International Conference on Sciene, Technology, Innovation and Management for Water Sustainability (STIM-WS)

Virtual Water Trade and Water Sustainability Issues in Managing Agricultural Trade

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Virtual Water Trade

- There are several definitions of virtual water; ours refers to the water embedded in a crop
- When an agricultural product is exported/imported, the water embedded is also exported/imported

- A trade network of food or agricultural products is accompanied by a network of virtual trading of water
- Unlike the water used and recycled, the virtual water in export goes outside the local water cycle.

Water availability and water surplus

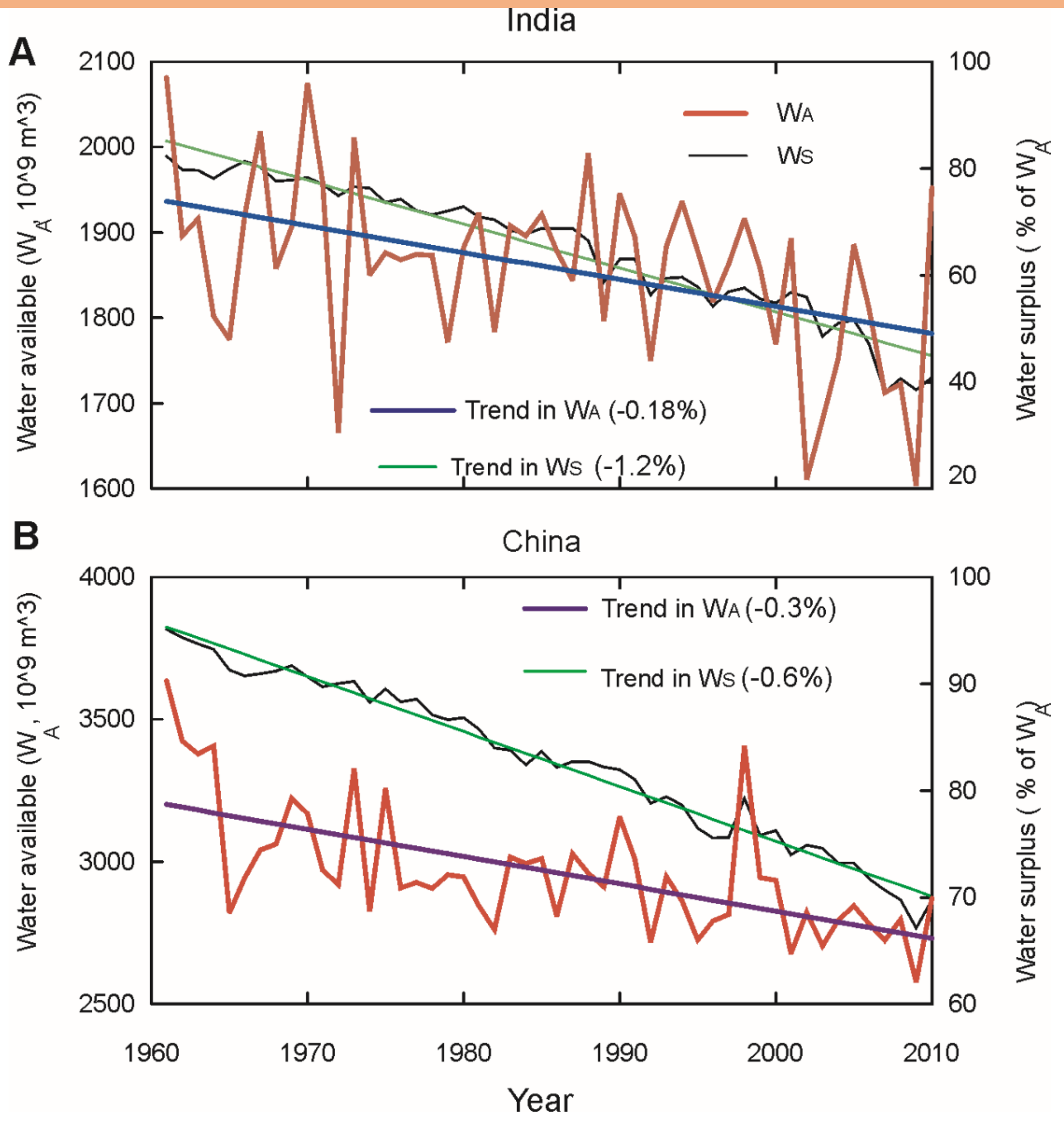

Fig. 1 Water availability, W_A, (left y axis, thick red line) and water surplus (W_S) (right y axis, thin black line) for India (**a**) and China (**b**). The blue line and green line, respectively, represents the linear trend for water available and water surplus for the respective case. The coefficients of linear trend are given in the brackets as percentage of respective mean in the corresponding panel.

Water footprint of the Food grains

Sl. No.	Crop	Water requirement (m^3/ton)			Water content (% of weight)
		Global	India	China	
1	Wheat	1827	2100	1597	Upto 15
2	Rice	2414	2986	1457	14-15
3	Barley	1423	2124	726	11-14
4	Maize	1222	2537	1160	10
5	Millet	4478	4029	1862	9.2
6	Rye	1544	-	2136	Upto 15
7	Oats	1788	-	898	12-14
8	Sorghum	3048	6026	3048	9
9	Buckwheat	--	--	--	9.75

Virtual water export in terms of water used for production for all crops

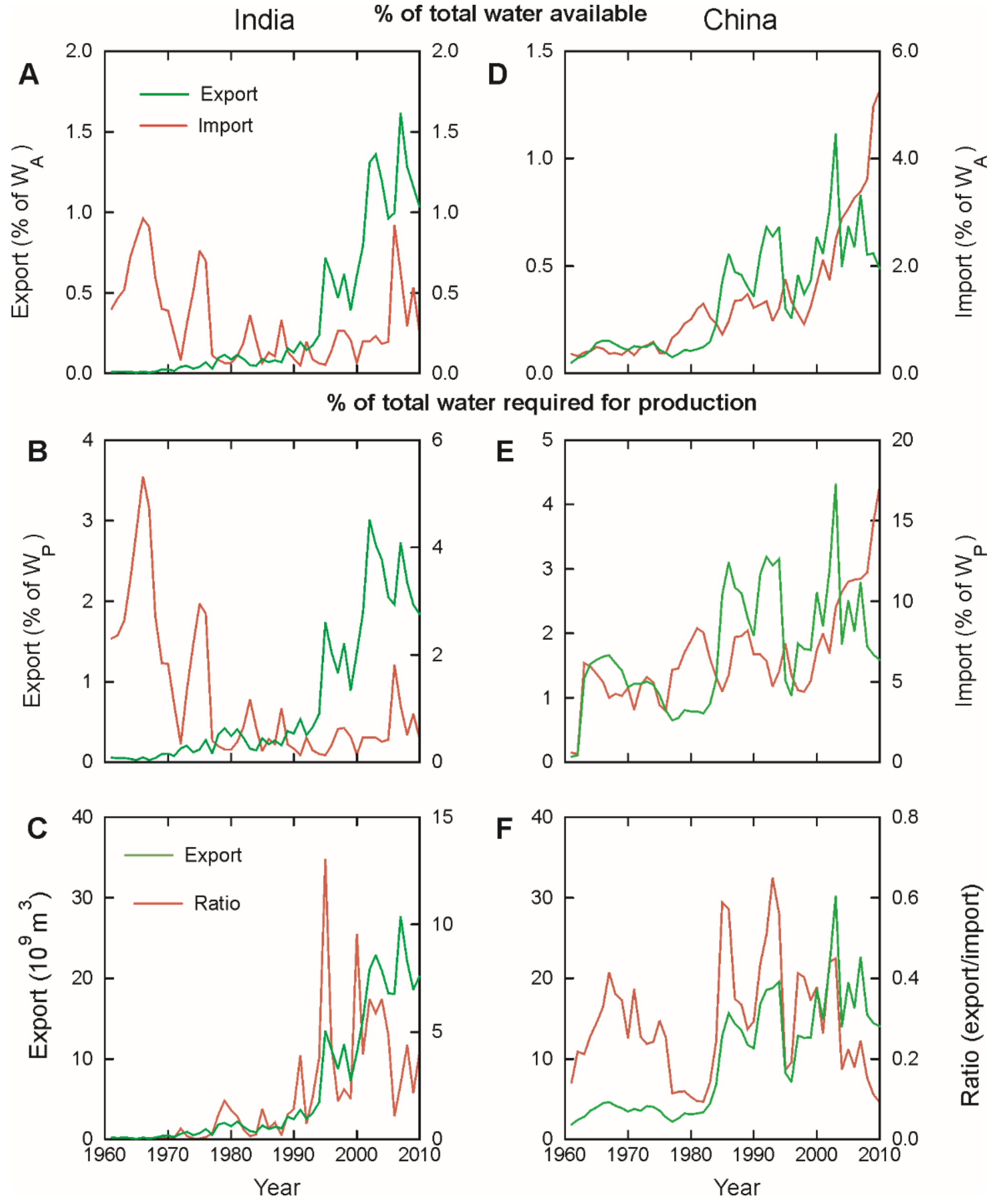

Fig. 2 Export (left y axis, green line) and import (right y axis, red line) in terms of water involved in production for all crops

a, d: As percentage of total water available for India (**a**) and China (**d**), respectively.

b, e: As percentage of total water required for production for all crops for India (**b**) and China (**e**), respectively.

c, f: Export (10^9 m^3, left y axis) and ratio of export to the import (right y axis, red line) for India (**c**) and China (**f**), respectively.

Virtual water export in terms of water used for production for food grains

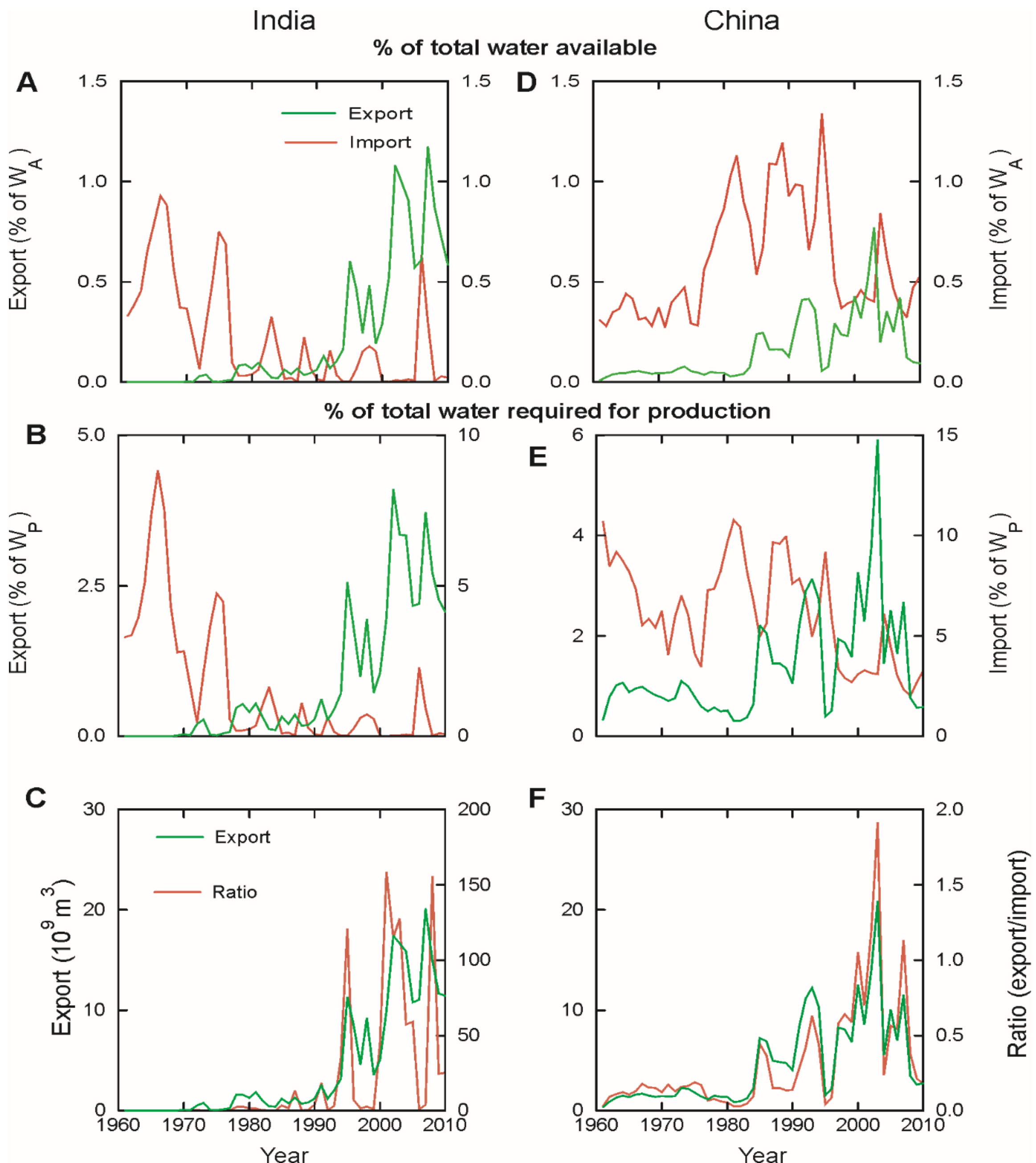

Fig. 3 Export (left y axis, green line) and import (right y axis, red line) in terms of water involved in production for food grains

a, d: As percentage of total water available for India (**a**) and China (**d**), respectively.

b, e: As percentage of total water required for production for all crops for India (**b**) and China (**e**), respectively.

c, f: Export (10^9 m^3, left y axis) and ratio of export to the import (right y axis, red) for India (**c**) and China (**f**), respectively.

Virtual water export in terms of Actual water embedded in the crops

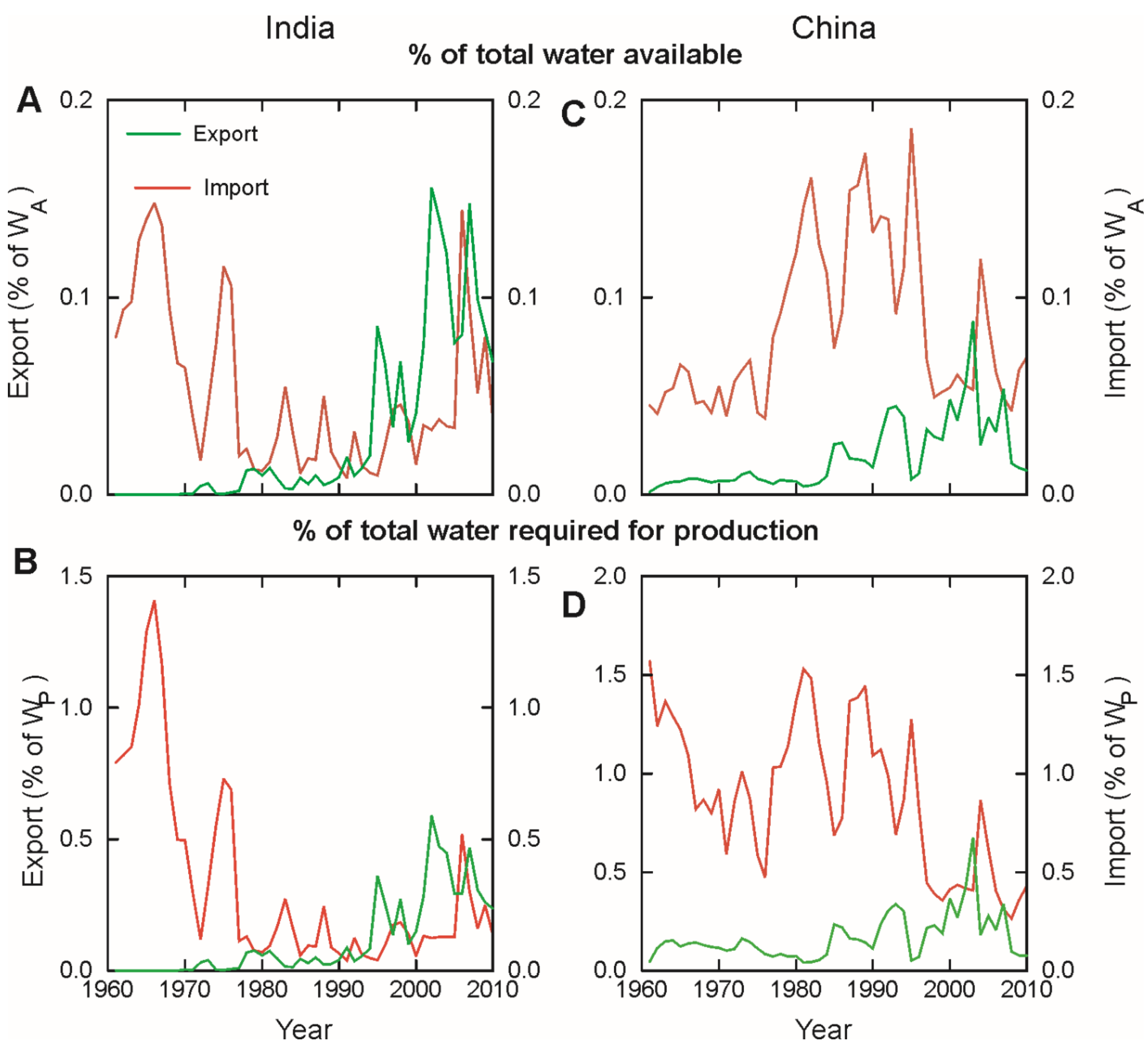

Figure 4 Export (green line) and import (red line) of actual water through export and import of food grains (as available in end-products of crops) for India and China as percentage of available water (top panel) and percentage of total water used for production (bottom panel).

Virtual water trade balance (net Export)

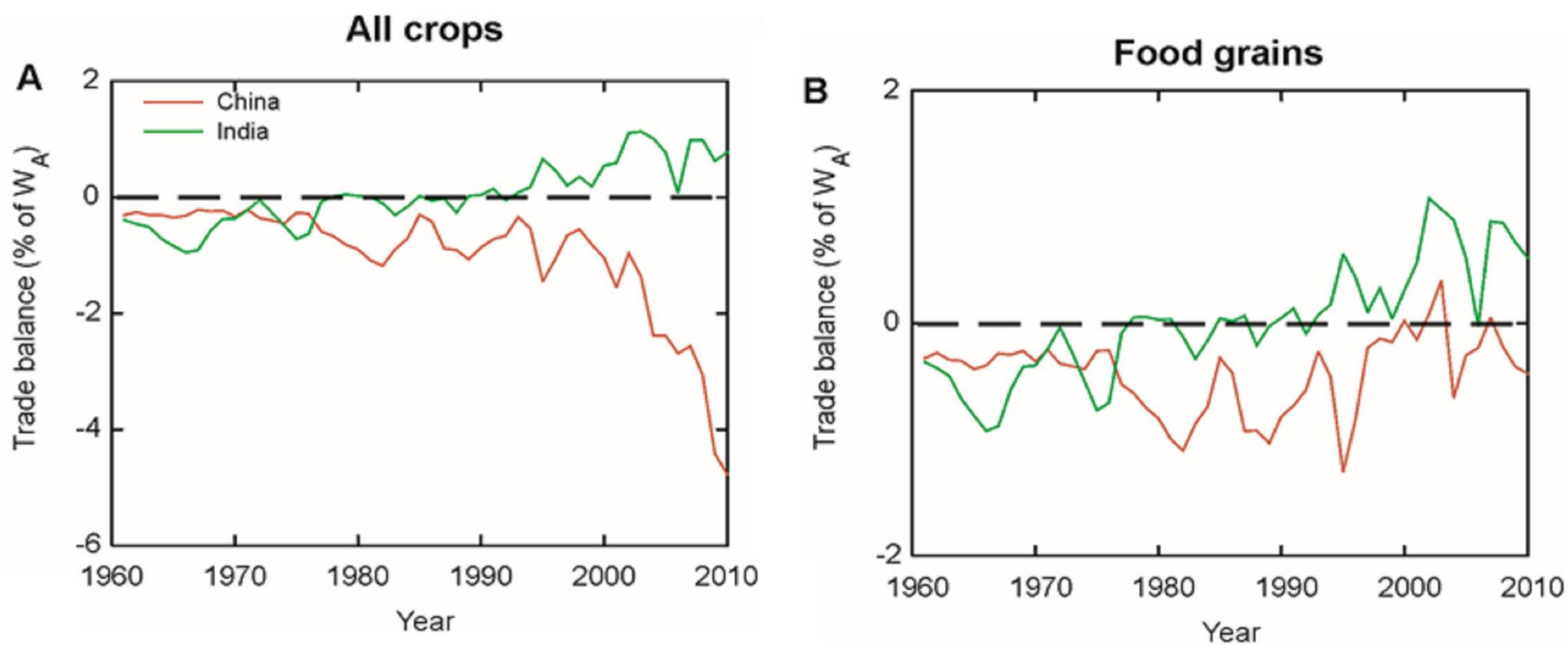

Figure 5 Trade balance in terms of total water involved in production as percentage of water available for all crops (**a**) and food grains (**b**) for India (green line) and China (red line).

Simulation and projection of water availability and population

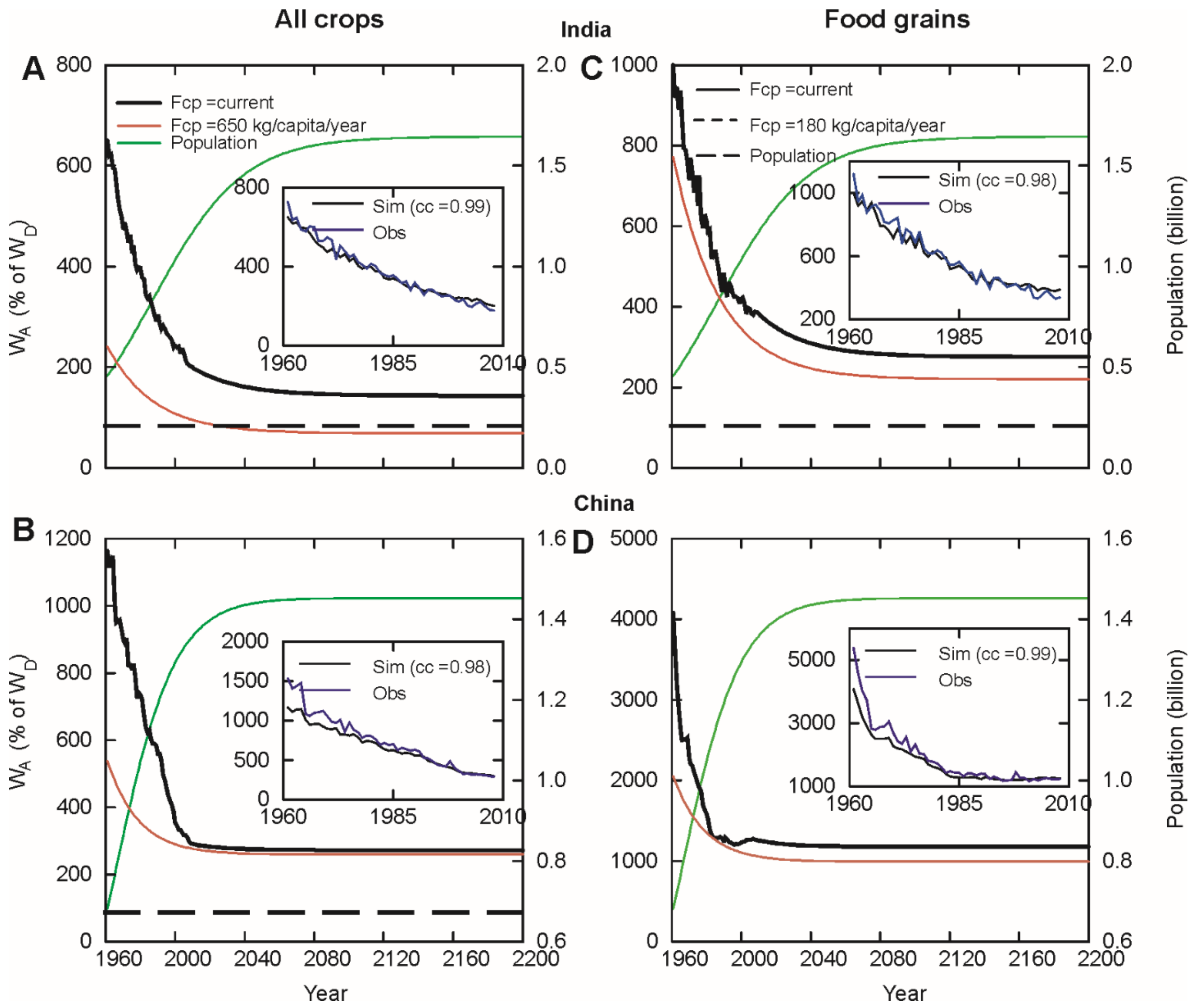

Figure 6 Simulation (1960-2010) and projection of water availability (2010-2200) (as percentage water demand) for all crops (left panels) and food grains (right panels) for two values of per capita food consumption

a, b: current and 650 kg/capita/year of all crops for India (**a**) and China (**b**).

c, d: current and 180 kg/capita/year of food grains for India (**c**) and China (**d**).

The horizontal long dash line represents the level at which the water demand equals the total water available.

The inset figure in each panel shows the simulation (solid line) and observation of the water availability as percentage of water demand for the annual per capita food consumption of all crops and food grains for the respective country; the correlation coefficient between simulation and observation is given in the bracket.

Time scale for loss of water sustainability through Net export

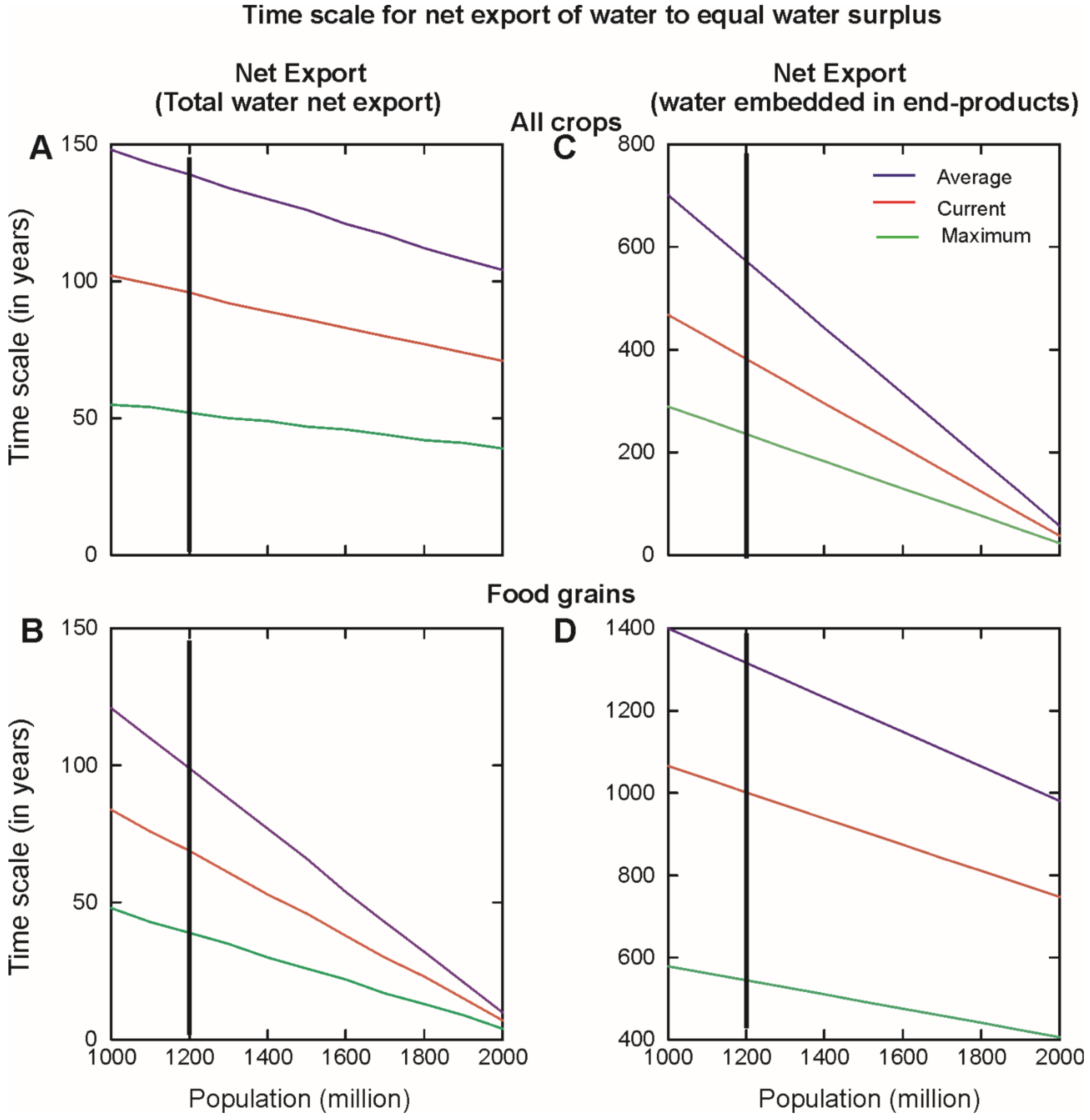

Figure 7 Time scales for India for loss of water sustainability through virtual net export in terms of water involved in production for all crops (**a**) and food grains (**b**), and in terms of water content in end-products for all crops (**c**) and food grains (**d**) equals to water surplus for all food crops (top panels) and food grains (bottom panels). The net export is projected by taking three different values of net export: Average (1990-2009, blue line), maximum (1990-2009, green line) and current (2005-2009; average, red line). We have taken 350 kg/capita and 150 kg/capita/year, respectively, per capita consumption of all crops and food grains. The vertical dash line represents the current population.

Time scale for loss of water sustainability through Export

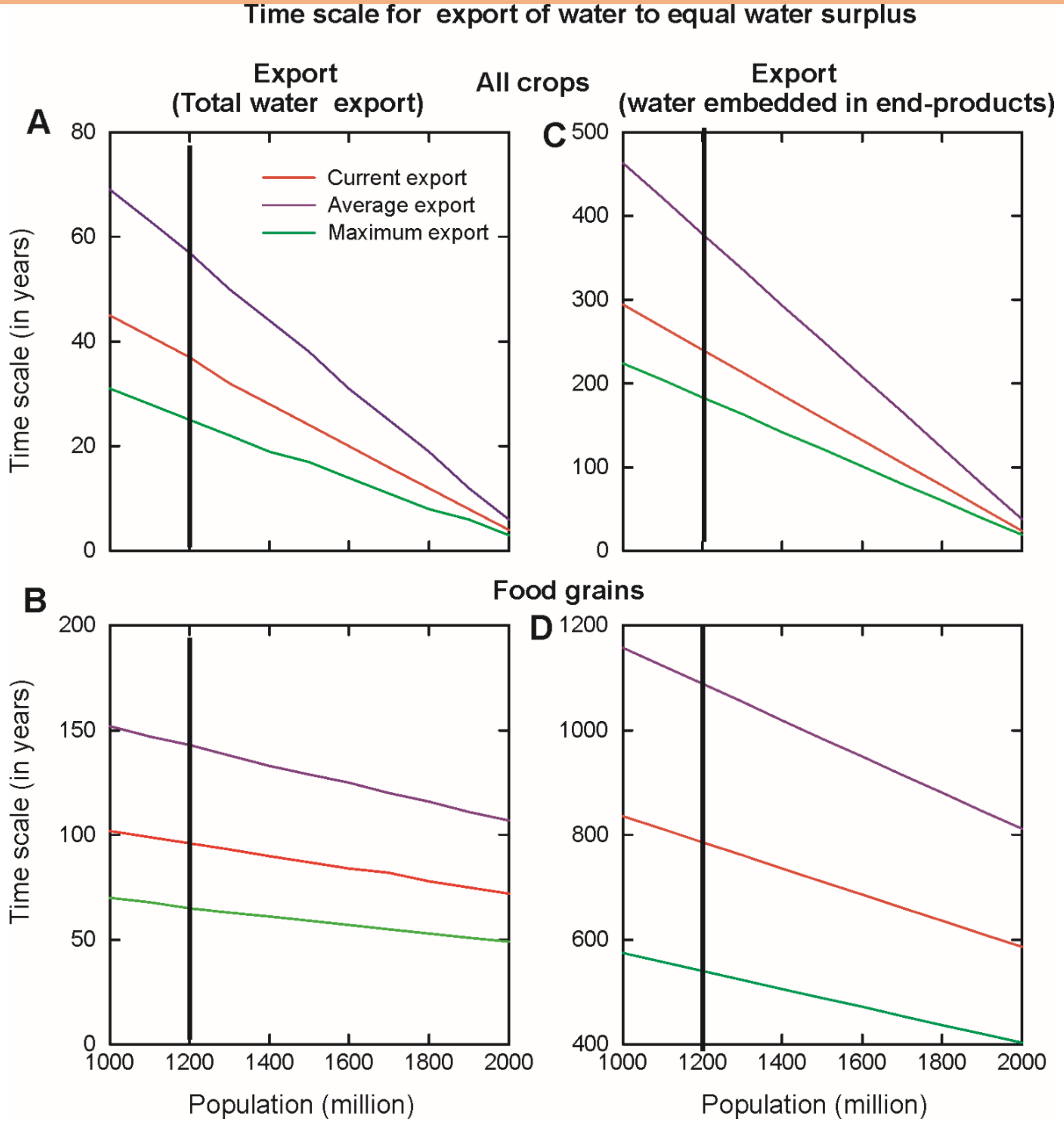

Figure 8 Time scales for India for loss of water sustainability through virtual export in terms of water involved in production for all crops (**a**) and food grains **(b),** and in terms of water content in end-products for all crops (**c**) and food grains **(d)** equals to water surplus for all food crops (top panels) and food grains (bottom panels). The export is projected by taking three different values of export: Average (1990-2009, solid line), maximum (1990-2009, dotted line) and current (2009; long dash line). We have taken 350 kg/capita and 150 kg/capita/year, respectively, per capita consumption of all crops and food grains. The vertical dash line represents the current population.

Time scales for loss of water sustainability

Time scale	Sustainability water export scenarios	Time (in years) for export scenario					
		Average export (1995-2010)		Maximum export (1961-2010)		Current export (Average 2005-2010)	
		Food grains	All crops	Food grains	All crops	Food grains	All crops
N_{CA}	$W_{EC} \sim W_A$	1505	889	747	431	1086	564
N_{CP}	$W_{EC} \sim W_P$	467	527	232	255	337	335
N_{CS}	$W_{EC} \sim W_S$	1089	378	540	183	786	240
N_{TA}	$W_E \sim W_A$	197	133	91	59	132	85
N_{TP}	$W_E \sim W_P$	62	79	28	35	41	51
N_{TS}	$W_E \sim W_S$	143	57	66	25	96	37

Table 1 Time scales for water export in terms of water content in end-product (W_{EC}) and total water involved in production of exports (W_{ET}) to equal total water available (W_A) and current water required for production (W_{PF}) and the water surplus (W_S) for India for three different scenarios of export of agricultural products (all crops and food grains): average (1990-2009), maximum (1990-2009) and current (2005-2009, average) of export.

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Virtual water trade and time scales for loss of water sustainability: A comparative regional analysis

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Assessment and policy design for sustainability in primary resources like arable land and water need to adopt long-term perspective; even small but persistent effects like net export of water may influence sustainability through irreversible losses. With growing consumption, this virtual water trade has become an important element in the water sustainability of a nation. We estimate and contrast the virtual (embedded) water trades of two populous nations, India and China, to present certain quantitative measures and time scales. Estimates show that export of embedded water alone can lead to loss of water sustainability. With the current rate of net export of water (embedded) in the end products, India is poised to lose its entire available water in less than 1000 years; much shorter time scales are implied in terms of water for production. The two cases contrast and exemplify sustainable and non-sustainable virtual water trade in long term perspective.

Water availability, quality, management and distribution have emerged as critical issues at regional scales for populous countries like China and India[1]. Several studies have highlighted the challenges faced by both China and India in meeting their water demands[2–5]. In general, water sustainability has emerged as a major global concern[6–8], with uncertainties and added vulnerability due to climate change[9,10]. An emerging issue of growing importance and debate in the context of water and food sustainability is the virtual water trade[11,12]. Virtual trade of water has become an important component of global fresh water demand and supply[13] and has resulted in globalization of water resource[14–17]. It has also become a medium of the global fresh water sharing[15–18]. It needs to be further emphasized that the demands of virtual trade of water also need to take into account the trade requirement of food, and hence the potential production[19–21]. The role of virtual water in the overall resource management has been recognized early[21–23]. Several studies have emphasized the role of virtual water trade in globalization of water resource and in the overall food requirement. Several studies have emphasized the emerging but critical roles of network of virtual water trade in water management[21–23] and regional water systems[22].

While virtual water can provide a more integrated approach to water management[23], it can also affect regional food sustainability[24] and other processes[25]. Importance and impacts of virtual water trade on food and water sustainability have been discussed at the global[26,27] as well as regional scale[28–30]. An index for water scarcity based on virtual water has been also proposed[25], highlighting the importance of water use efficiency; however, such an index is focused on usage and influence of virtual water and not on implications for water sustainability due to trade of virtual (embedded) water. Analysis of virtual water profiles at global and regional scales using input-output model for 112 nation-level regions revealed India, USA, and China as the world's leading virtual water consumers[16,17].

In terms of agriculture and food, virtual water can be defined both in terms of water required for the production, and as water content embedded in the end products[24,27]. In production perspective, the volume of water used to produce an agricultural product is considered; this volume of water depends on the agricultural practices, water use efficiency, place and time of production[31,32]. Water footprint of a crop also strongly depends on local climate conditions; for example, water required for producing 1 kg of a crop in an arid region is two or three times more than that in a humid region[31,32]. Thus assessment of water sustainability in terms of agricultural production needs to adopt a regional perspective. The issue of virtual water is a particularly important concept for water scarce countries[19–28] with large demands. India and China are the two most populous countries with limited arable land[33] and fresh water resources. Similarly, fresh water resources of India and China are, respectively, 3.83 percent and 6 percent of the world's fresh water resources[34]. A large fraction of the total annual rainfall is

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A deterministic model of a research organization's evolution and dynamics of performance

Prashant Goswami[1], Shiv Narayan Nishad[1] and Dhanya Selvaratnam[1]

ABSTRACT Quantitative descriptions of complex social systems hold promise for many applications such as understanding and quantifying group behaviour, organizational performance and inter-personal interactions. Since social systems are interacting and evolving systems, dynamical modelling of them enables the possibility to study time evolution under different scenarios in a quantitative and possibly predictive framework. There are, however, several challenges in developing such dynamical models, one of which is that unlike in physical systems, it is difficult to identify unambiguous, let alone unique, casual relations in social dynamics. A further major difficulty is in quantifying attributes like performance, personal choice and leadership. Here, we provide such a quantitative model of a sociological system, namely a research organization, with its performance as a dynamical variable. We use the model to study the evolution and sensitivity of the performance of a research organization under different conditions. The performance is measured as the sum of contributions from the individual members of the organization in terms of metrics, such as number of research publications. The individual performances are driven by various benchmarks, personal goals and other processes that respond to time-dependent internal and external factors. The factors that arise from institutional and individual aspects, like institutional average and national benchmark, are represented mathematically to describe the dynamics. The model demonstrates complex behaviour that a research institution can exhibit in response to internal as well as external factors. The model is applied to quantify the roles of various processes like initial selection criteria and leadership response in the institutional dynamics and the categories of performers. The novel feature in our formalism is a somewhat mechanistic, and deterministic, description of a research organization's evolution over time. Our results demonstrate that a social system such as a research organization can be modelled as an initial and boundary value dynamical system. Unlike qualitative or static models, such a dynamical model allows us to chart institutional trajectories under different organizational conditions. This concept and the methodology can be extended to other social systems—such as electorates or a publicly funded organization—with appropriate dynamical variables.

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thethirdpole.net
UNDERSTANDING ASIA'S WATER CRISIS

Virtual water trade: India loses, China gains water through food trade

Food exports are running India dry, while China is conserving its water supply by importing water intensive crops such as soya, a new analysis of the two countries water footprint reveals

The dried bed of Nirguna river near Balapur, district Akola, Maharashtra.

T.V. Padma, July 8, 2015

THE NEW INDIAN EXPRESS
Tuesday, November 24, 2015

India Losing 'Virtual Water' Through Food Exports

By IANS | Published: 19th April 2015 12:27 PM Last Updated: 19th April 2015 12:27 PM

Email 0

Kolkata: Have you heard of water export? Apparently, India has been sending "virtual" water to other countries through its food exports, and this trend is likely to continue.

"Water used in agriculture is recirculated, but the (virtual) water exported out when we export food is not recoverable. Over a period of time, if food export is extensive, the country's water reserves go down affecting water sustainability," says Prashant Goswami, a researcher at the CSIR Fourth Paradigm Institute, Bengaluru.

In answers send by email and given on the phone, Goswami, a Shanti Swarup Bhatnagar awardee, says that in contrast, China is a net importer of food and is therefore amplifying its water reserves. He suggests a change in India's food policy.

Goswami, a climate and atmospheric modelling expert, warns in a study that if the current rate of net export of water in end products continues, India will lose its "entire available water in less than 1,000 years."

This projection may go down further if parameters like increase in food demand and reduction in surface water due to climate change are taken into consideration, according to the study.

The findings of the study 'Virtual water trade and time scales for loss of water sustainability: A comparative regional analysis' were published in the March 20 edition of Nature Scientific Reports.

India, the US, and China are known to be the world's leading virtual water users and in the wake of growing consumption, such water trade plays a key role in the water sustainability of a nation, the study's author Goswami said.

Goswami also said that for several decades, China has maintained a positive trade balance (more import than export) in virtual water trade and it is supplementing its water reserves.

The study says India's water import through food grains is virtually nil. From an import-intensive paradigm during 1960-70, India had moved to an export-intensive regime in virtual water trade, it says.

Stressing that a sustainable food or agricultural policy must be based on zero trade deficit or positive trade balance in virtual water, Goswami said that as water demand in other sectors like manufacturing, services and construction increases, this will put additional pressure on water sustainability in India.

Virtual Trade and Water Sustainability

- A net export of water through export of agricultural products, as in the case of India, can lead to slow but irreversible loss of water sustainability

- The time scales for loss of water sustainability through virtual export is less than 300 years for water requirement and less than 500 years for water available

- Increase in food demand, and reduction in surface water due to climate change can further reduce these time scales

- Careful Trade Management can lead to zero or positive (more import) Trade balance in virtual water through agricultural trade

THANK YOU