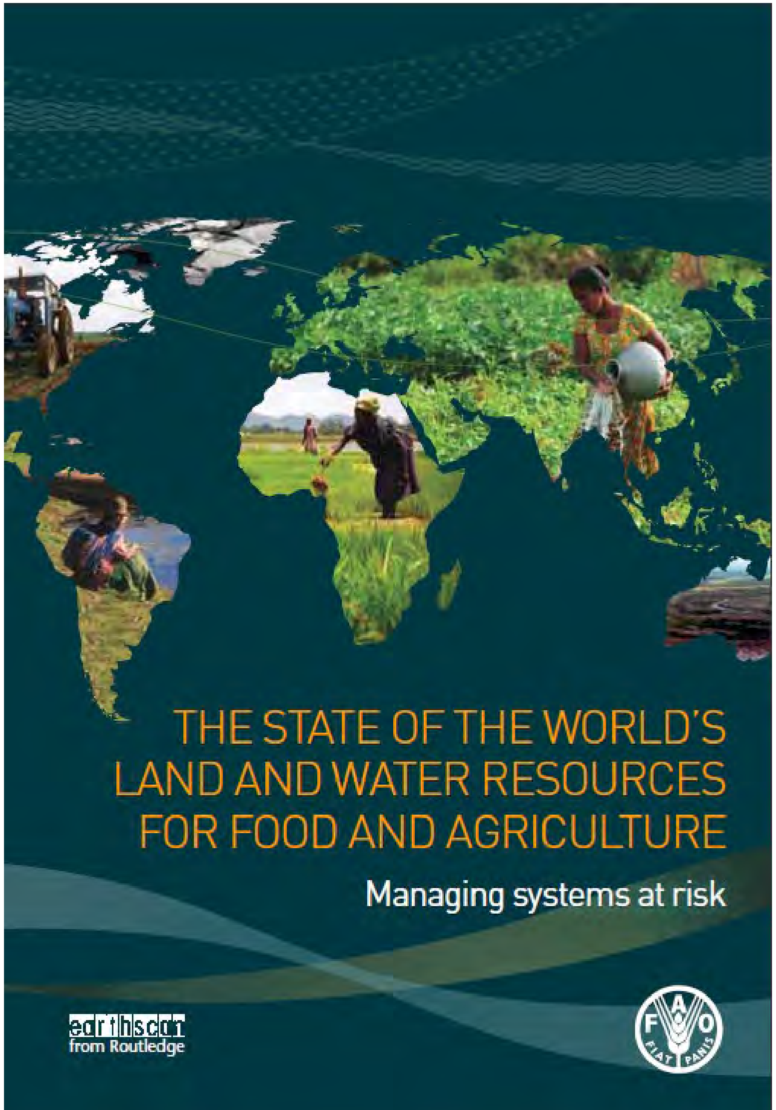
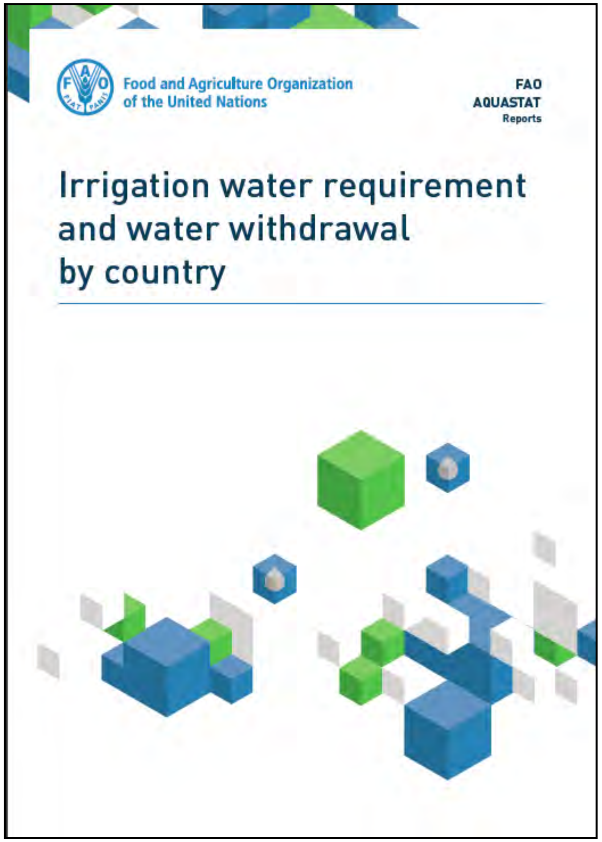


TABLE 1.4: WATER WITHDRAWAL BY MAJOR WATER USE SECTOR (2003)

Continent Regions	Total withdrawal by sector: Municipal km³/yr	Municipal %	Industrial km³/yr	Industrial %	Agricultural km³/yr	Agricultural %	Total water withdrawal * km³/yr	Total freshwater withdrawal km³/yr	Freshwater withdrawal as % of IRWR
Africa	**21**	**10**	**9**	**4**	**184**	**86**	**215**	**215**	**5**
Northern Africa	9	9	5	6	80	85	94	94	201
Sub-Saharan Africa	13	10	4	3	105	87	121	121	3
Americas	**126**	**16**	**280**	**35**	**385**	**49**	**791**	**790**	**4**
Northern America	88	15	256	43	258	43	603	602	10
Central America and Caribbean	6	26	2	11	15	64	24	24	3
Southern America	32	19	21	13	112	68	165	165	1
Asia	**217**	**9**	**227**	**9**	**2 012**	**82**	**2 456**	**2 451**	**20**
Western Asia	25	9	20	7	227	83	271	268	55
Central Asia	5	3	8	5	150	92	163	162	61
South Asia	70	7	20	2	914	91	1 004	1 004	57
East Asia	93	14	150	22	434	64	677	677	20
Southeast Asia	23	7	30	9	287	84	340	340	17
Europe	**61**	**16**	**204**	**55**	**109**	**29**	**374**	**374**	**6**
Western and Central Europe	42	16	149	56	75	28	265	265	13
Eastern Europe and Russian Federation	19	18	56	51	35	32	110	110	2
Oceania	**5**	**17**	**3**	**10**	**19**	**73**	**26**	**26**	**3**
Australia and New Zealand	5	17	3	10	19	73	26	26	3
Pacific Islands	0.01	14	0.01	14	0.05	71	0.1	0.1	0.1
World	**429**	**11**	**723**	**19**	**2 710**	**70**	**3 862**	**3 856**	**9**
High-income	145	16	392	43	383	42	920	916	10
Middle-income	195	12	287	18	1 136	70	1 618	1 616	6
Low-income	90	7	44	3	1 191	90	1 324	1 324	18
Low-income food deficit	**182**	**8**	**184**	**8**	**1 813**	**83**	**2 180**	**2 179**	**16**
Least-developed	**10**	**5**	**3**	**1**	**190**	**94**	**203**	**203**	**5**

* Includes use of desalinated water

1) Water use statistics

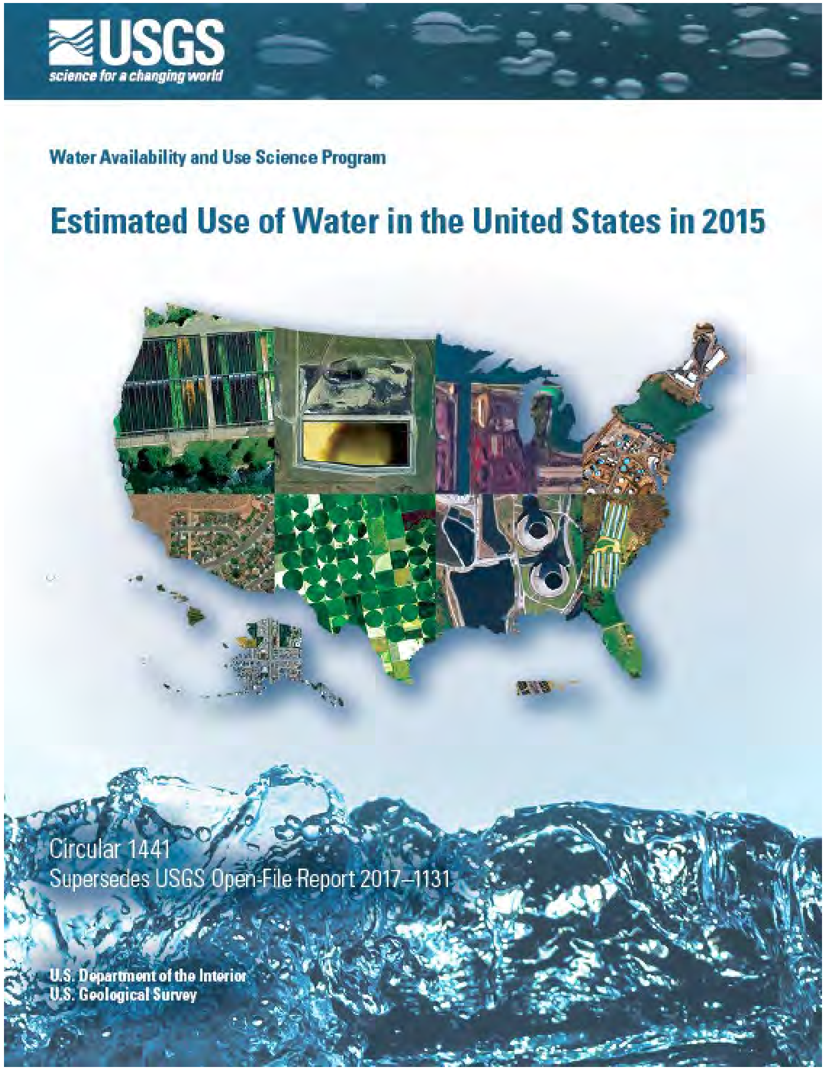


For most of the countries the FAO-aquastat database only contains **1 record within the period 1958-2017 for irrigation water withdrawal** and 2-3 records for agricultural water withdrawal

Data driven trends of global water withdrawal cannot be obtained

For 118 out of the 165 countries and territories information on water withdrawal is available from national sources (i.e. not estimated). In order to fill the data gaps regarding the 47 countries for which this information is not available (or only estimated), a ratio of the estimated irrigation water requirement to the actual irrigation water withdrawal is calculated for countries for which such data is available:

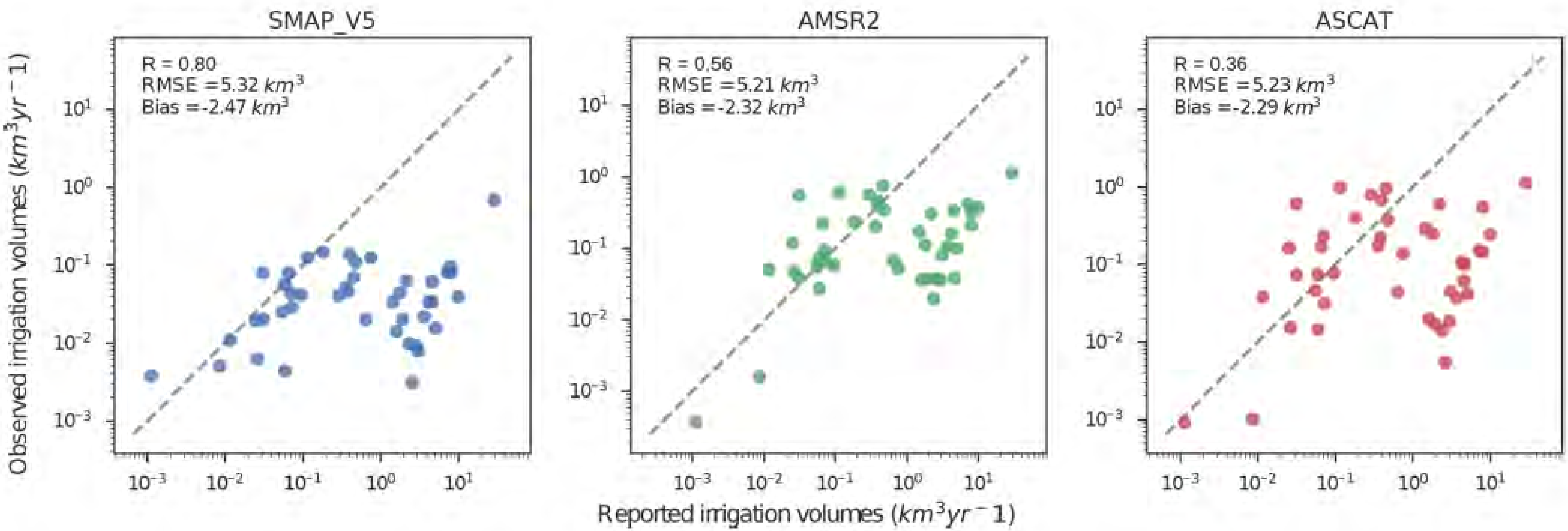
1) Water use statistics



The main data source for FAO statistics are national water statistics such as those from USGS. But even in the countries with the most sophisticated water reporting, irrigation water withdrawals, in particular groundwater withdrawals, are **hardly measured but estimated or simulated**.

Sources of data for irrigation withdrawals and irrigated acres included State and Federal crop reporting programs, irrigation districts, canal companies, incorporated management areas, satellite data depicting 2015 cropland landscapes, and evapotranspiration estimates. Withdrawals were estimated using information on irrigated crop acreages by crop type and specific crop water-consumption coefficients, or irrigation-system application rates, as well as soil-moisture balance models. Estimation methods varied from one State to the next and sometimes between geographic areas within a State.

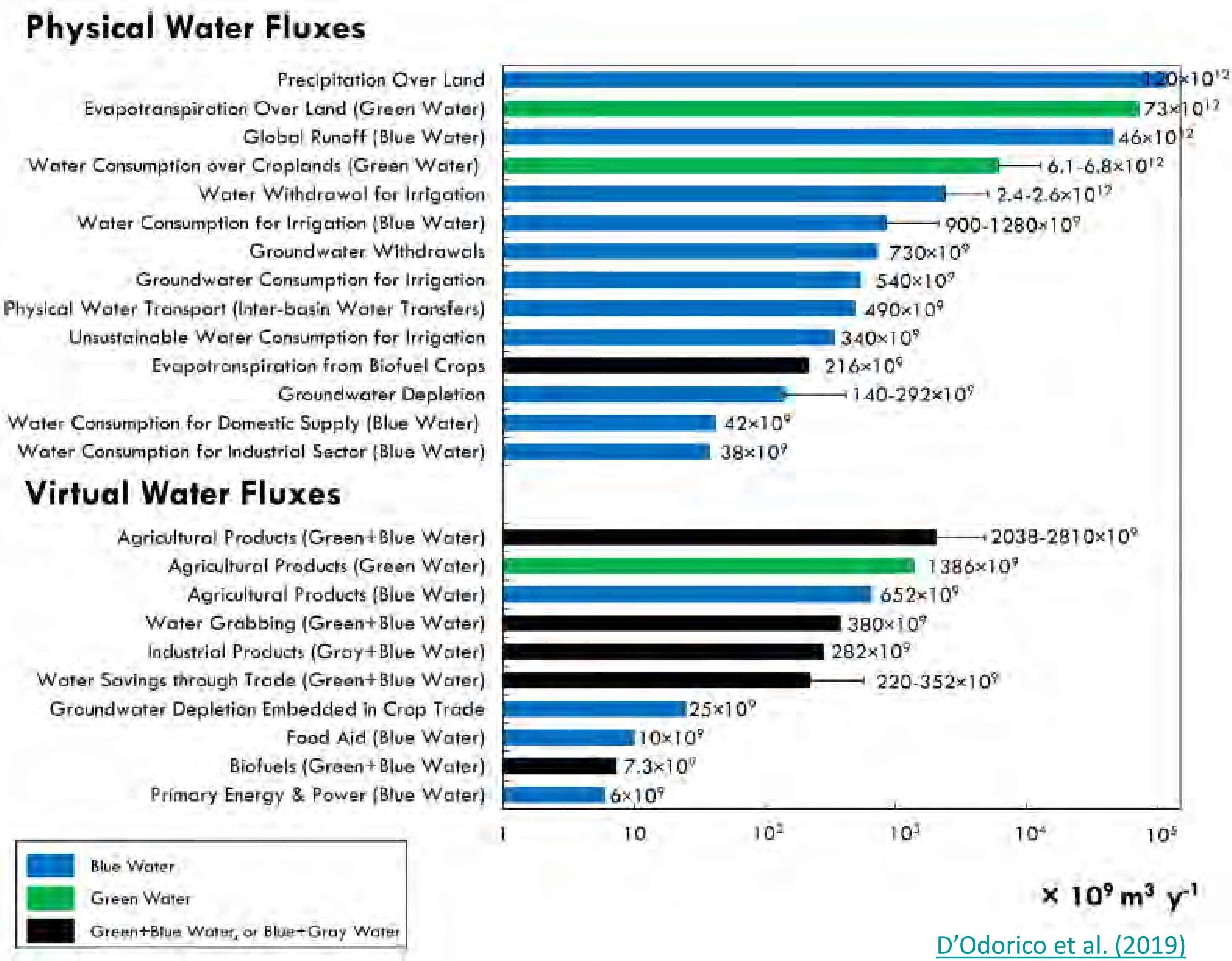
2) Remote sensing



Zaussinger et al., 2019

Even with the most advanced techniques there is poor agreement between reported state level irrigation water withdrawals for the US and those estimated by using remote sensing.

3) Modeling



D'Odorico et al. (2019)

Recent compilation of estimates for global water storages and fluxes, that are mainly based on modeling

3) Modeling

To simulate **irrigation water requirements** it is required to know:

- the extent of irrigated crops
- the growing period of irrigated crops.

This information is only available for the period around year 2000.

Global data set of monthly irrigated and rainfed crop areas around the year 2000 (MIRCA2000)

A data set of monthly growing areas of 26 irrigated and rainfed crops was developed and related crop calendars for 402 spatial units were compiled. The selection of the crops consisted of all major food crops including regionally important ones (wheat, rice, maize, barley, rye, millet, sorghum, soybeans, sunflower, potatoes, cassava, sugar cane, sugar beet, oil palm, rape seed/canola, groundnuts/peanuts, pulses, citrus, date palm, grapes/vine, cocoa, coffee), major water-consuming crops (cotton), and unspecified other crops (other perennial crops, other annual crops, fodder grasses). The data set refers to the period 1998-2002 and has a spatial resolution of 5 arc-minutes by 5 arc-minutes which is about 9.2 km by 9.2 km at the equator.

Big uncertainties in irrigation requirement trends simulated with crop- or hydrological models

To simulate **irrigation water use** it is required to know the irrigation efficiency which varies considerable due to:

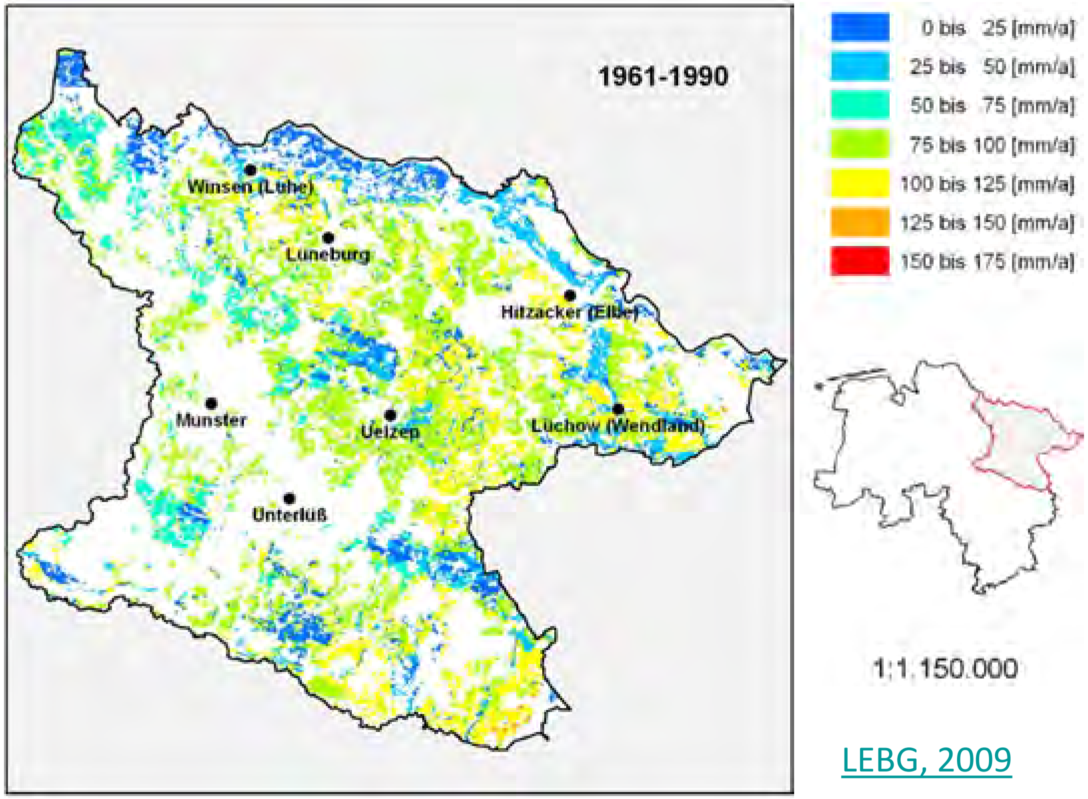
- different irrigation techniques and field sizes
- surplus irrigation used to leach salts
- deficit irrigation practices
- reduced irrigation water use because of constraints in water supply.

At the large scale only estimates are available with unknown uncertainty.

Challenges with quantifying dynamics in water use

1) Water use statistics

Irrigation water requirement in Lower Saxony, Germany

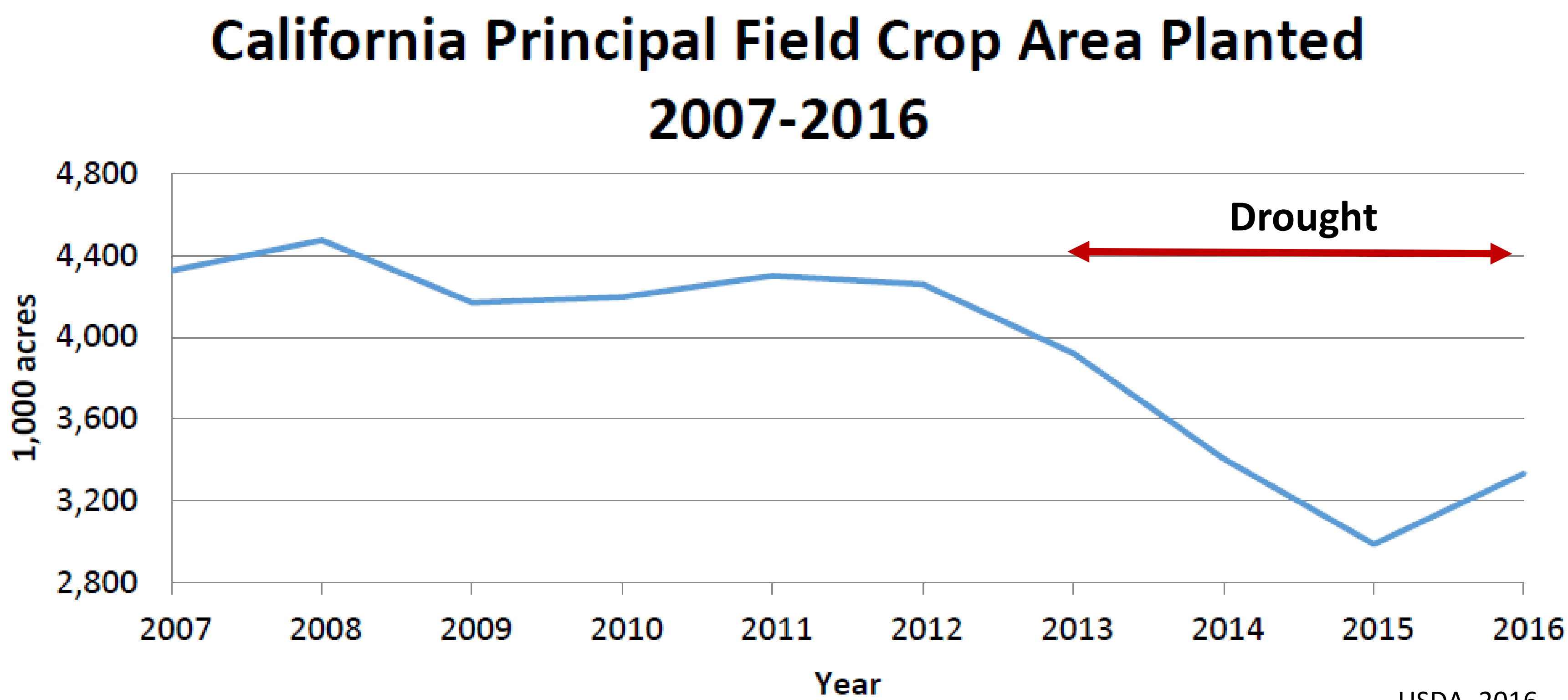


LEBG, 2009

In the **exceptional dry year 2018** irrigation water requirements of up to 400 mm for sugar beets in Lower Saxony!
This will **never show up in the official statistics** because data are only collected in years when EU farm structure surveys are undertaken (2010, 2013, 2016, 2020).

In most countries water use data are collected in time steps between 3 and 10 years
=> Dynamics in water use cannot be obtained

2) Modeling



USDA, 2016

California: arid region => irrigated crop area in dry years smaller

To simulate dynamics in irrigation water use, time series in irrigated crop area are needed. This information is not available at global scale => Dynamics in water use are underestimated

2) Modeling

	Beregende oppervlakte			Wet year		Dry year	
	hectaren cultuurgrond	normaal jaar (1999/2000)	%	nat jaar (1998/99)	%	droog jaar (1996/97)	%
Bouwhoek en Hogeland	105	5,6	5	0,7	1	7,0	7
Veenkoloniën en Oldambt	195	8,5	4	2,2	1	20,7	11
Noordelijk weidegebied	308	7,9	3	1,4	0	31,1	10
Oostelijk veehouderijgebied	328	21,3	7	20,5	6	70,9	22
Centraal veehouderijgebied	53	2,6	5	2,4	4	8,8	16
IJsselmeerpolders	109	20,7	19	5,8	5	14,2	13
Westelijk Holland	96	2,0	2	0,3	0	2,6	3
Waterland en Droogmakerijen	28	0,2	1	-	0	2,1	7
Hollands/Utrechts weidegebied	92	2,6	3	-	0	6,7	7
Rivierengebied	64	6,3	10	3,7	6	25,2	39
Zuidwestelijk akkerbouwgebied	173	5,5	3	3,1	2	2,6	1
Zuidwest Brabant	21	5,6	26	7,3	34	11,3	53
Zuidelijk veehouderijgebied	210	70,5	33	75,6	36	103,5	49
Zuid Limburg	48	1,5	3	0,4	1	1,5	3
Nederland	1.831	160,5	9	123,3	7	308,7	17

Hoogeveen et al., 2003

The Netherlands: humid region => irrigated crop area in dry years larger

To simulate dynamics in irrigation water use, time series in irrigated crop area are needed. This information is not available at global scale => Dynamics in water use are underestimated

Summary

There are many estimates in the literature concerning trends and dynamics in water requirements for agriculture but the **underlying data are weak** so that **big uncertainties should be expected**.

A consolidated effort is urgently needed to improve spatial information regarding:

- time series of harvested area of irrigated and rainfed crops
- growing periods of irrigated and rainfed crops
- the ratio between irrigation water requirement and irrigation water withdrawal
- response of these variables to climate variability (dry and wet years)
- integration and complementation of data originating from independent sources
- methodological improvements to represent better the impact of climate variability and extreme years