Water, water everywhere

not a drop to drink!

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Is there a water crisis?

Facts About Water

- 1.1 billion people lack access to improved water supply and 2.4 billion to improved sanitation. Per capita daily water use in high-income areas is 100-600 liter; while it is only 10-40 liter in water scare areas

- Every 8 seconds a child dies from drinking contaminated water (that is 10,000 a day)

- Over 250 million people are directly affected by desertification. In addition, some 1 billion people in over 100 countries are at risk

- Droughts are undoubtedly the most far-reaching of all natural disasters. From 1991 to 2000 alone, drought has been responsible for over 280,000 deaths and has cost tens of millions of US dollars in damage

Rivers in Northern China Dry up

All three rivers feeding China's Northern Plain are severely polluted, damaging health and limiting irrigation. The lower reaches of the Yellow river, which feeds China's most important farming region, ran dry for 226 days in 1997.

Northern China is home to 2/3 of the country's cropland but 1/5 of its water.

As competing demands for water are made by cities, industry and agriculture, the land is drying up. During 1991- 1996, the water table beneath the north China plain fell by an average of 1.5 meters a year.

Water is more Precious than Oil in the Middle East

Water is the most precious resource in the Middle East, more important even than oil. Competition for water from the River Jordan was a major cause of the 1967 war. As populations increase, water becomes more scarce, aggravating regional tensions.

Water Conflicts Among African Countries

There is already fierce national competition over water for irrigation and power generation - most notably in the Nile river basin. Cairo warned in 1991 that it was ready to use force to protect its access to waters of the Nile, which also runs through Ethiopia and Sudan.

Why do we need so much water?

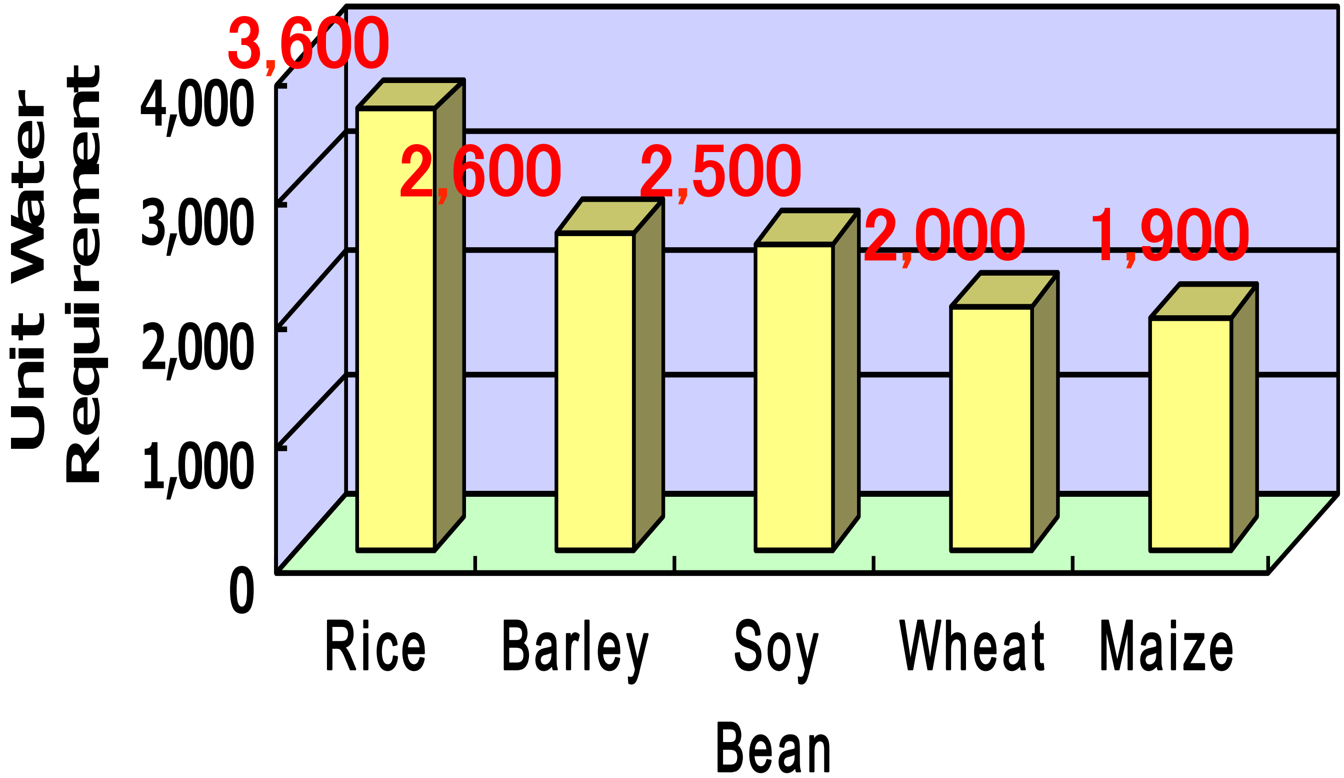
- Just 1 m^3/year/person for drinking
- 1~100 m^3/year for domestic water use
  - drinking(5)+cooking(10)+bathing(15)+sanitation (20) = 50 liter/day ➔ ~20 m^3/year/person
- ~100 m^3/year/person for industrial water use
- 500~2000 m^3/year/person for agricultural water withdrawals

Water crisis is really a ‘water for food’ crisis

Unit Requirement of Water

--Crops--

(m³/t)



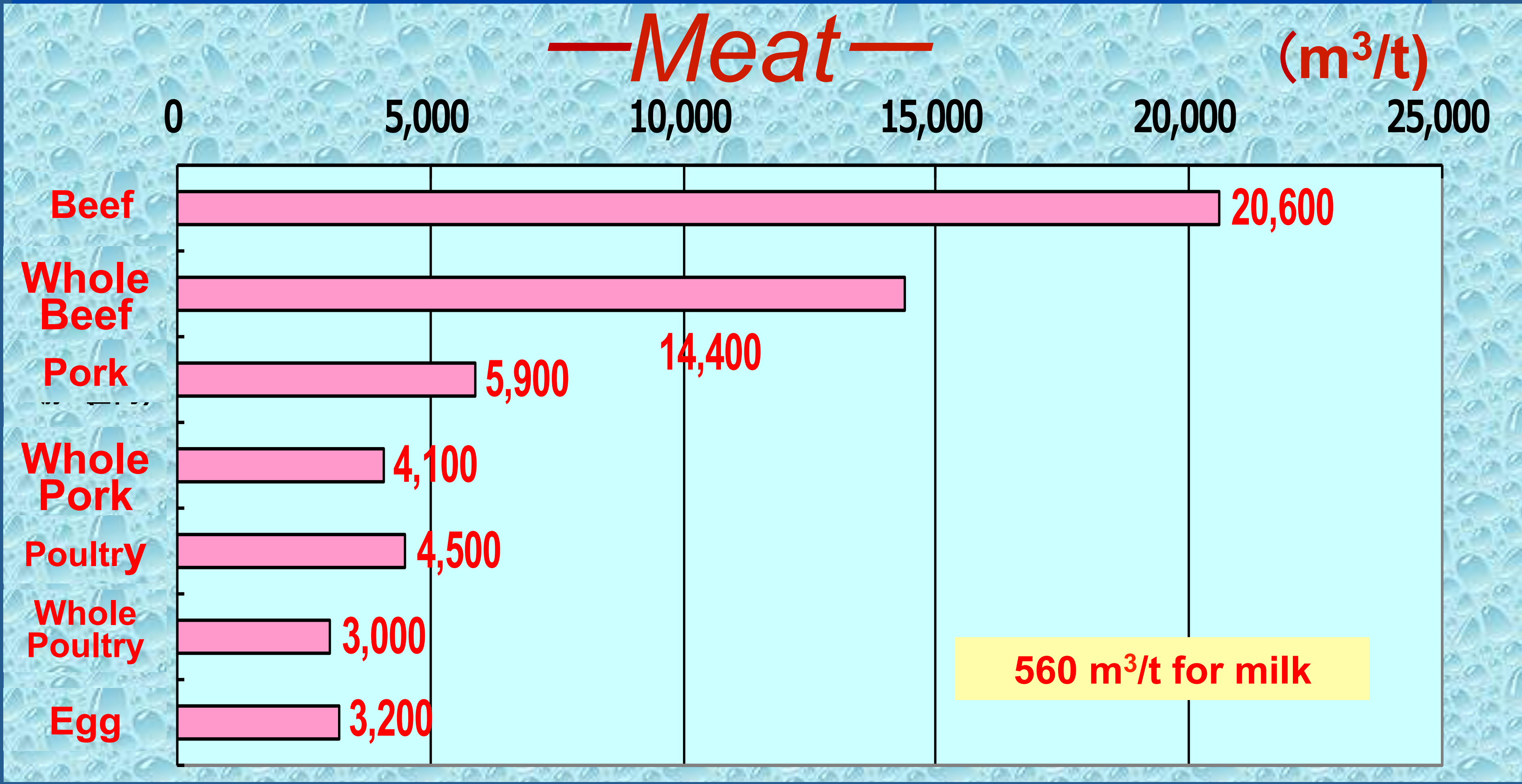
Unit Water Requirement of Major Crops

(based on crop yield in Japan、FAOSTAT mean 1996-2000)

(Oki, et. al, 2002, IHE-UNESCO)

Unit Water Requirement

—Meat—



Unit Water Requirement of Major Meat

(based on crop yield and the way of raising in Japan)

(Oki, et. al, 2002, IHE-UNESCO)

Required Water for Fast Food

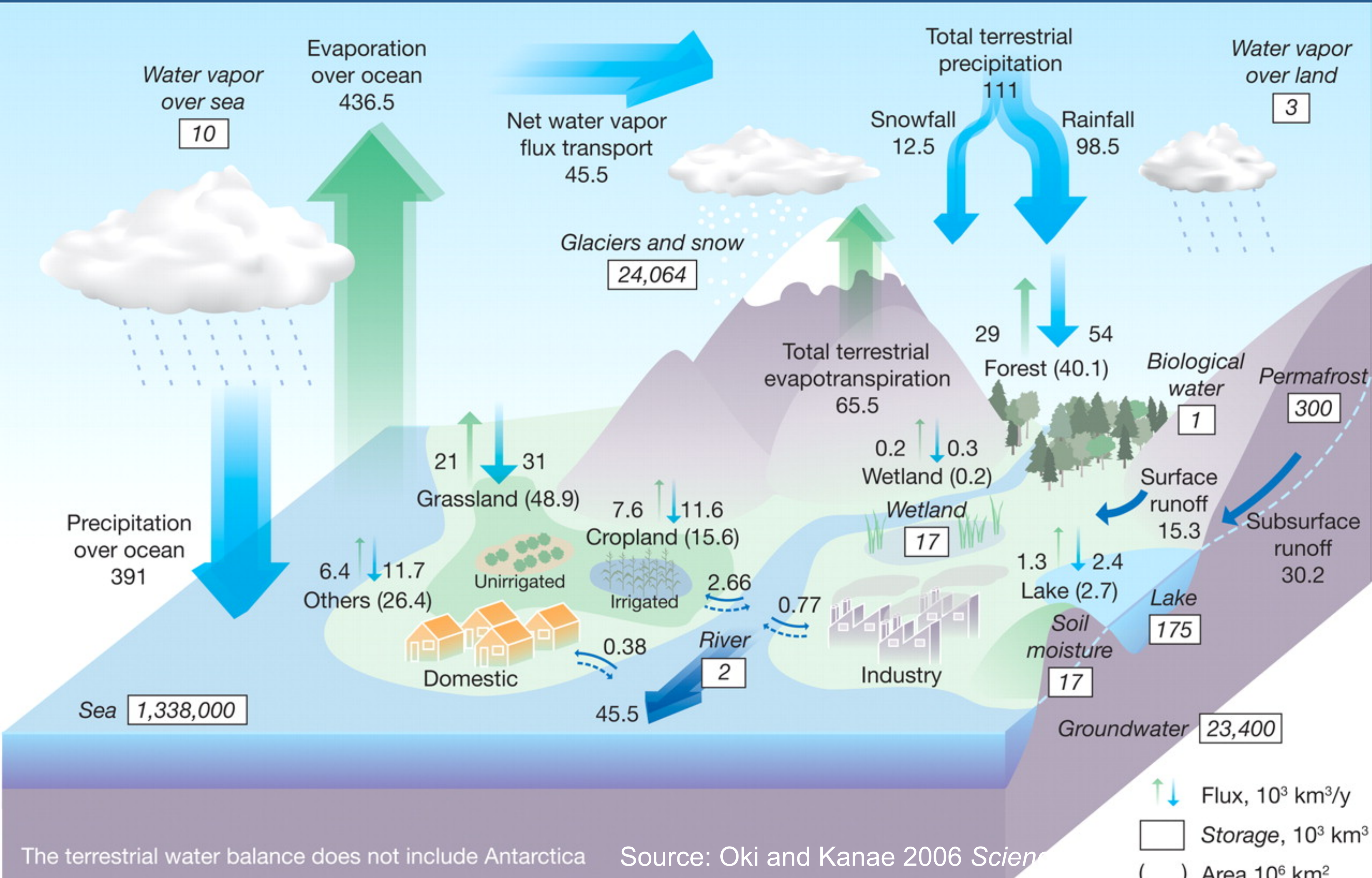
Beef Bowl	Regular JY280	710kcal	1,890L
Hamburger Sandwich	2 regular Small Fries JY268	745kcal	2020L
Hamburger Sandwich	Teriyaki Burger Regular Fries JY430	911kcal	530L
Buckwheat noodle	With Egg JY300	377kcal	750L
Pasta (Udon)	Plain JY290	341kcal	120L

Key numbers for water demand (from John Holdren's 2007 AAAS Presidential Address):

	cubic kilometers per year
Global withdrawals for human use	5,000 (~6x800)
of which agriculture	*3,500*
…industry	*1,000*
…domestic	*500*
of which drinking water	*5*
…bottled water	*0.17*

	cubic meters per person per year
Global average withdrawals per person	800
Nigeria…	50
Israel…	300
China…	500
Mexico…	800
Italy…	1,000
United States…	2,000

Global Hydrologic Cycle



Source: Oki and Kanae 2006 *Science*

Freshwater is highly variable in space and time

- Per capita freshwater available is ~ 9,000 m^3/year compared to ~800 m^3/year (but poorly distributed)
- Highly variable – 180,000 m^3/year (Canada, Alaska, Oceania), 3,400 m^3/year in Asia, to as little as 200-300 m^3/year in North Africa and Arabian peninsula
- Water stressed - < 1,700 m^3/year
- Water scarce (seriously stressed) - < 1,000 m^3/year
- Variability is much more than this – variability within countries and regions, variability over time – seasons, inter-annual and inter-decadal variability

Freshwater is a limited renewable resource

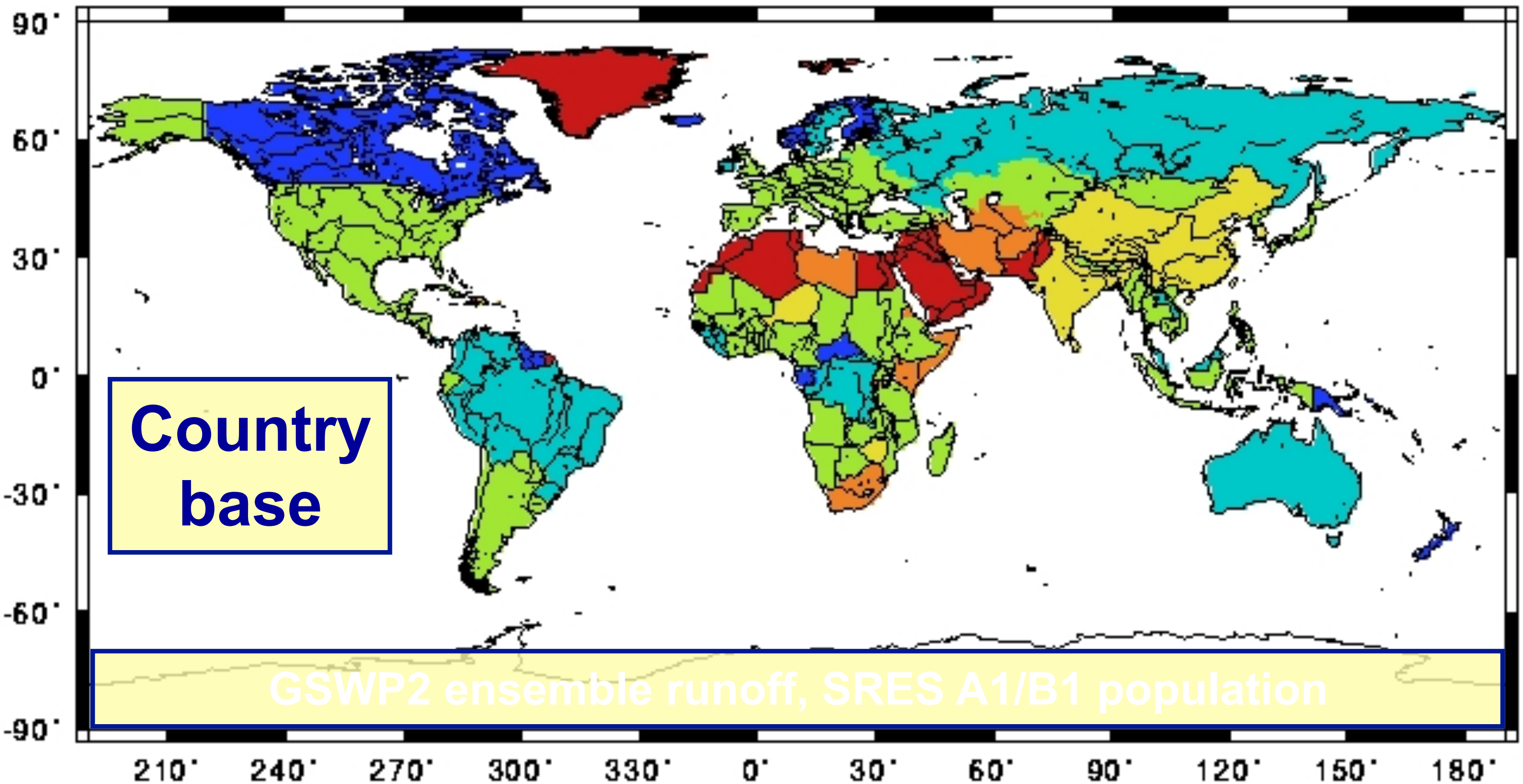
- Freshwater is a limited renewable resource
- 97% of the water is salt water, too salty to drink or grow crops
- The only water we can use year after year is the planet’s renewable supply, the 3% of all water that is cycled and recycled
- To be sustainable water cannot be withdrawn from rivers, lakes, dams, groundwater aquifers at a rate faster than it is replenished through the natural hydrologic cycle

Water in the environment

- Water is essential for all forms of life, hence is linked to the health of the environment
- Vital for the survival of ecosystems and the plants and animals that live in them
- Ecosystems help to regulate the quantity and quality of water and must be protected at all cost
- Natural ecosystems have evolved and adapted themselves to the natural fluctuations of the water cycle – every part is connected to every other part
- Every piece of the system has a function – rivers, wetlands, riparian corridors, lakes, deltas – each has a function, each has its place

Conventional Water Resources Assessment

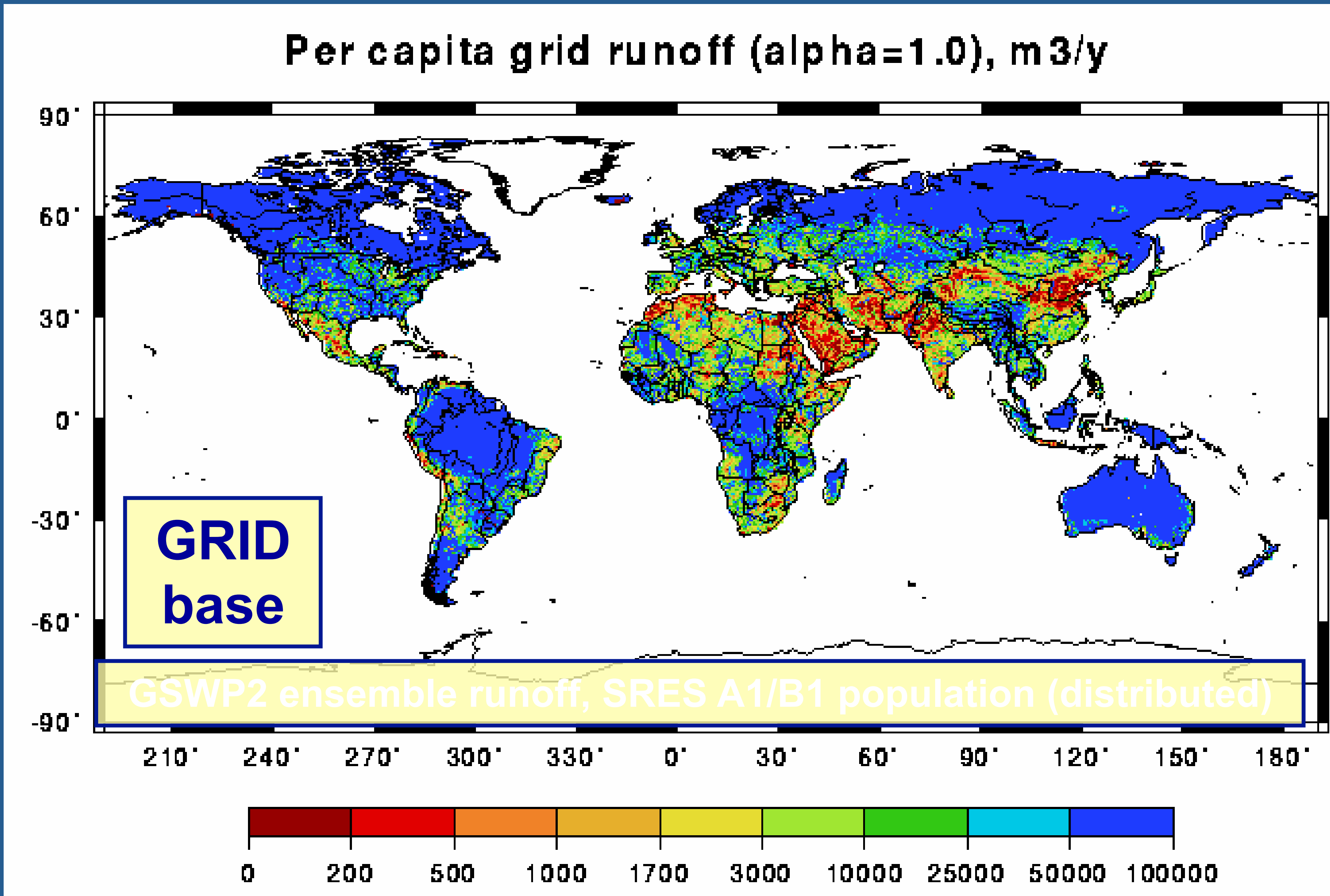
Potentially Available Water Resources per Capita in 2000



- Seriously Stressed (~1)
- Stressed (1~2)
- Slightly Stressed (2~5)
- Moderate (5~10)
- Rich (10~)

10^3 m^3/capita/year

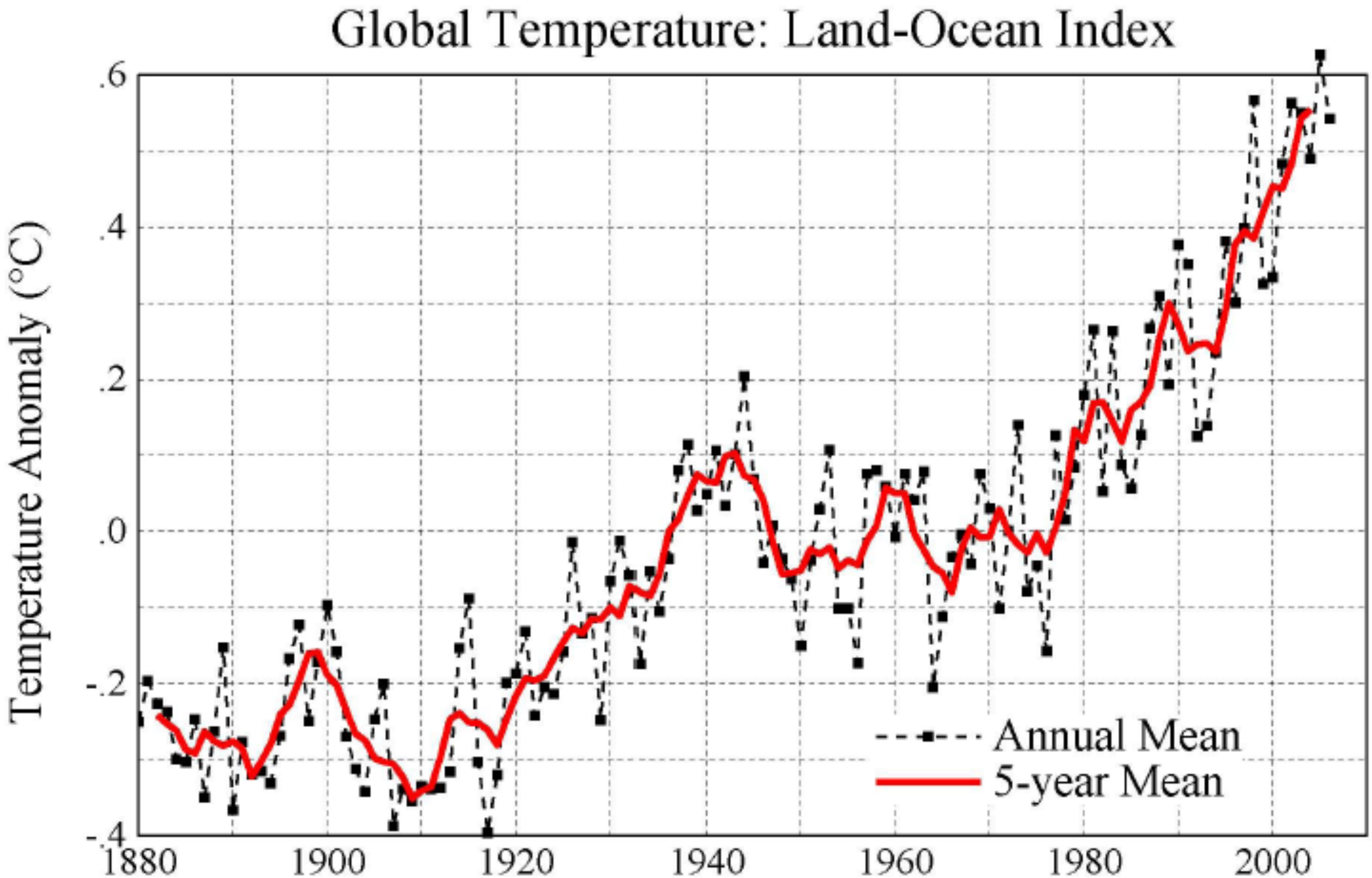
Conventional Water Resources Assessment



(Islam et al., 2006, *Water Res. Manage.*)

Environmental Change Impacts: Prognosis for the Future?

During the 20th Century, the planet warmed at a rate of 0.06°C per decade; that rate has increased to 0.18°C per decade for the last 30 years.



Detection of human influence on twentieth-century precipitation trends

nature Vol 448 26 July 2007

Xuebin Zhang[1], Francis W. Zwiers[1], Gabriele C. Hegerl[2], F. Hugo Lambert[3], Nathan P. Gillett[4], Susan Solomon[5], Peter A. Stott[6] & Toru Nozawa[7]

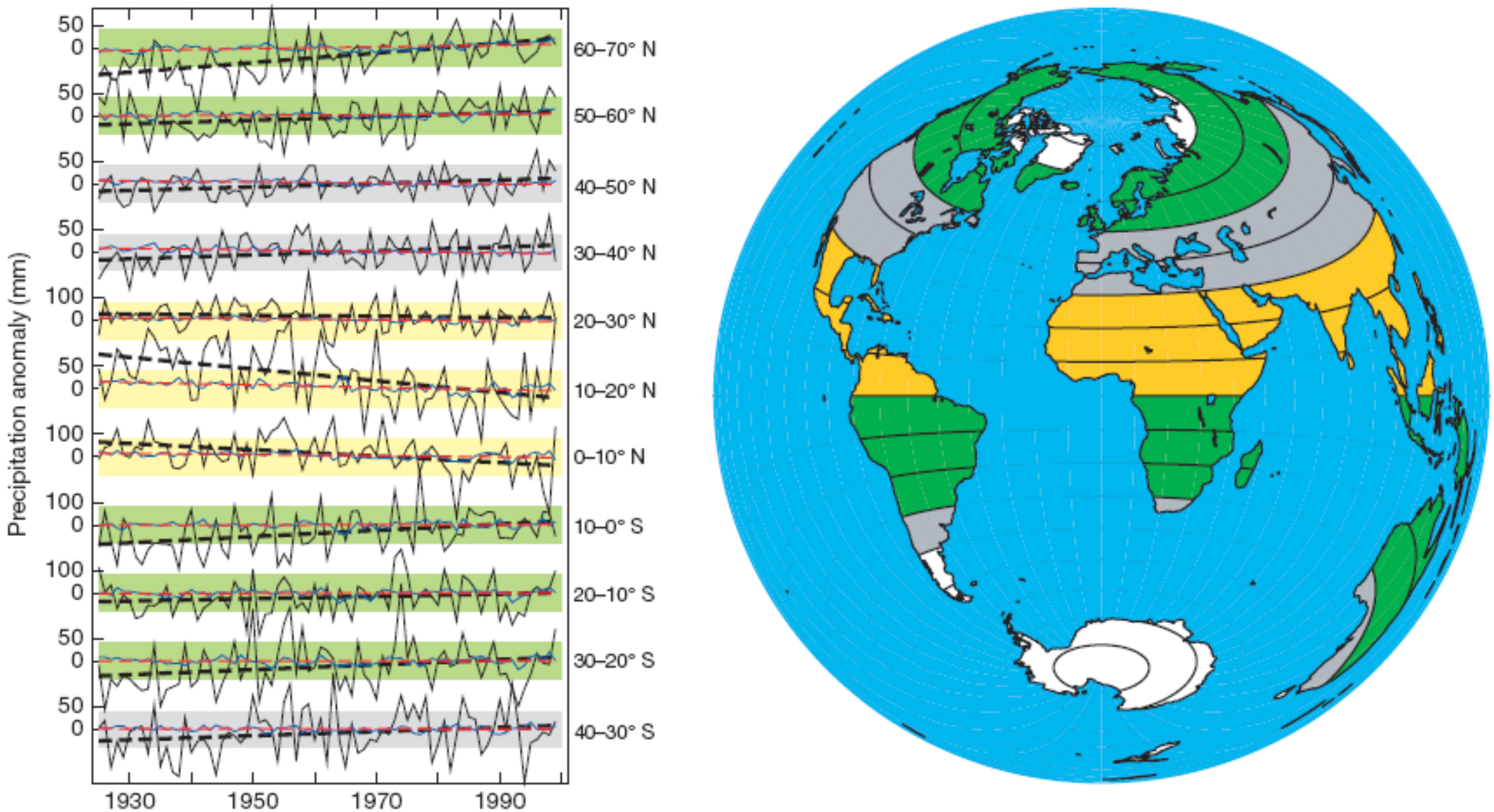


Figure 2 | 1925–1999 changes in observed and simulated precipitation anomalies. Time series (left panel) of observed annual zonal mean precipitation anomalies in 10° latitude bands (thin black trace) together with ensemble mean annual zonal mean precipitation anomalies in the 50 available ALL simulations (thin blue trace). Straight dashed black and red lines indicate the trends. Green (or yellow) shading identifies latitude bands with increasing (or decreasing) trends in both observations and models; grey shading indicates disagreement between observed and simulated trends. The map (right panel) indicates the different 10° latitude bands and whether trends agree in sign. Areas with insufficient data are shown in white. Only land precipitation data are used.

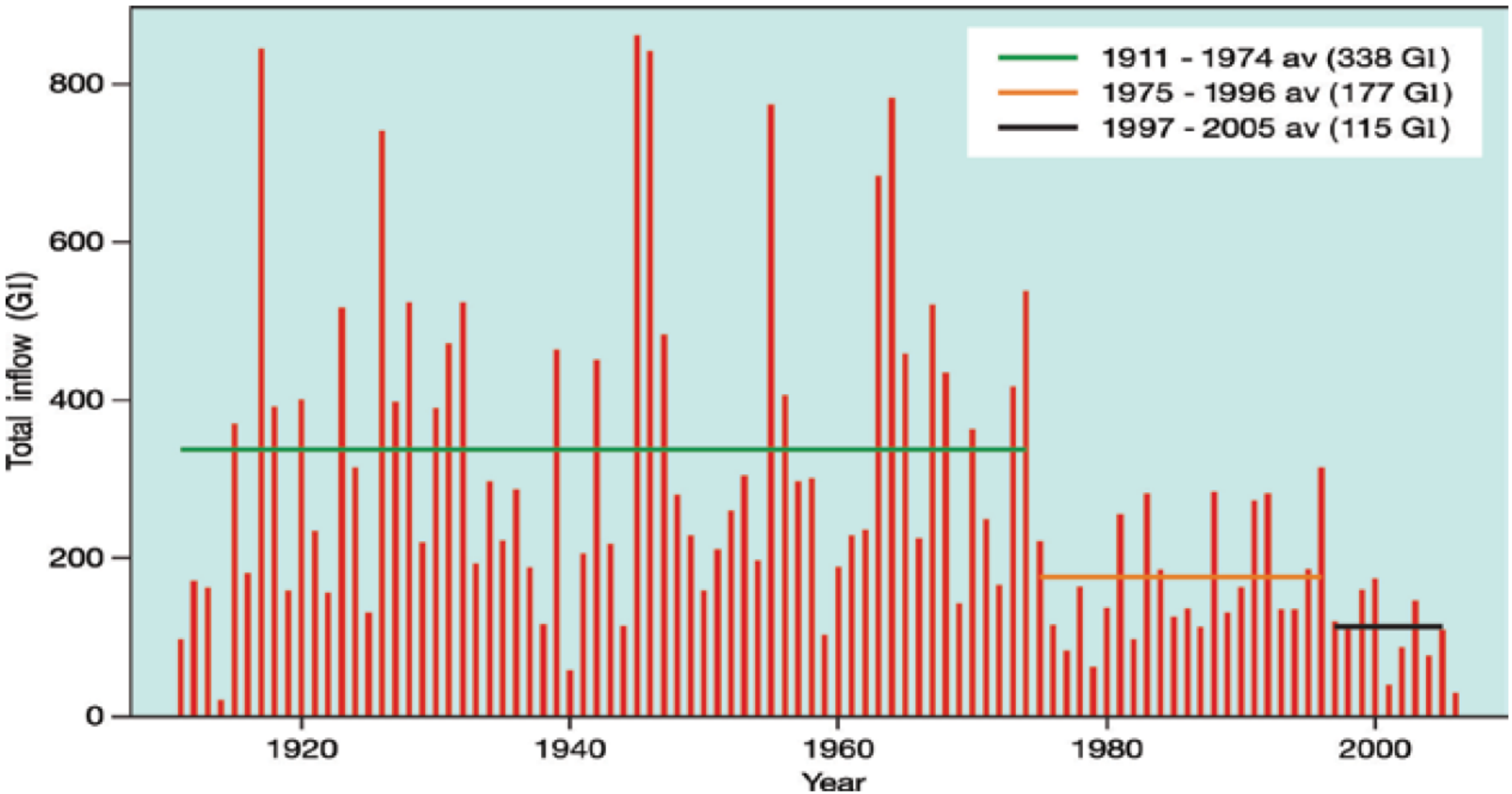
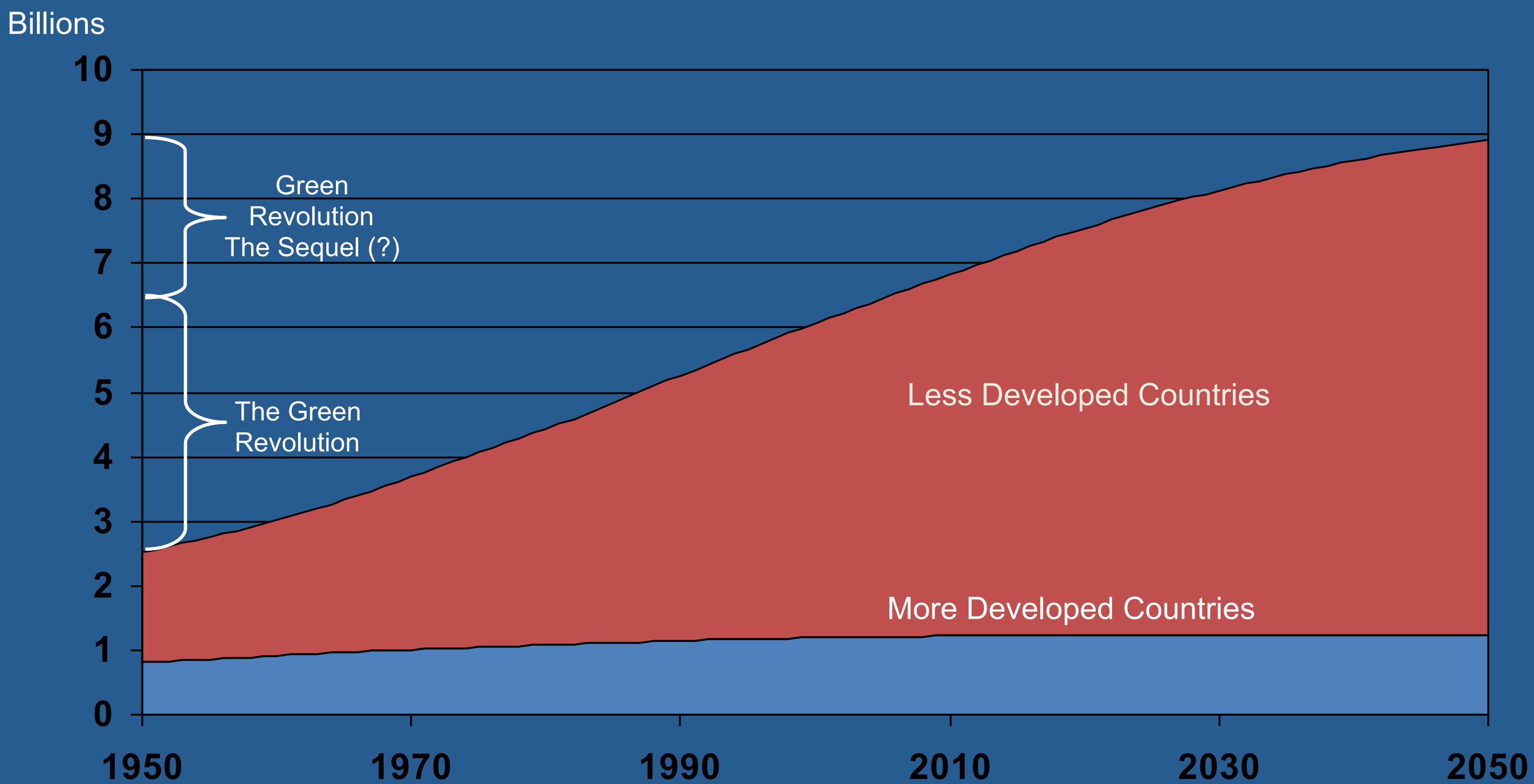


Figure 5.7: *Annual inflow to Perth Water Supply System from 1911 to 2006. Horizontal lines show averages. Source: http://www.watercorporation.com.au/D/dams_streamflow.cfm (courtesy of the Water Corporation of Western Australia). [WGII Figure 11.3]*

Effect of population growth on water and food?



Source: United Nations, *World Population Prospects: The 2002 Revision* (medium scenario), 2003.

- Lifestyle changes and food consumption patterns on water requirements in China: reasons –
  - Population of 1.3 billion – largest no. of consumers
  - Constraint on water scarcity– concerns for food production, food security and the global food market
  - Fast and sustained economic growth of over 8% - fast rising incomes, rapid dietary change → more meat consumption, leading to more water demand

CWRF and TWRF

- CWRF – amount of water used to produce food requirements per capita
  - Basic – based on consumption of wheat, and energy intake of 2250 kCal/day/capita
  - Subsistence – based on recommended daily amounts of food intake – food guide pagoda
  - Cultural levels – based on actual consumption patterns
- TWRF – total amount of water used to produce food requirements
  - = CWRF x size of population (but accounting for population changes, changes in dietary patterns, improvements in water productivity etc.)

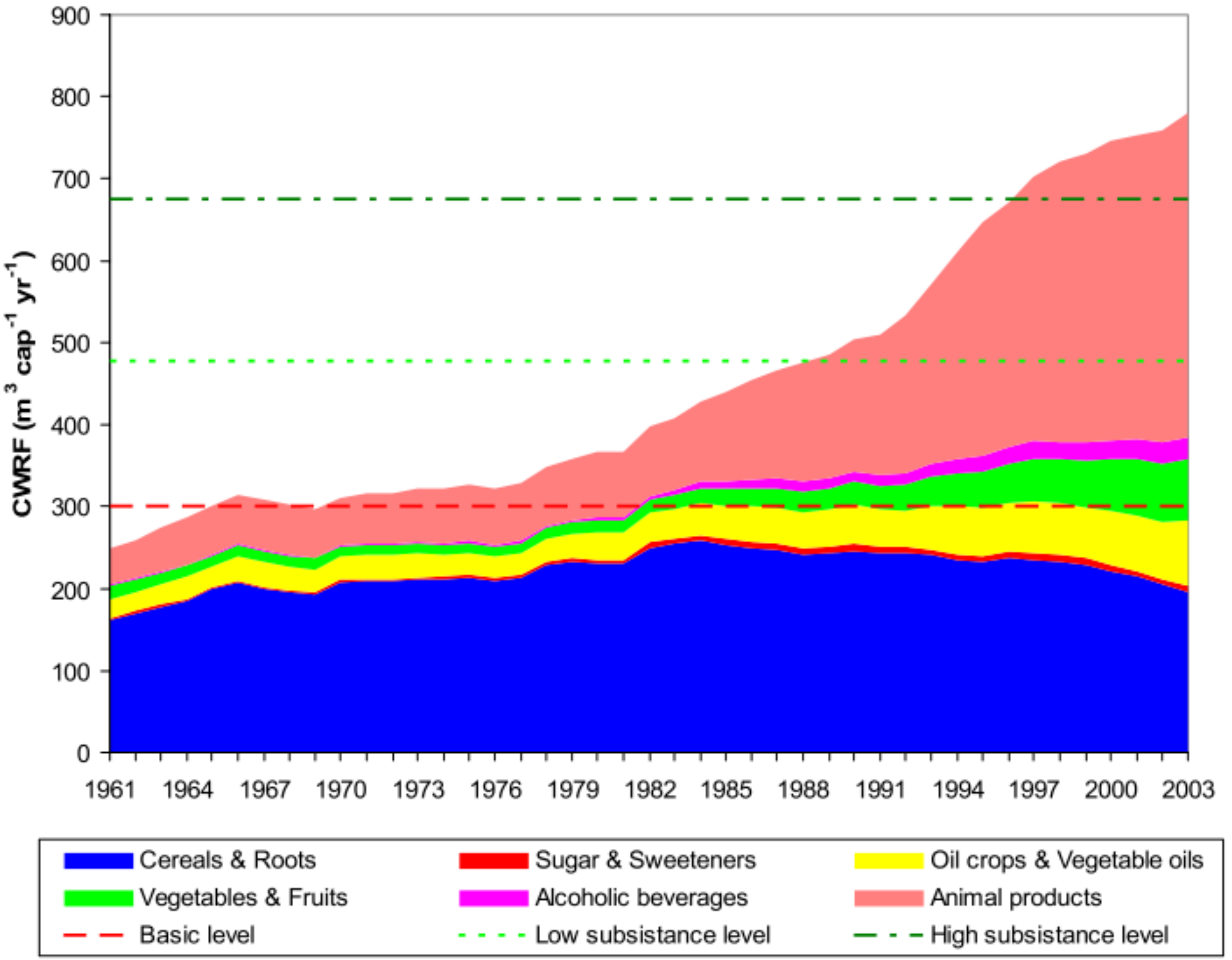


Fig. 1. The per capita water requirement for food (CWRF) at the basic, subsistence and cultural levels.

Historical food consumption patterns in China

- Shift towards animal products
- Meat consumption has increased by a factor of 3.7 from 1980 to 2003 (mainly due to increase in income, urbanization and market expansion
- Starch consumption has relatively stayed stable
- Significant increase in vegetable and fruit consumption – 4-fold increase since 1961

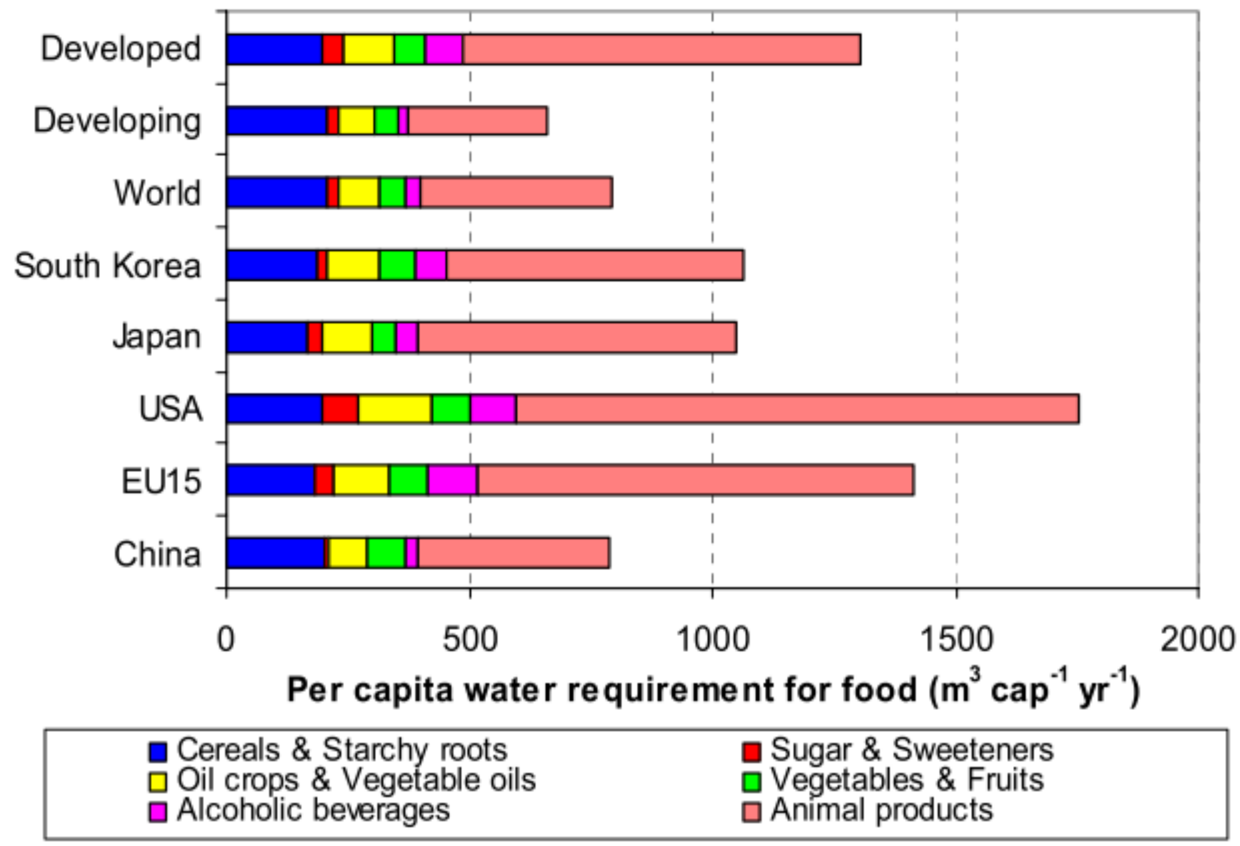


Fig. 3. Per capita water requirement for food (CWRF) at the cultural level in 2003 in different regions.

- Imagine when China and the rest of the world catch up to the consumption patterns of the USA!!

Global Water Crisis: Causes

- Rapidly increasing demand
  - Fast rising human populations
  - Changing lifestyles
- Declining resource base
  - Human land use – agriculture, housing, industry
  - Environmental degradation and loss of ecosystem services
- Poor resource distribution in relation to human demand (time and space)
  - Inability to move water (e.g., bulky) or people
  - Changing lifestyles
- Uncertainty in resource availability
  - Effects of climate change
  - Links to energy demand

Global Water Crisis: A crisis in *water management*

- Water management in the context of fast increasing demand, decline of a poorly distributed resource base (which is "special", in terms of being a public good), in the presence of considerable uncertainty (e.g., due to climate change), and subject to significant social and economic bottlenecks (i.e. taboos and subsidies)

Global Water Crisis: Solutions

- Reduce demand
  - Population control
  - Change lifestyles
  - Improve efficiency
  - Reduce waste/recycle
- Protect the resource base
  - Move towards rain-fed agriculture
  - Protect the environment (land and water)
- Alleviate poor distribution
  - Irrigation, rainfall harvesting
  - Virtual water trade
- Assess and reduce uncertainty
  - Measure more
  - Understand and predict

Change behavioral patterns

- Watering lawns, washing cars
- Should we use potable water for these uses?
- Should drinking water be used to transport and disperse household and industrial waste products?
- Why should drinking quality water be used to transport household waste over large distances for dispersal or disposal?

Cut down waste

- Over 70% of global water withdrawal goes to agriculture – the most inefficient sector – 60-75% of irrigation water never reaches the crops
- Improve water efficient of agriculture and maximize food output while minimizing water inputs – better use of technology and management
- e.g drip irrigation: losses can be brought under 5% and yet it is still employed by less than 1% of world's irrigated areas.

Improve water use efficiency

- Water is commonly treated as if it had no substitute
- This is only true for the water we drink, and for the water that has to be left to maintain ecosystems
- In every other case, there are options to avoid the use of water
- Efficiency of water using technologies, changes in lifestyles and personal preferences, agricultural policies
- Don’t ask how to use water efficiently, ask why use water at all, e.g., is water necessary in toilets at all?
- How about growing food with rain-fed techniques, instead of irrigation

Rain-fed agriculture over irrigated agriculture

- Water crisis is really a crisis of water for food
- In the past strong preference for large irrigation schemes – these have led to disastrous consequences
- Income distribution – loss of control, dependence on subsidies
- Rain-fed agriculture can be practised with localized water management – harvesting and storing water where it falls

Protect water resources from pollution

- Population increases- degrading the very source of water they drink from
- Dams – getting polluted by nutrients, heavy metals
- Large scale irrigation – land salinization, waterlogging
- Over-exploitation of groundwater

Rationalize the use of water: raise its price!

- Water conservation faces real challenges.
- Water is free for the taking. It cannot be traded like oil, or give in aid like food or medicine
- Rationalized global use of water is not possible when prices are subsidized and seriously distorted.
- Price must include real cost of water, including environmental and replacement costs

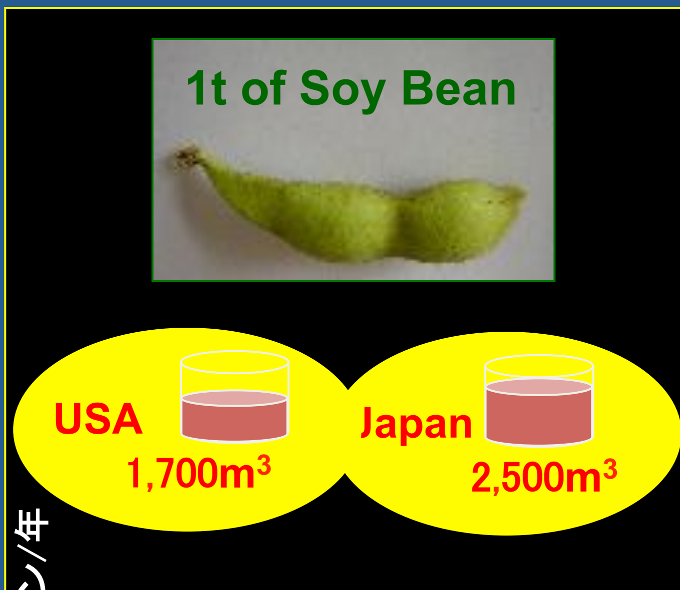
Virtual water

It requires 1000 tonnes (m3) of water to produce a tonne of wheat.

Importing a tonne of wheat means that 1000 m3 of water does not have to be mobilised locally

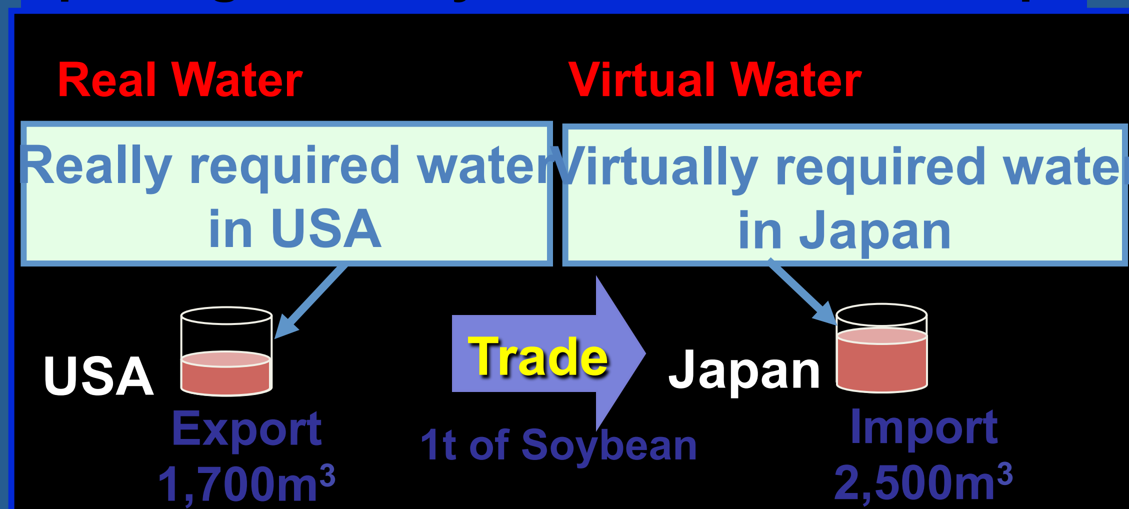
How Virtual Water Trade Saves the Water Resources Globally

Comparing the required water to produce 1 ton of soy bean in USA and Japan



億トン/年

Exporting 1t of Soy bean from USA to Japan

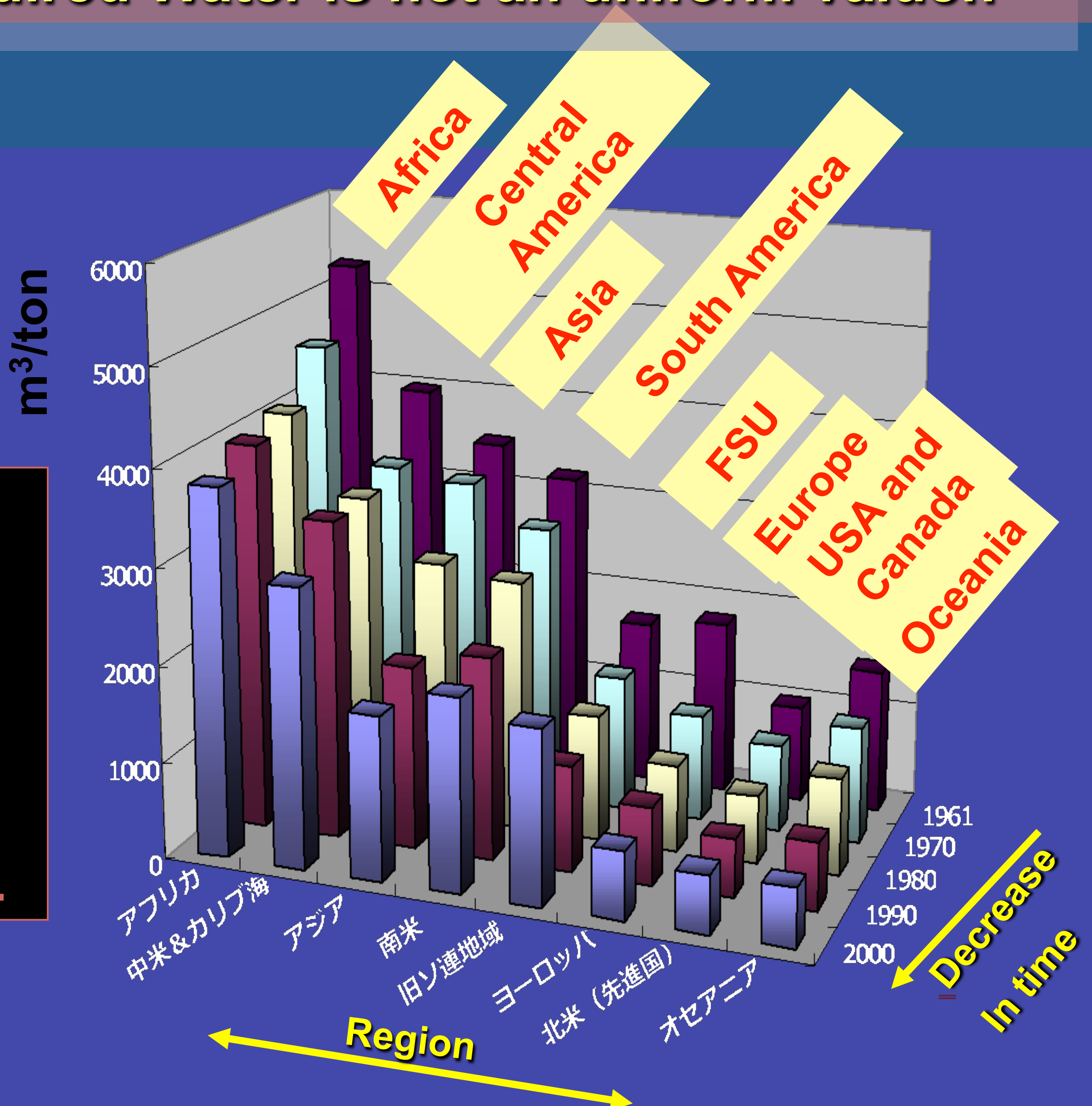


$2{,}500 - 1{,}700 = 800\,m^3$

Water Resources is saved by the *VW* trade!

←Comparative advantage of water efficiency

Unit Required Water is not an uniform value!!

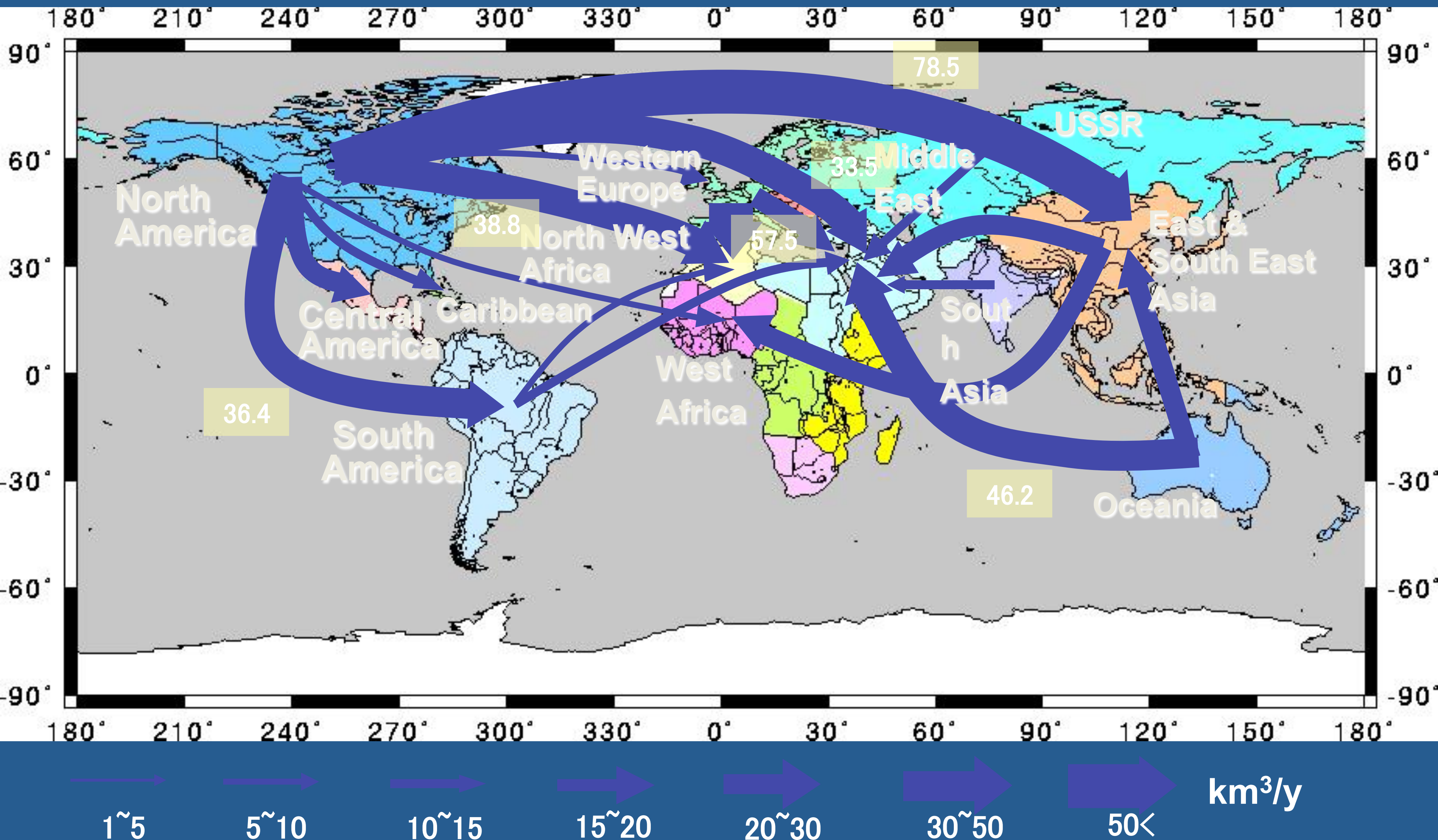


For an example

Required water to produce 1 ton of maize changes region by region.

Even different in different years in the same country.

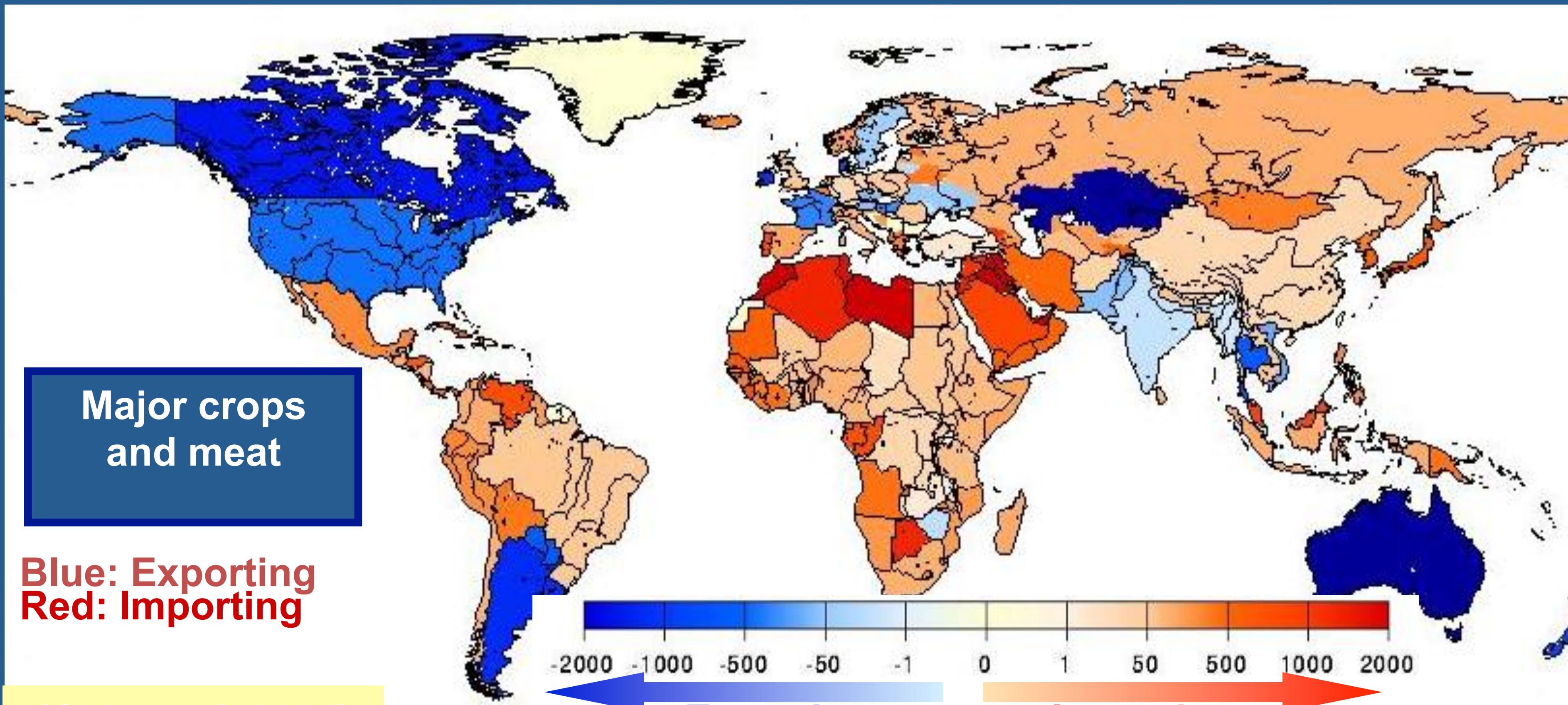
"Virtual Water" Trade between Regions in 2000 (cereals only)



(Oki, et. al, 2004)

(Based on Statistics from FAO etc., for 2000)

Virtual Water Balance in Countries ($m^3/c/y$) in 2000



Major crops and meat

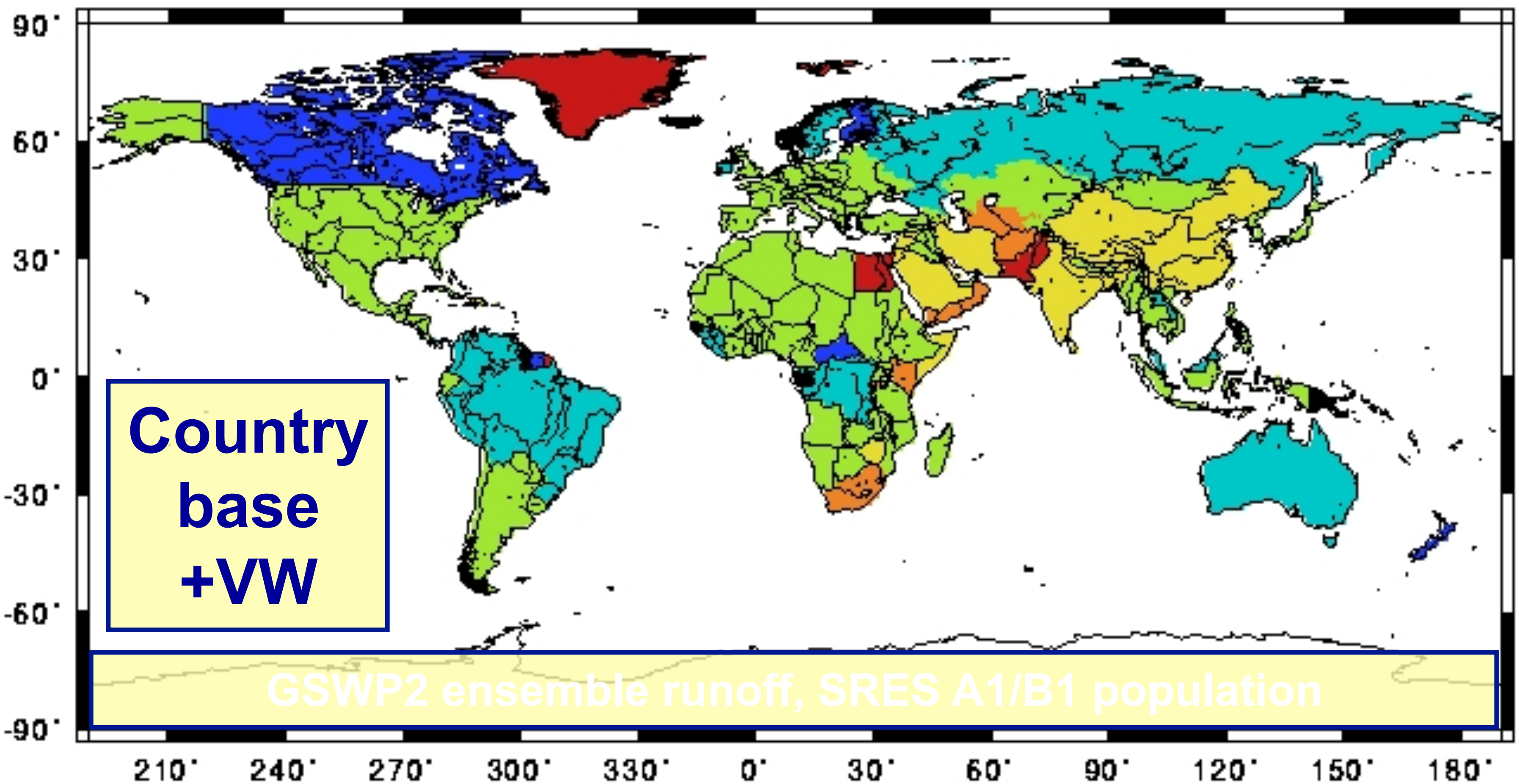
Blue: Exporting
Red: Importing

(Oki, et. al, 2004)

- **7 out of top 10 importing countries are seriously poor in water resources.**
- **7 out of top 10 exporting countries are rich in water resources.**
- **Denmark (10) and India (18) are water stressed but exporting *RW* in net**

World Water Resources Considering Virtual Water Trade

Potentially Available Water Resources per Capita in 2000



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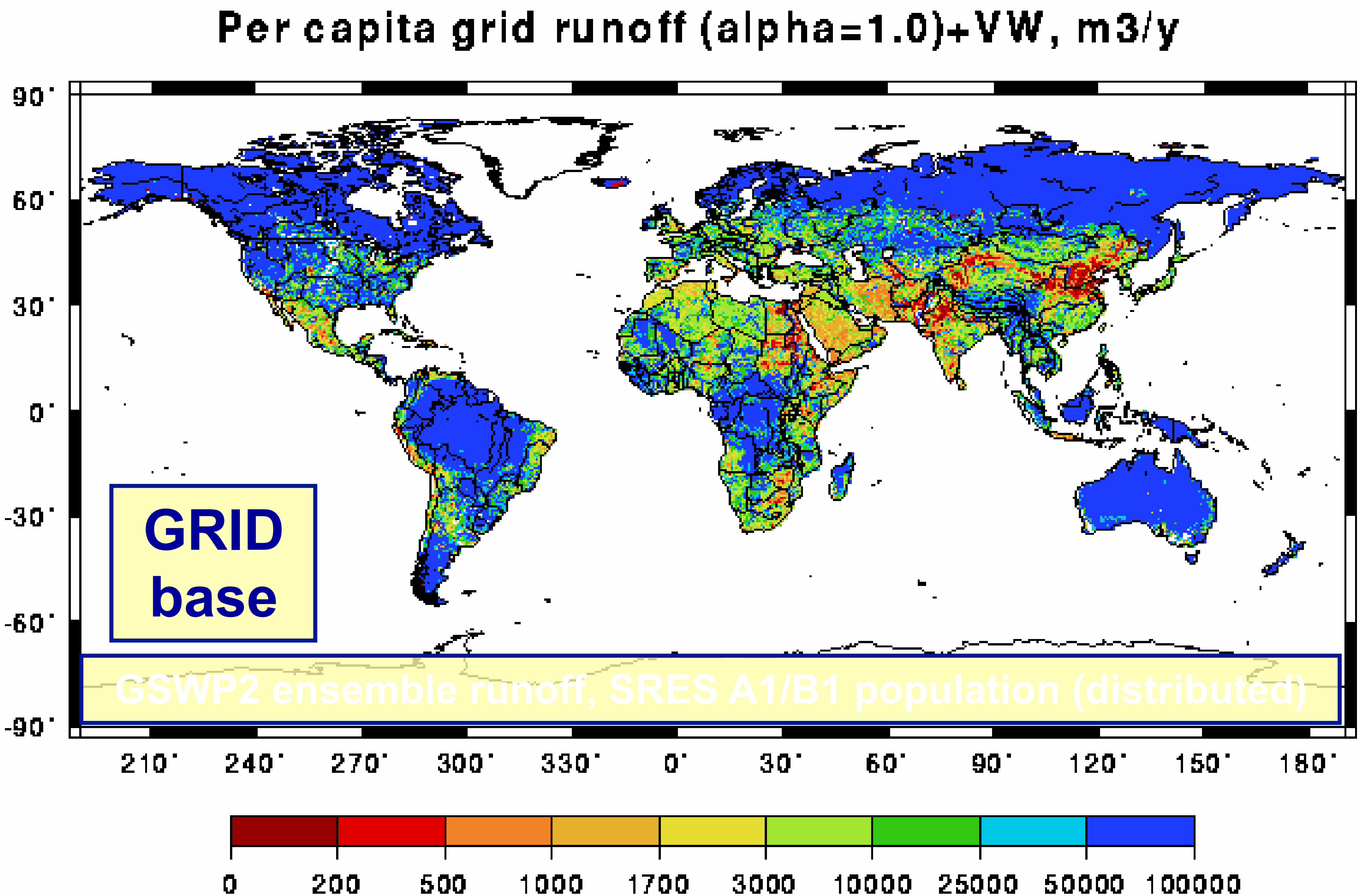
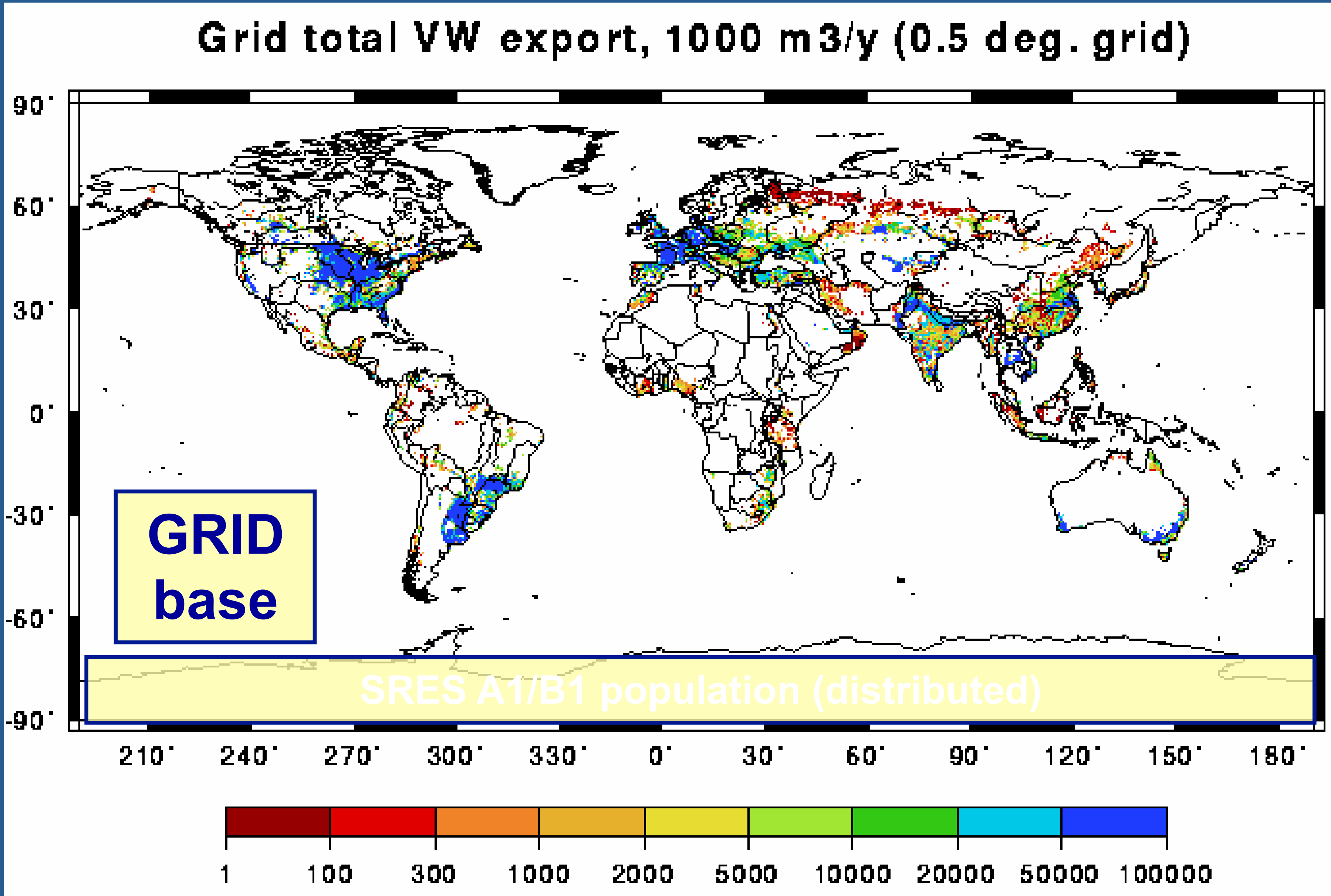
10^3 m^3/capita/year

Conventional Water Resources Assessment +VWT



(Islam et al., 2006, *Water Res. Manage.*)

Virtual Water Export (Grid Base)



(Islam et al., 2006, *Water Res. Manage.*)

Global Water Crisis: Strategies

- Social: population control, lifestyle changes, recycling, policy development
- Technology: agricultural (irrigation, rainwater harvesting, plant breeding), recycling
- Economics: pay for ecosystem services, fair price for water, enhancement of trade
- Science: predict water cycle dynamics under global change amid uncertainty, predict resource availability and hazards, value the environment

The way forward

- Raise the price of water and remove all subsidies
- Encourage the use of rain-fed agriculture and localized water management
- Invest returns from high prices into existing and new infrastructure in increase water supply, new science and technology
- Encourage the use of the virtual water trade
- Reform the system of water rights on the basis of equitable allocation to different sectors, including the environment
- Leadership and stewardship at all levels: households, communities, cities, nations, and the entire world