Globalization of Water Resources through Virtual Water Trade

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1. Concept of virtual water

1.1. Terminologies concerning virtual water

Virtual water: water required for the production of food commodities (crops, meat, etc.),

Why ‘virtual‘ ?

Exogenous, embedded, external, etc.

Virtual water concept

- Established in the early 1990s by Tony Allan (199), ‘father’ of the virtual water.
- Many water scarce countries import water intensive crops, which reduced the water demand in domestic food production. E.g., Middle Eastern and North African countries.
- Water scarce countries can oft for importing a portion of water intensive crops to compensate for domestic water scarcity.
- ……..

Virtual water content

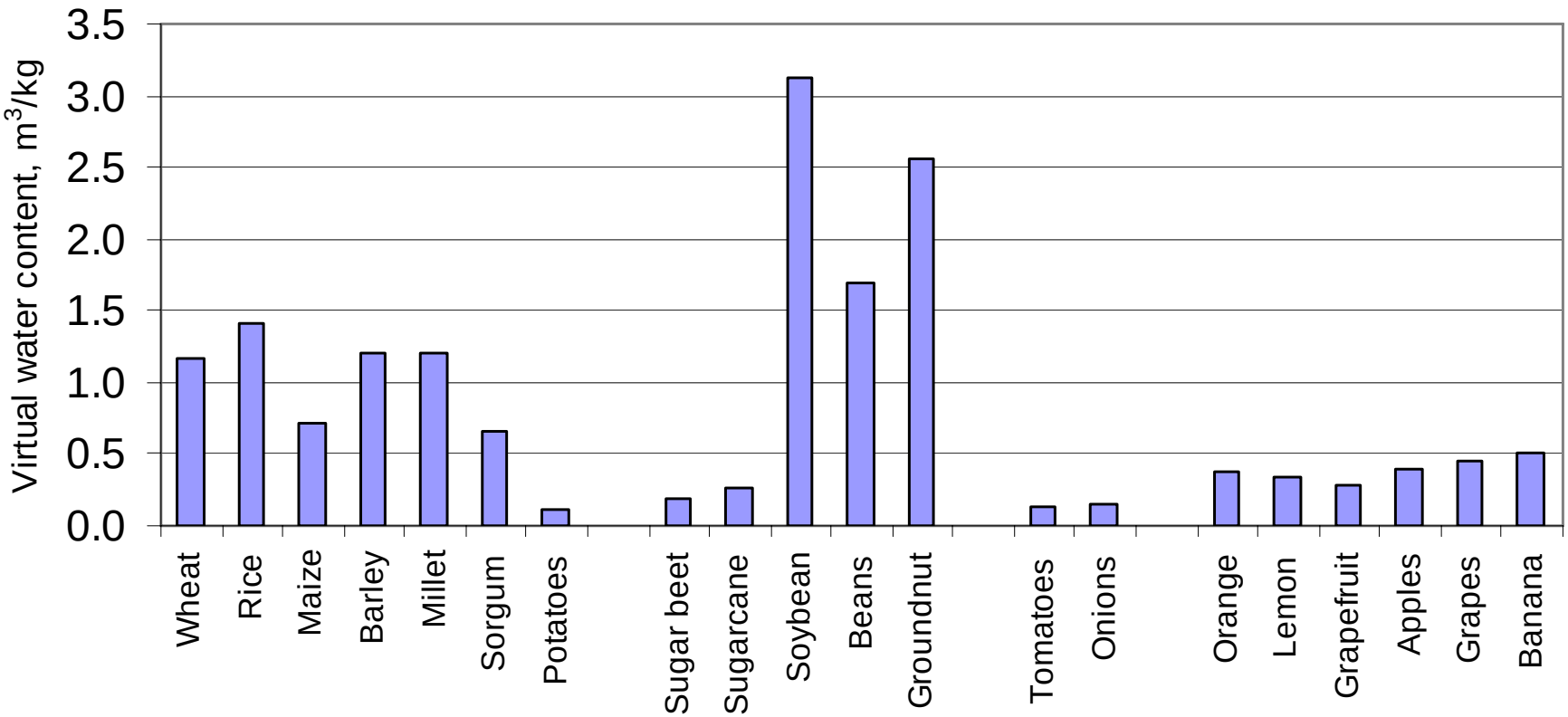
- Definition: water required to produce a unit of food commodity, measured in m^3/kg.

  e.g. wheat: $1m^3/kg$,

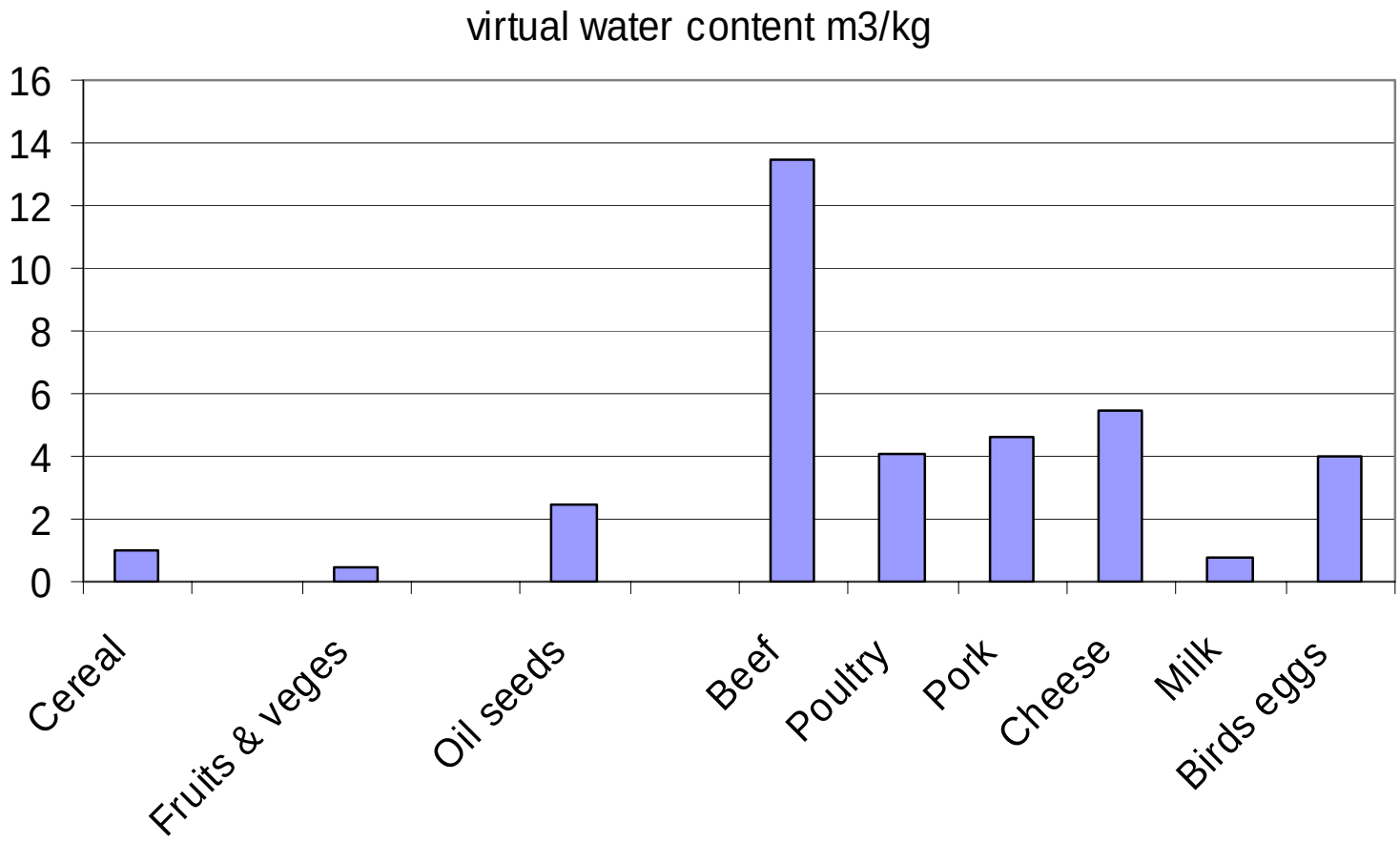
  beef: $10\text{-}13m^3/kg$

- In value term, virtual water content is the inversion of water productivity, in kg/m^3

World average virtual water content of crops



Global average virtual water content of crops and animal products

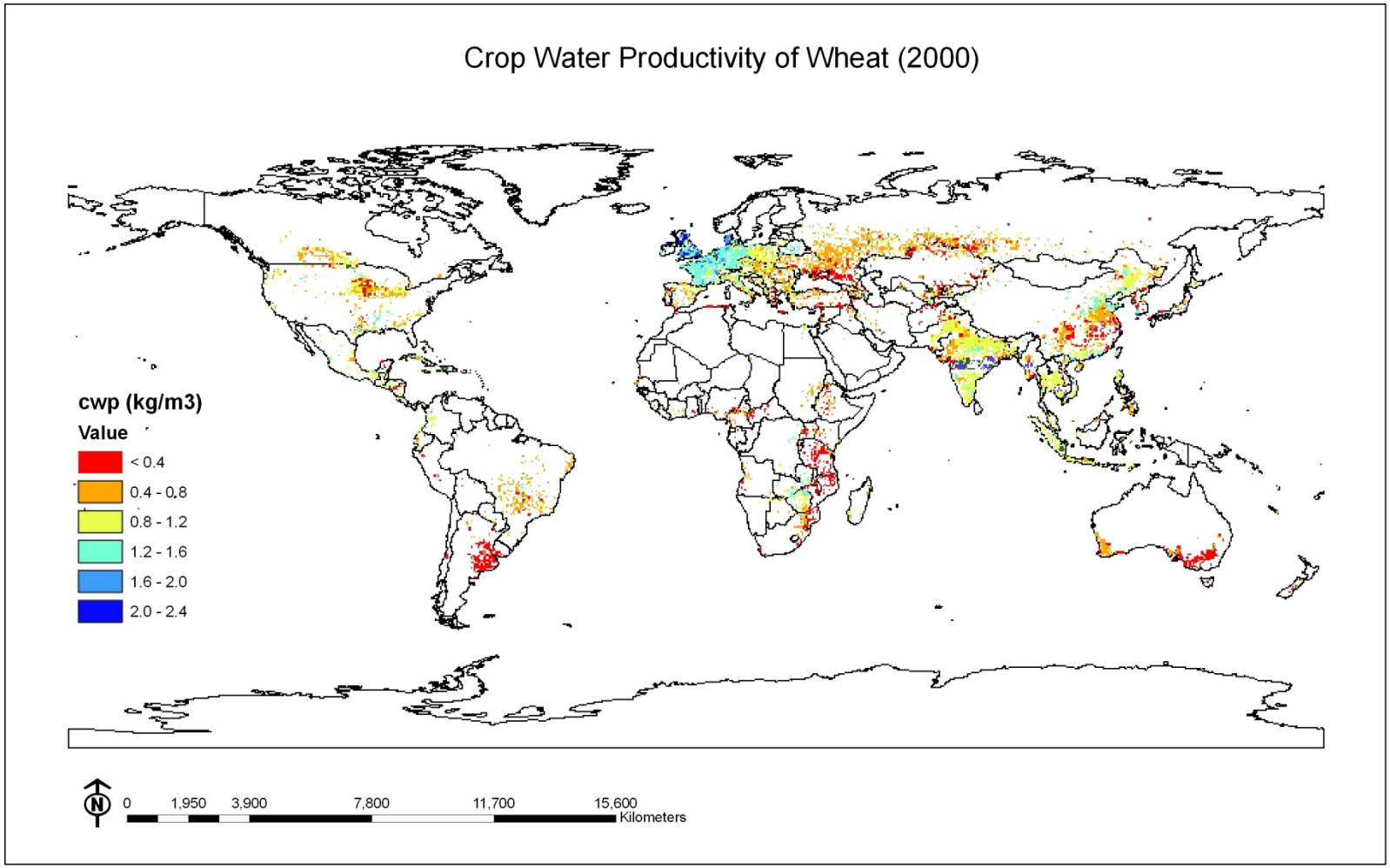


1.2 Variations in virtual water contents across regions, (m^3/kg)

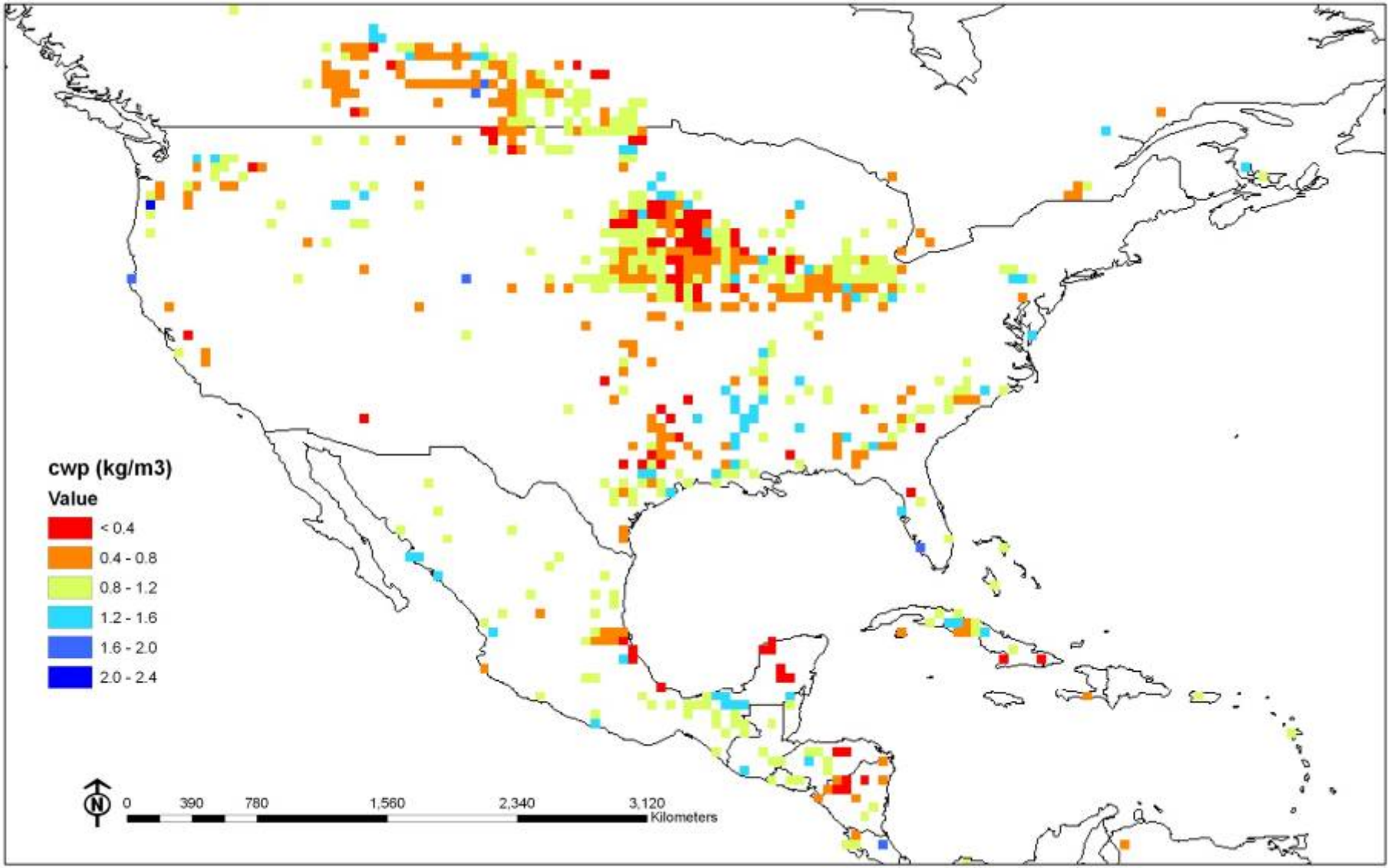
Virtual water content is a function of climate conditions, agronomic practices, field management, etc.

Wheat:	USA	1.30
	Morocco	4.14
	Algeria	7.22
Maize:	France	0.35
	USA	0.38
	Mexico	1.34
Rice:	China	1.07
	Thailand	4.05
	USA	1.33

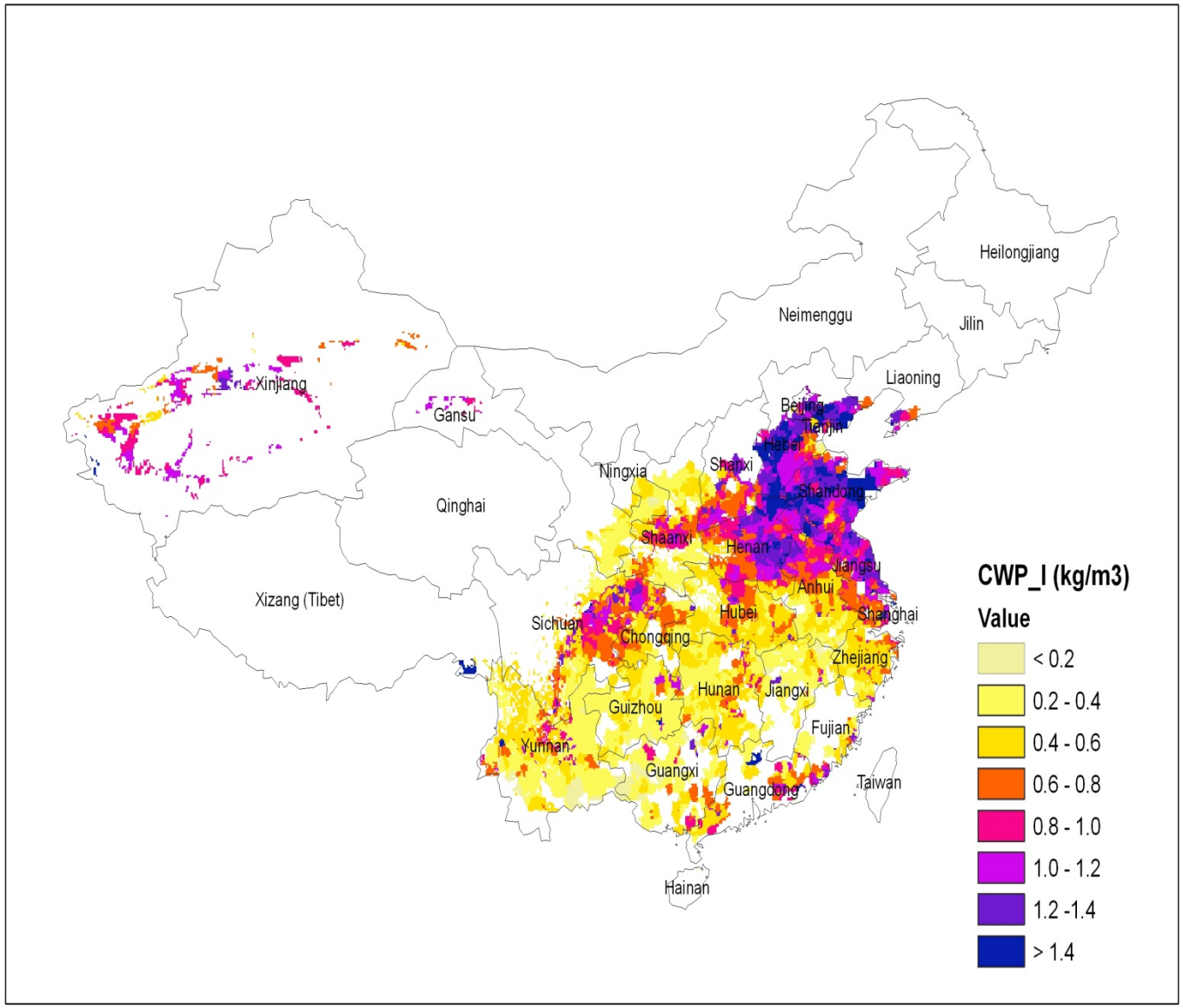
Global map of water productivity of wheat, estimated with GEPIC (GIS based EPIC model)



Simulated wheat virtual water content (WR) in the USA



Simulated winter wheat water productivity under irrigation



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2. Global virtual water flows associated with food trade

The gross volume of virtual water import (*GVWI*) to a country is the sum of crop imports (CI_c) multiplied by their associated crop water contents ($CVWC_c$) in that country:

$$GVWI = \sum_c (CI_c \times CVWC_c) \qquad (1)$$

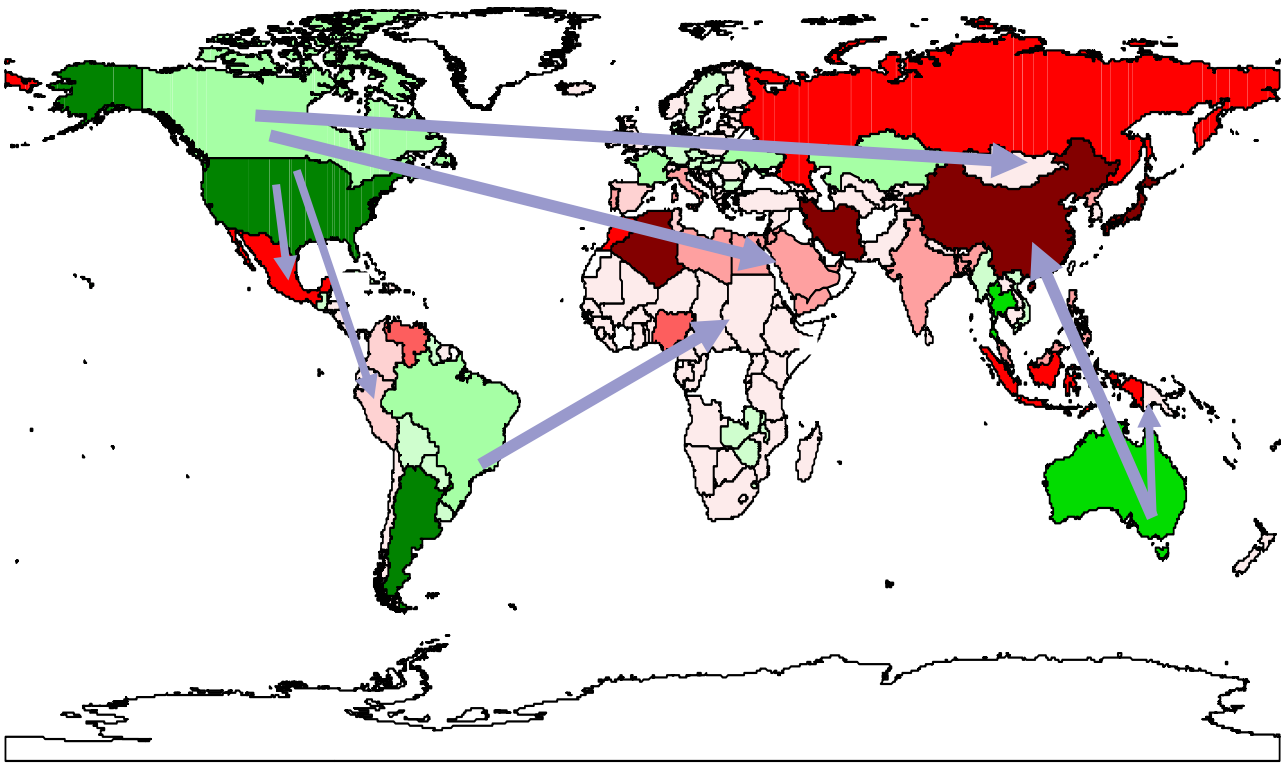
The gross volume of virtual water export (*GVWE*) from a country is the sum of crop exports (CE_c) multiplied by their associated crop water contents ($CVWC_c$) in that country:

$$GVWE = \sum_c (CE_c \times CVWC_c) \qquad (2)$$

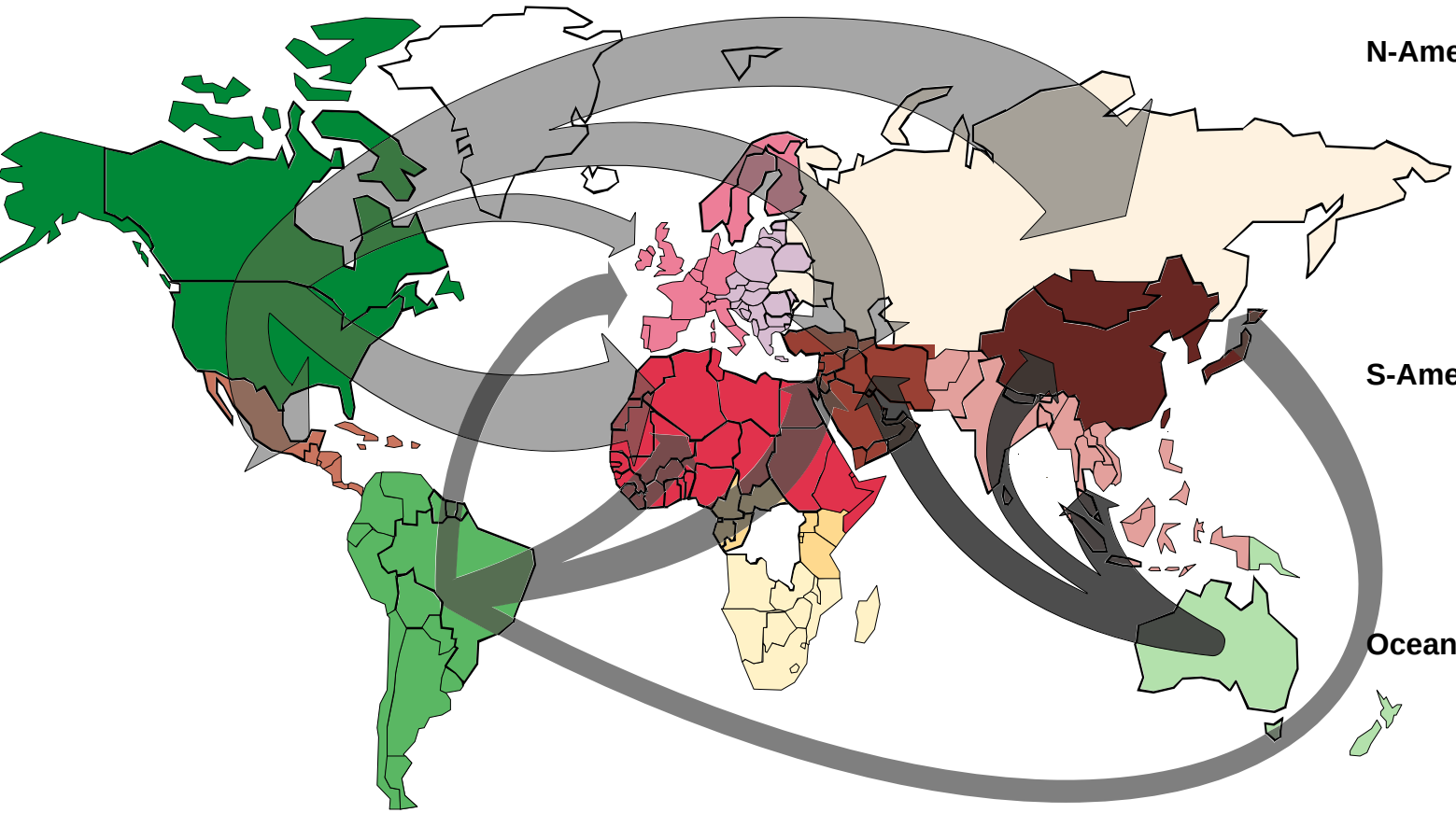
Net virtual water trade for individual countries

$$NVWT = GVWI - GVWE$$

Net virtual water import/export by country (average over the period 1997-2001)



Virtual water flows from export and import perspectives

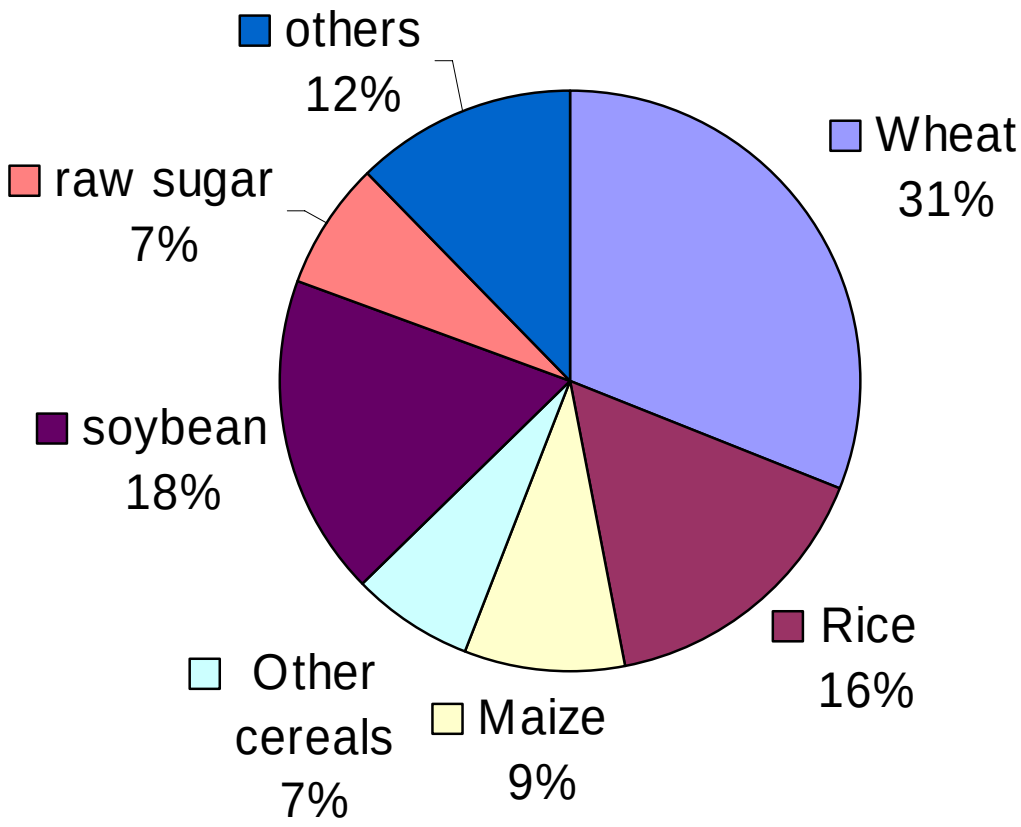


Exporter	VW (km^3)	Importer	VW (km^3)
N-America	73	E-Asia	149
	30	C-Am.	64
	22	N-W-Af.	58
	17	M-East	55
	12	W-Eur.	17
	27	Others	71
S-America	30	W-Eur.	26
	21	E-Asia	25
	18	M-East	35
	12	N-W-Af.	21
	15	Others	38
Oceania	15	E. Asia	20
	11	S-E-Asia	24
	10	M-East	14
	13	Others	24

Total amount of crop-related global virtual water flows

- Total water use by crops in the world: 5400km^3/year
- Total virtual water flows (annual average of 1995-1999): 695 km^3/year (exporting perspective)
- About 13% of the water used for crop production in the world is for external consumption

Components of global crop related virtual water trade (%)



Cereal has a large share

3. The role of virtual water in compensating for national water deficiency

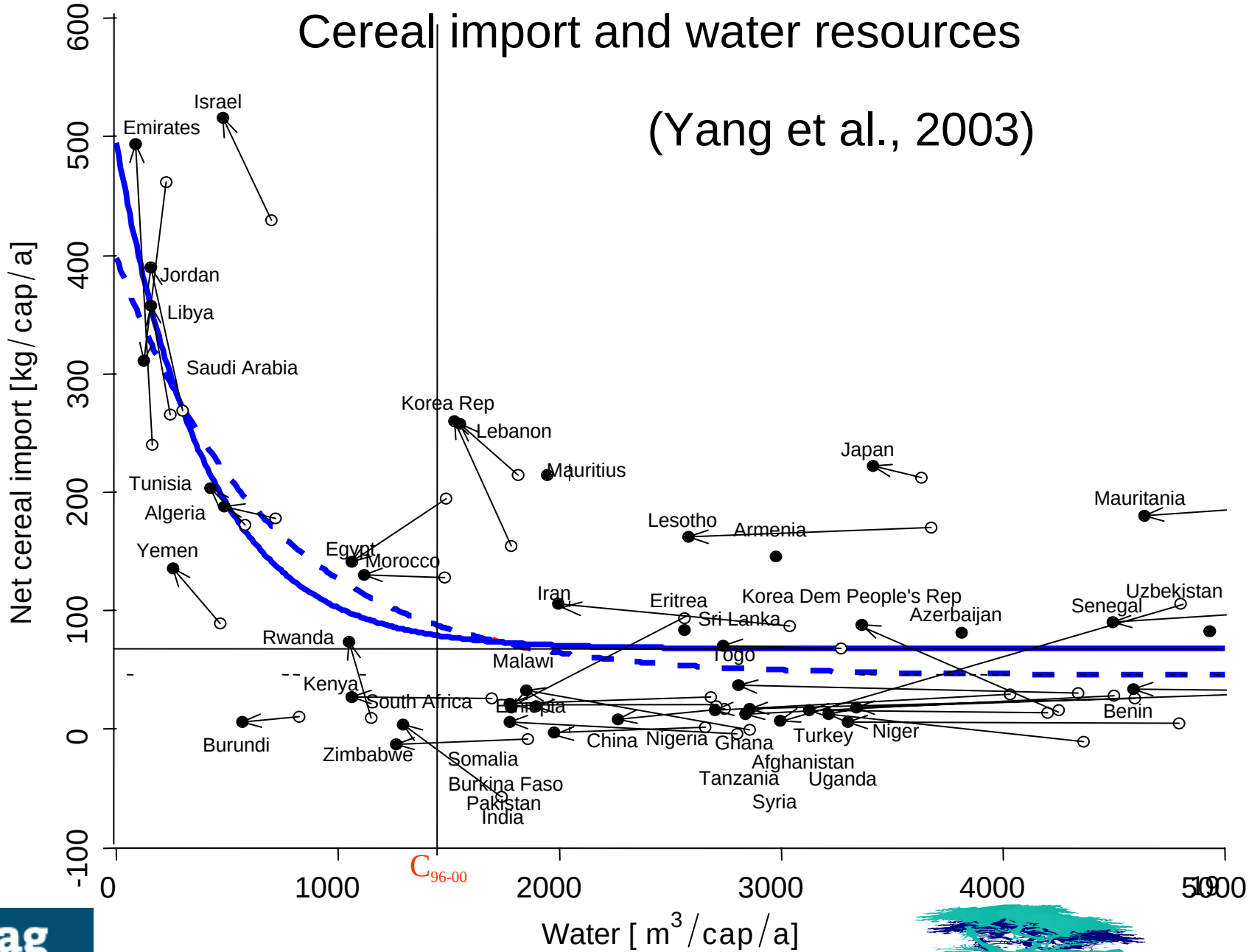
Net virtual water import by country groups, average of 1997-2001 (viewed from the importing side).

	All net virtual water import countries	Of which, Countries with water availability below 1700m^3/capita. year	Of which, Countries with water availability between 1700-2500m^3/capita. year	Of which, Countries with water availability above 2500m^3/capita. year
Net virtual water import, km^3/year	715.5	145.8	82.1	487.1
As percentage of total net virtual water import, %	100	20.4	11.5	68.1

Not all the food trade is related to water scarcity

Cereal import and water resources

(Yang et al., 2003)



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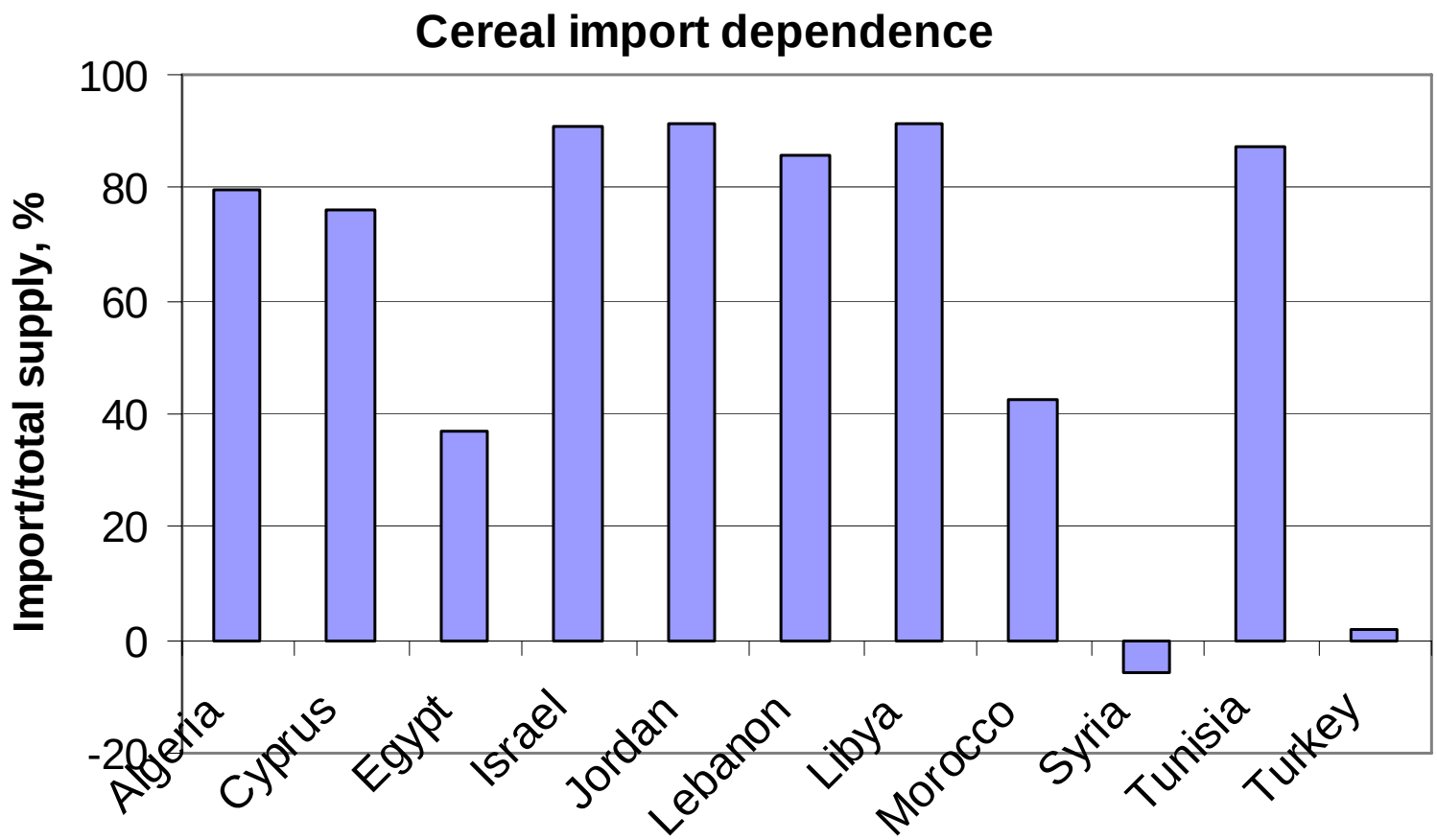
Water resource indicators in the MENA countries

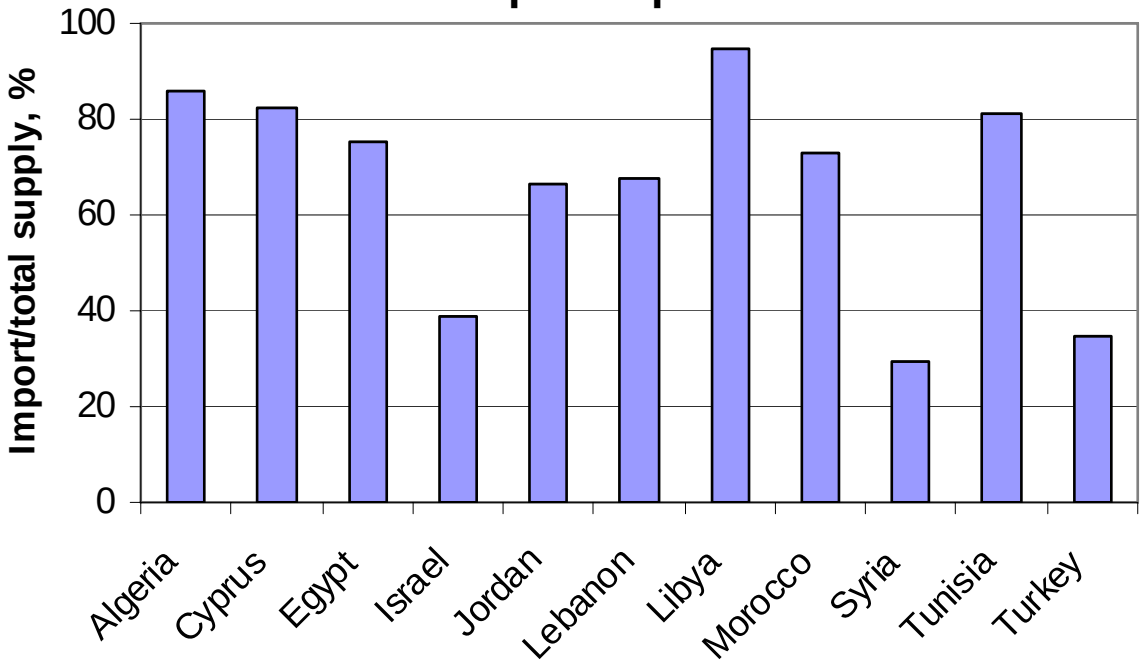
Country	Per capita water resources (m^3/capita, year)	Water use per capita in 2000 (m^3/capita, year)	Percentage of water use as total water resources (%)	Ratio of irrigated area to total crop area (%)
Algeria	452	201	44.40	15.77
Cyprus	1009	311	30.86	33.37
Egypt	831	1011	121.72	100.00
Israel	265	287	108.30	57.87
Jordan	169	207	122.32	37.62
Lebanon	1122	392	34.98	40.21
Libya	108	870	805.56	64.59
Morocco	991	399	40.26	18.14
Syria	1514	844	55.74	26.98
Tunisia	517	312	60.38	13.37
Turkey	3280	563	17.16	21.08
MENA	**1533**	**652**	**42.55**	**24.00**

Some countries are >100%

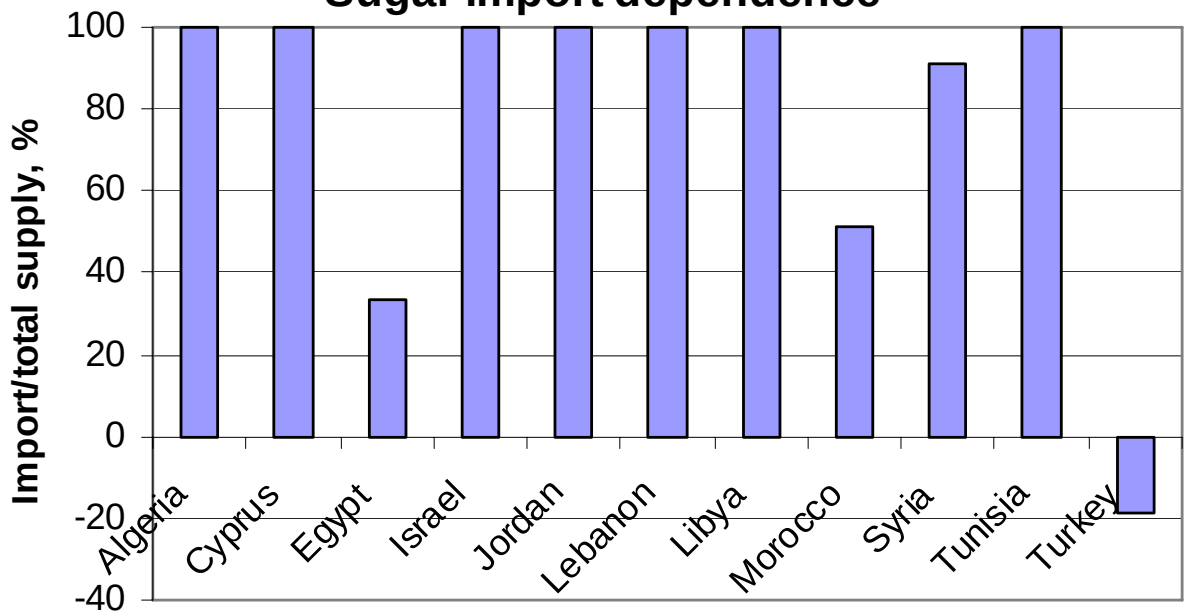
Food import vs. domestic supply in the MENA countries



Edible oil import dependence



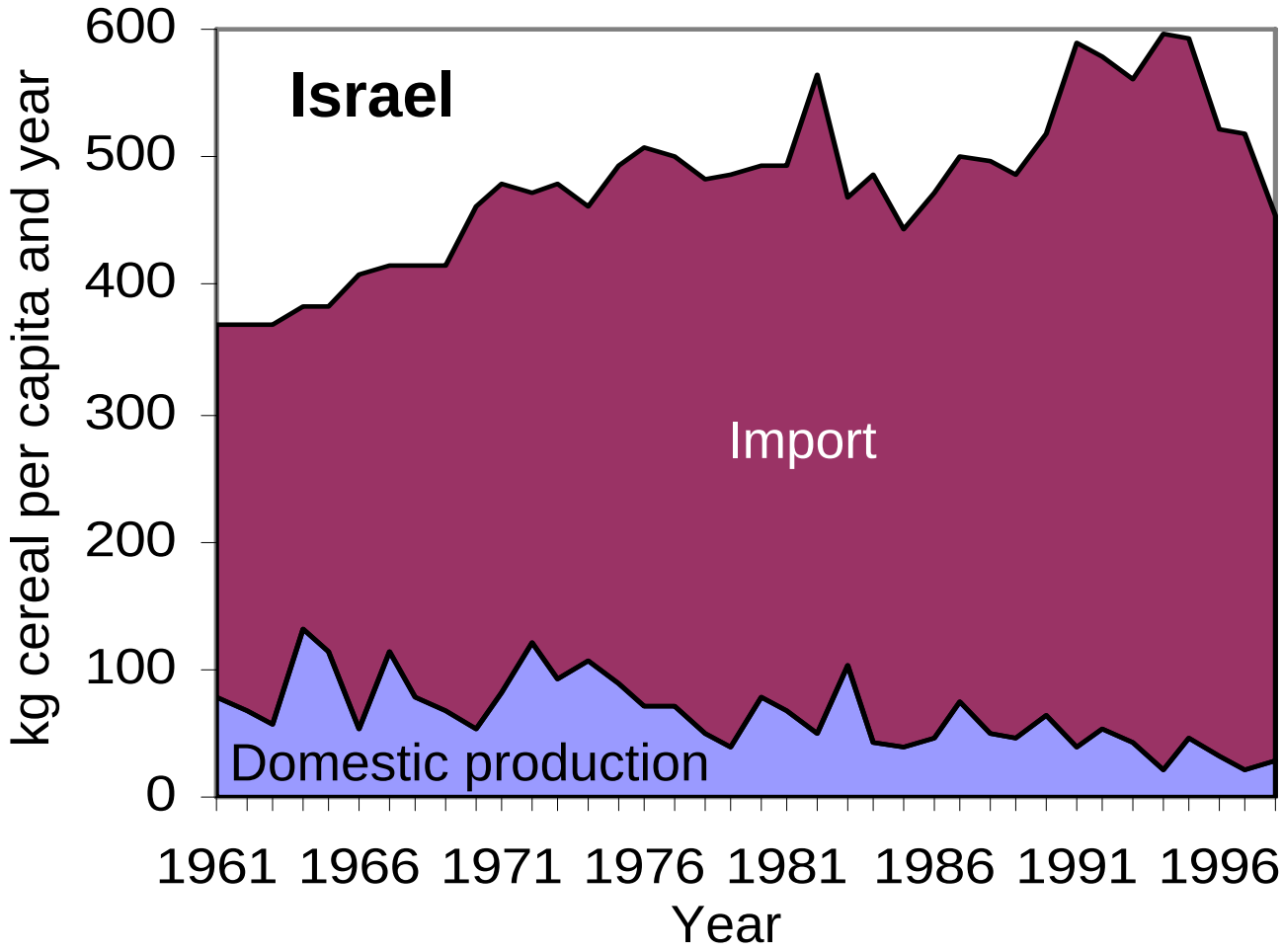
Sugar import dependence



Net virtual water import in MENA countries (million m^3) (1995-2000)

COUNTRY	Cereal	Vegetable oil	Sugar	Sum of net virtual water import	Net virtual water import as a % of water resources
Algeria	7539.9	2417.8	1275.8	11233.5	79.2
Cyprus	439.3	70.8	45.0	555.1	67.5
Egypt	10048.8	2840.2	1006.4	13895.5	23.5
Israel	2700.6	436.0	429.8	3566.4	207.4
Jordan	1249.6	326.3	247.8	1823.7	195.7
Lebanon	833.9	274.5	188.4	1296.8	28.7
Libya	2214.4	729.3	248.5	3192.2	557.1
Morocco	3944.8	1934.7	694.6	6574.1	21.9
Syria	-315.4	553.5	809.3	1047.4	3.6
Tunisia	3486.5	1018.9	411.3	4916.6	96.9
Turkey	621.8	2446.9	-451.3	2617.5	0.7
				0.0	
Sum	32764.4	13048.9	4905.7	50719.0	13.3

Changes and sources of per capita cereal supply, 1961–1998 (kg/capita)



Data from Yang & Zehnder, 2002

4. ‘Blue’ vs ‘green’ virtual water trade

Marlin Falkenmark (1995): ‘Mother’ of the green water

Definition:

- Blue Water: refers to the water in rivers, lakes, reservoirs, ponds and aquifers. **Irrigated agriculture typically uses blue water.**

- Green Water: water stored in the unsaturated soil and can be used by plants for evapotranspiration. **Green water is the water source of rainfed agriculture**.

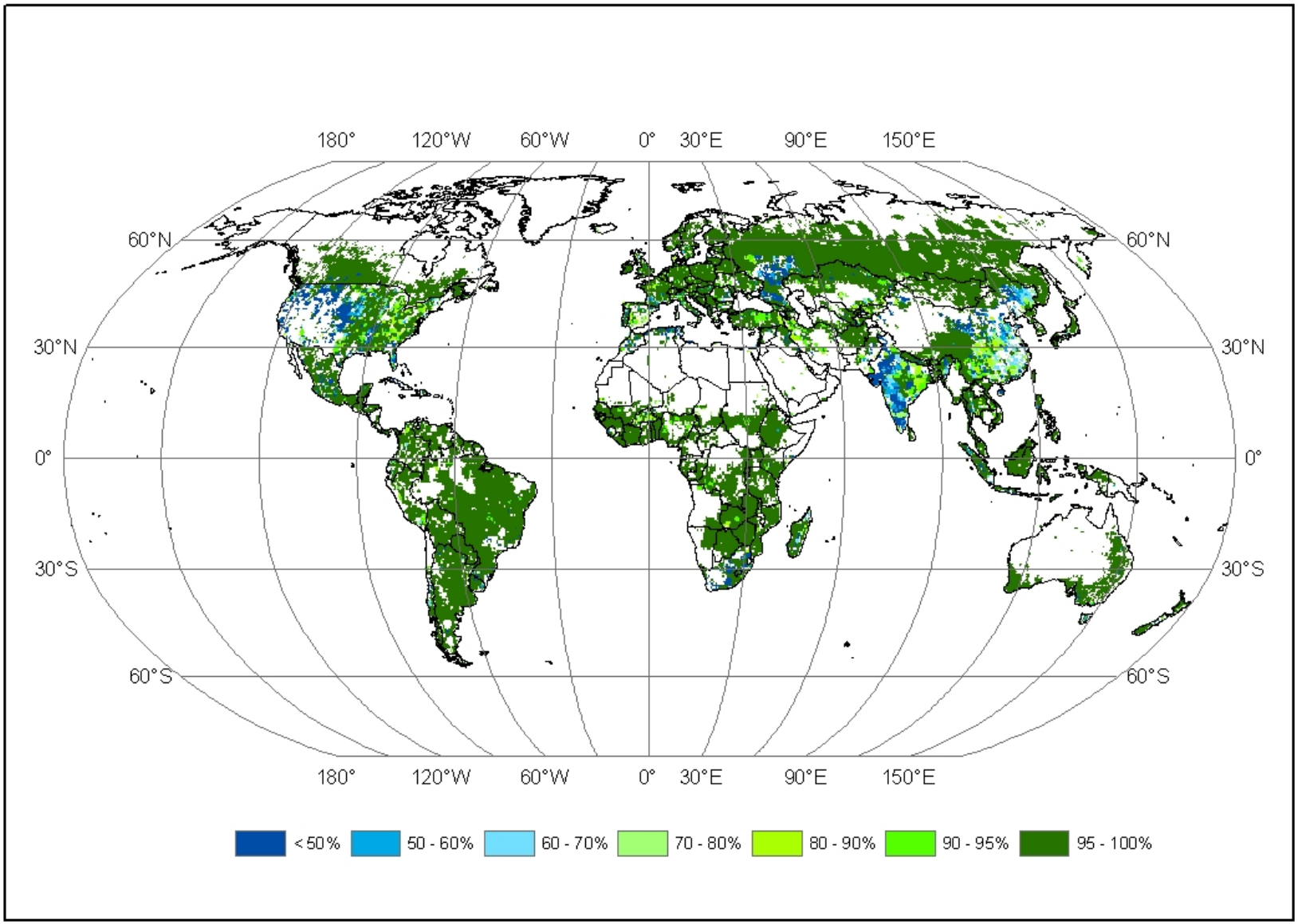
Characteristics of blue and green water

Type of water	Blue	Green
Sources	rivers, lakes, reservoirs, ponds, aquifers	stored in the unsaturated soil and can be used for evapotranspiration
Mobility	highly mobile	highly immobile
Substitution of sources	possible	impossible
Competitive uses	many	few
Conveyance facilities	required	not required
Cost of use	high	free
Impact on hydrological system	significant ?	less significant ?
Adverse effects on soil	significant (e.g., salinization and water logging)?	less significant?

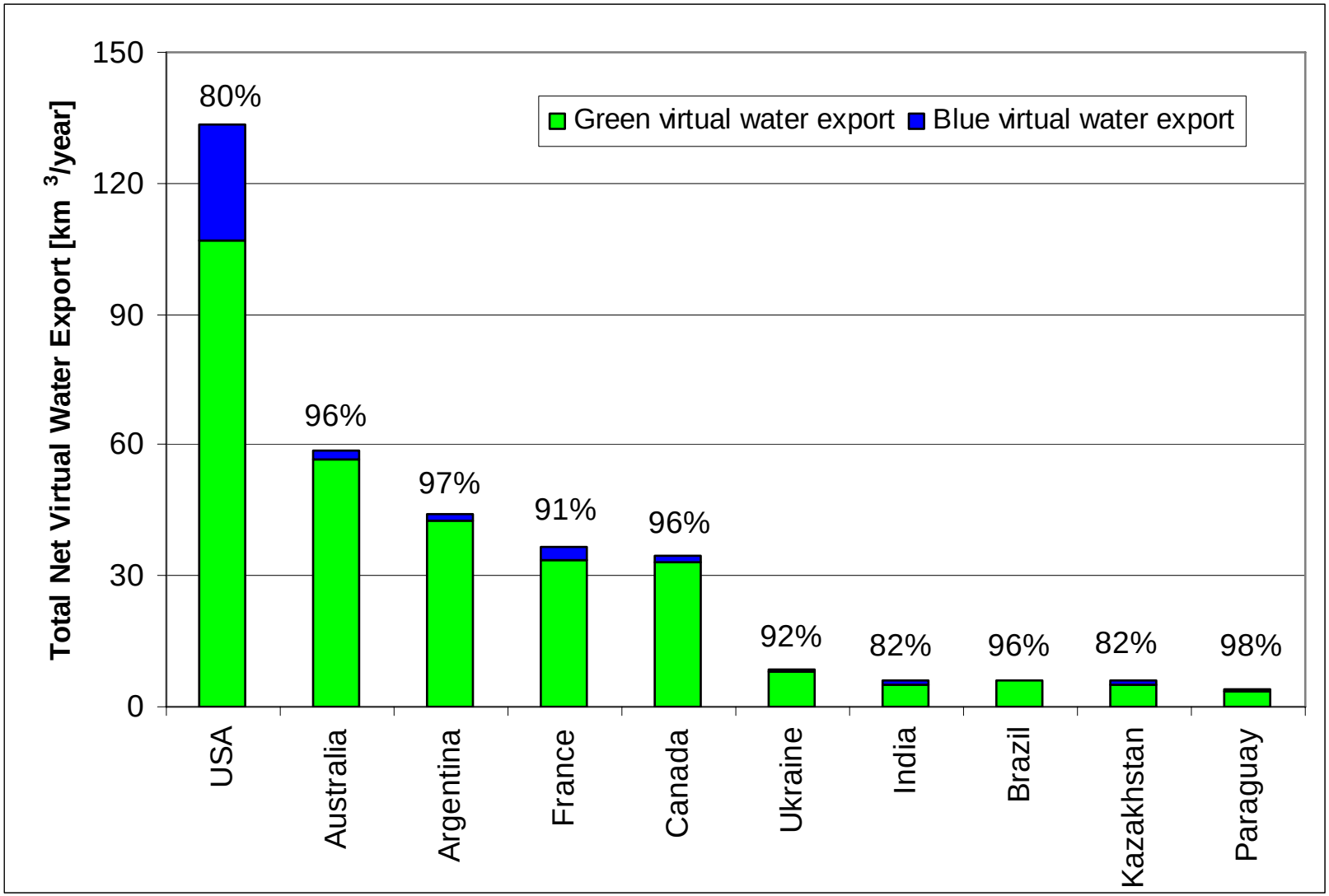
Efficiency of blue and green water use in agriculture

- Opportunity costs: blue water > green water.
- Environmental impacts: blue water > green water.
- For individual countries: exporting green virtual water is more efficient than exporting blue virtual water in terms of resources utilization.

Green water proportion in food production



Blue and green virtual water export



Conclusion I:

- Virtual water plays an important role in compensating for water scarcity in water scarce countries,

- Virtual water import is a matter of fact, not an imposed idea,

- Virtual water import can effectively reduce the blue water use in the recipient countries and regions.

- Water scarce countries should seek ways to consciously and efficiently utilize virtual water to alleviate domestic water scarcity.

Thank you!