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Applications of Water Footprint Methodology as a Decision Support Tools for Water Management Tasks in Egypt

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RESEARCH OUTLINE

1- Introduction to Water Footprint

2- Egyptian National Water, Food, and Virtual Water Trade Modeling

I-Egyptian water foot print and food security

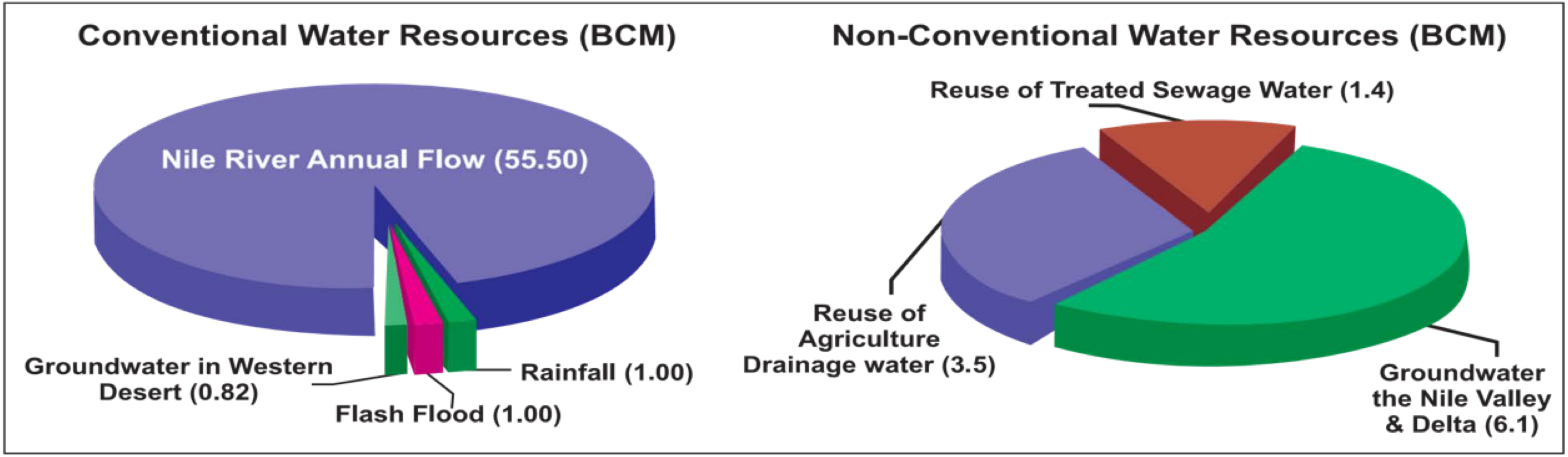
II-The National Water-Food &Trade NWFT

3- Conclusions

4- Recommendations

1-Water resources in Egypt

More than 96 percent of all the Egyptian fresh water resources are supplied by the **river Nile**, which originates from outside the country boundaries and supplies ten countries among which Egypt. Egypt s share of Nile water is limited according to the 1959 international agreement between Sudan and Egypt at **55.5 BCM** (Abu-Zeid, 1991). The rest of the water requirements is met by a **renewable groundwater** with **4.8 BCM/year** and a **drainage water reuse**, which is estimated at **4.5 BCM**. Treated municipal and industrial wastewater water returns to the closed water system **0.7 and 6.5 BCM**, respectively (UN CCA, 2001).



Water Resources of Egypt

Introduction to Water Footprint

Water Footprint / Virtual Water

The term "**virtual water**" (VW) is generally used to refer to the **sum of water used or consumed in the various steps of the production processes of a commodity**(Allan, 2003).

It is generally agreed that both VW and the WF are measures of **direct and indirect water consumption** and only account for freshwater appropriation. It has been suggested that an important distinction between the two concepts is that a WF "*does not simply refer only to a* ***water volume****, as in the case of the term virtual water content 'of a product*", instead the **WF** is a "***multidimensional indicator, not only referring to a water volume used, but also making explicit where the water footprint is located, what source of water is used and when the water is used***" (Hoekstra *et al*., 2011).

Water footprint

Water footprint as **an indicator of human consumption of freshwater resources** can be measured as volume over time (**mostly m^3/yr**). A **country's water footprint** is the *volume of water used to produce goods and services consumed by the inhabitants of a country, including imported* goods be measured as volume over time over per capita (**mostly m^3/yr/capita**). .

Components of a water footprint

Green water footprint

► Refers to the volume of **rainwater consumed** (i.e. evaporated or absorbed into the product).

Blue water footprint

► Refers to the volume of **surface water and ground water** consumed during production processes (i.e. evaporated or absorbed into the product).

Grey water footprint

► Refers to the **volume of freshwater that is required to eliminate the load of pollutants**. It is calculated as the volume of water that is required to maintain the water quality according to **agreed water quality standards**

Table Average virtual water content of some selected products for a number of selected countries (m^3/ton).

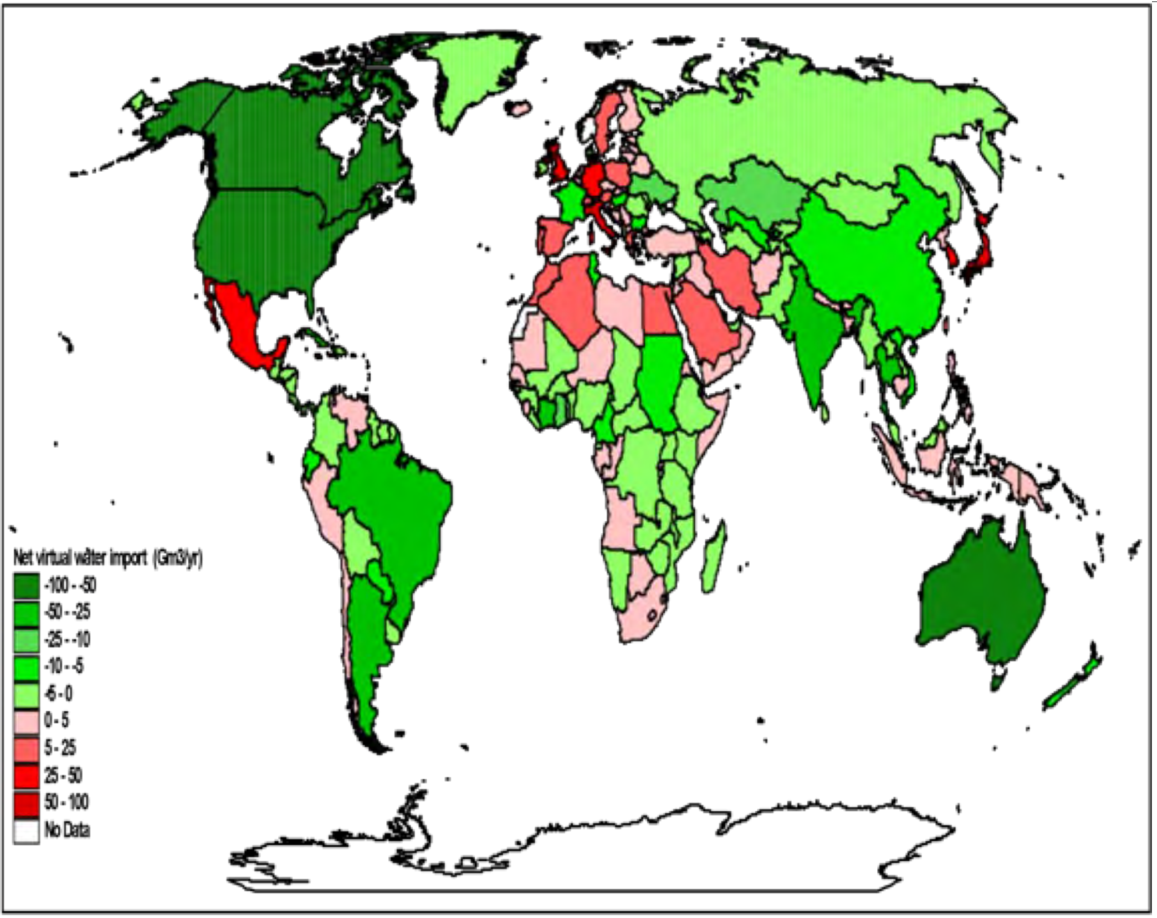
	USA	China	India	Russia	Indonesia	Australia	Brazil	Japan	Mexico	Italy	Netherlands	World Average
Rice (paddy)	1275	1321	2850	2401	2150	1022	3082	1221	2182	1679		2291
Rice (husked)	1656	1716	3702	3118	2793	1327	4003	1586	2834	2180		2975
Rice (broken)	1903	1972	4254	3584	3209	1525	4600	1822	3257	2506		3419
Wheat	849	690	1654	2375		1588	1616	734	1066	2421	619	1334
Maize	489	801	1937	1397	1285	744	1180	1493	1744	530	408	909
Soybeans	1869	2617	4124	3933	2030	2106	1076	2326	3177	1506		1789
Sugar cane	103	117	159		164	141	155	120	171			175
Cotton seed	2535	1419	8264		4453	1887	2777		2127			3644
Cotton lint	5733	3210	18694		10072	4268	6281		4812			8242
Barley	702	848	1966	2359		1425	1373	697	2120	1822	718	1388
Sorghum	782	863	4053	2382		1081	1609		1212	582		2853
Coconuts		749	2255		2071		1590		1954			2545
Millet	2143	1863	3269	2892		1951		3100	4534			4596
Coffee (green)	4864	6290	12180		17665		13972		28119			17373
Coffee (roasted)	5790	7488	14500		21030		16633		33475			20682
Tea (made)		11110	7002	3002	9474		6592	4940				9205
Beef	13193	12560	16482	21028	14818	17112	16961	11019	37762	21167	11681	15497
Pork	3946	2211	4397	6947	3938	5909	4818	4962	6559	6377	3790	4856
Goat meat	3082	3994	5187	5290	4543	3839	4175	2560	10252	4180	2791	4043
Sheep meat	5977	5202	6692	7621	5956	6947	6267	3571	16878	7572	5298	6143
Chicken meat	2389	3652	7736	5763	5549	2914	3913	2977	5013	2198	2222	3918
Eggs	1510	3550	7531	4919	5400	1844	3337	1884	4277	1389	1404	3340
Milk	695	1000	1369	1345	1143	915	1001	812	2382	861	641	990
Milk powder	3234	4648	6368	6253	5317	4255	4654	3774	11077	4005	2982	4602
Cheese	3457	4963	6793	6671	5675	4544	4969	4032	11805	4278	3190	4914
Leather (bovine)	14190	13513	17710	22575	15929	18384	18222	11864	40482	22724	12572	16656

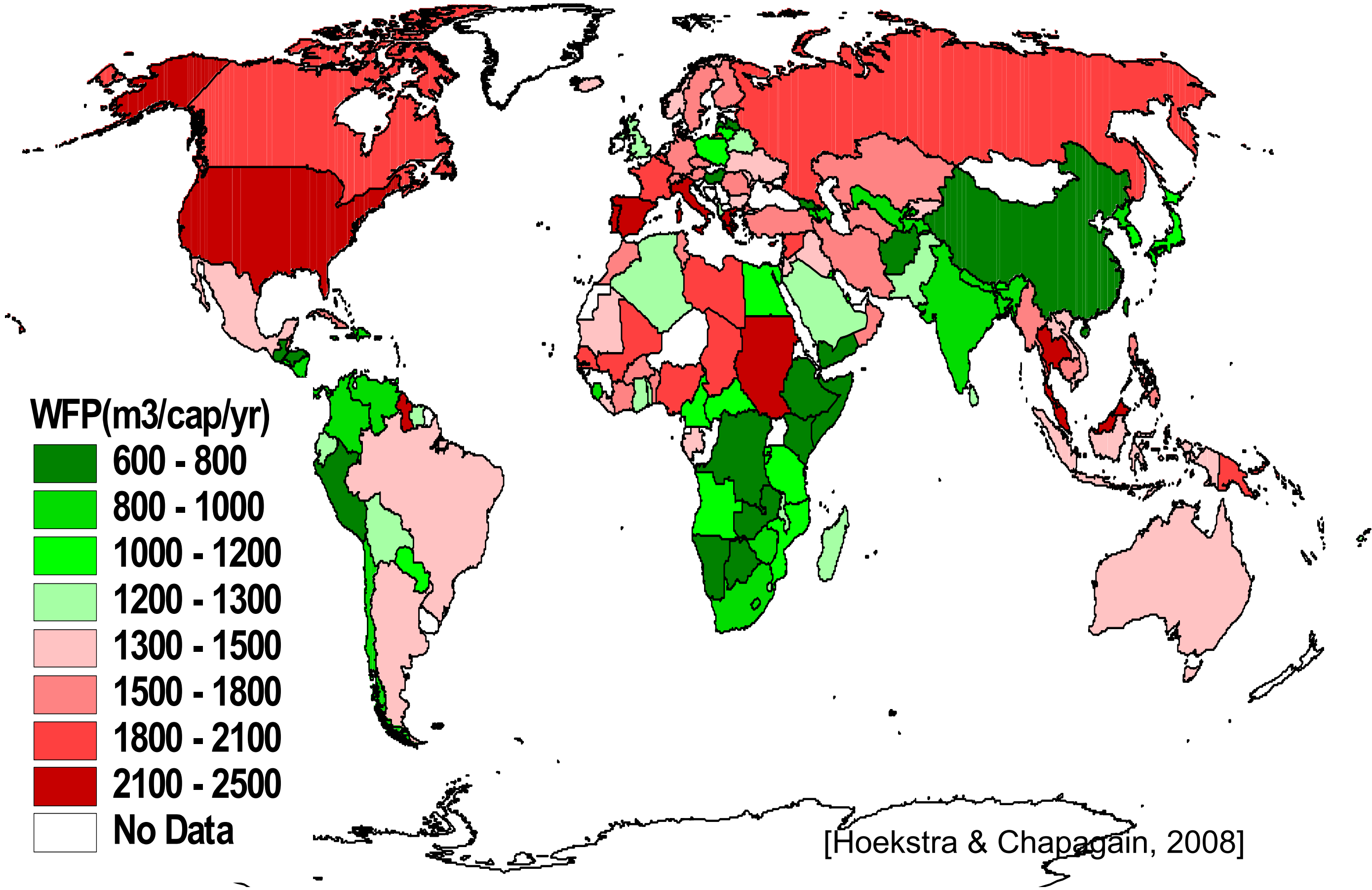
Virtual water content of processed crop and livestock products

Table Global average virtual water content of some selected products, per unit of product

Product	Virtual water content (litres)		Product	Virtual water content (litres)
1 glass of beer (250 ml)	75		1 glass of wine (125 ml)	120
1 glass of milk (200 ml)	200		1 glass of apple juice (200 ml)	190
1 cup of coffee (125 ml)	140		1 glass of orange juice (200 ml)	170
1 cup of tea (250 ml)	35		1 bag of potato crisps (200 g)	185
1 slice of bread (30 g)	40		1 egg (40 g)	135
1 slice of bread (30 g) with cheese(10 g)	90		1 hamburger (150 g)	2400
1 potato (100 g)	25		1 tomato (70 g)	13
1 apple (100 g)	70		1 orange (100 g)	50
1 cotton T-shirt (medium sized, 500 g)	4100		1 pair of shoes (bovine leather)	8000
1 sheet of A4-paper (80 g/m^2)	10		1 microchip (2 g)	32

The water footprint of a country can be **related to the population**. The result is the national average water footprint in **m³ per person in one year (m³/person/year).** The worldwide **average is about 1240 m³/cap/yr.** The majority is used by **food and other agricultural products (86%).** The calculations of national net virtual water balances **(virtual water imported – virtual water exported)** showed that **developed countries generally have a more stable virtual water balance** than the **developing countries**. Countries that are **relatively close to each** other in terms of geography and development level can have a rather **different virtual water balance**. Germany, the Netherlands and the UK are net importers whereas France is a net exporter. USA and Canada are net exporter whereas Mexico is a net importer.





[Hoekstra & Chapagain, 2008]

2- Egyptian National Water, Food, and Virtual Water Trade Modeling

I- Food Production and Trade in Egypt

Wheat, maize, and rice are the primary food crops in Egypt. The per capita supplies of wheat, maize, and rice in Egypt have **increased substantially since the 1960s**, even though the population has grown from **about 30 million to 100 million**. Those increases have been made possible by improvements in agricultural technology, policy reforms that have encouraged farmers to enhance productivity, and increasing imports of wheat and maize. **Imports** of food and fodder crops, and the **virtual water** contained in those crops, have contributed to Egypt's ability to maintain **food security**.

However, Egyptian farmers also **produce large amounts of water-intensive and low-valued crops for both domestic production and export**. Hence, virtual water is imported and exported from Egypt through its involvement in international trade. **Domestic production of wheat and maize** has been **increasing** somewhat sharply since the middle 1980s (Wichelns 2001) (Figure a, b).

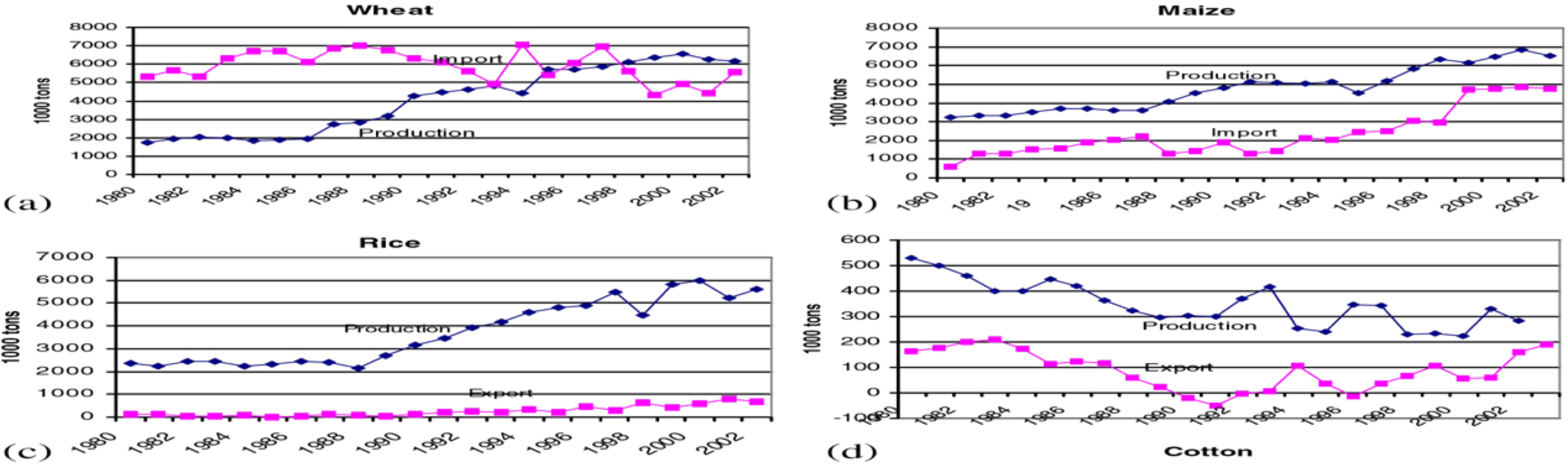
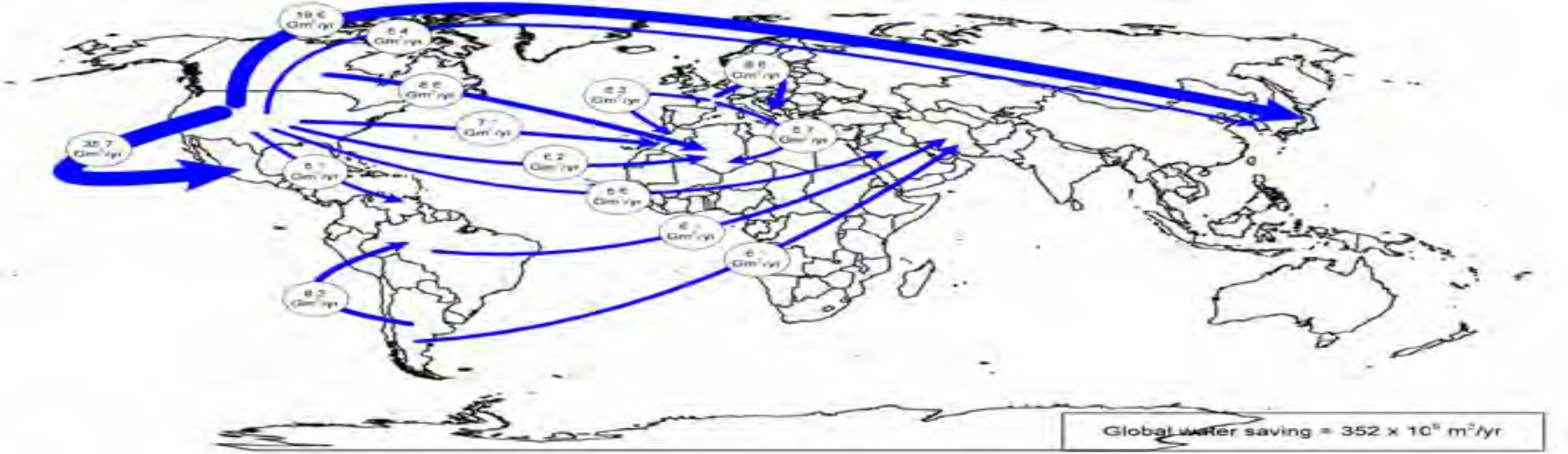


Figure. Production, import and export of: wheat (**a**), maize (**b**), rice (**c**) and cotton (**d**) (El-Sadek, A., 2010).

Virtual Water Trade in Egypt as a Policy Option

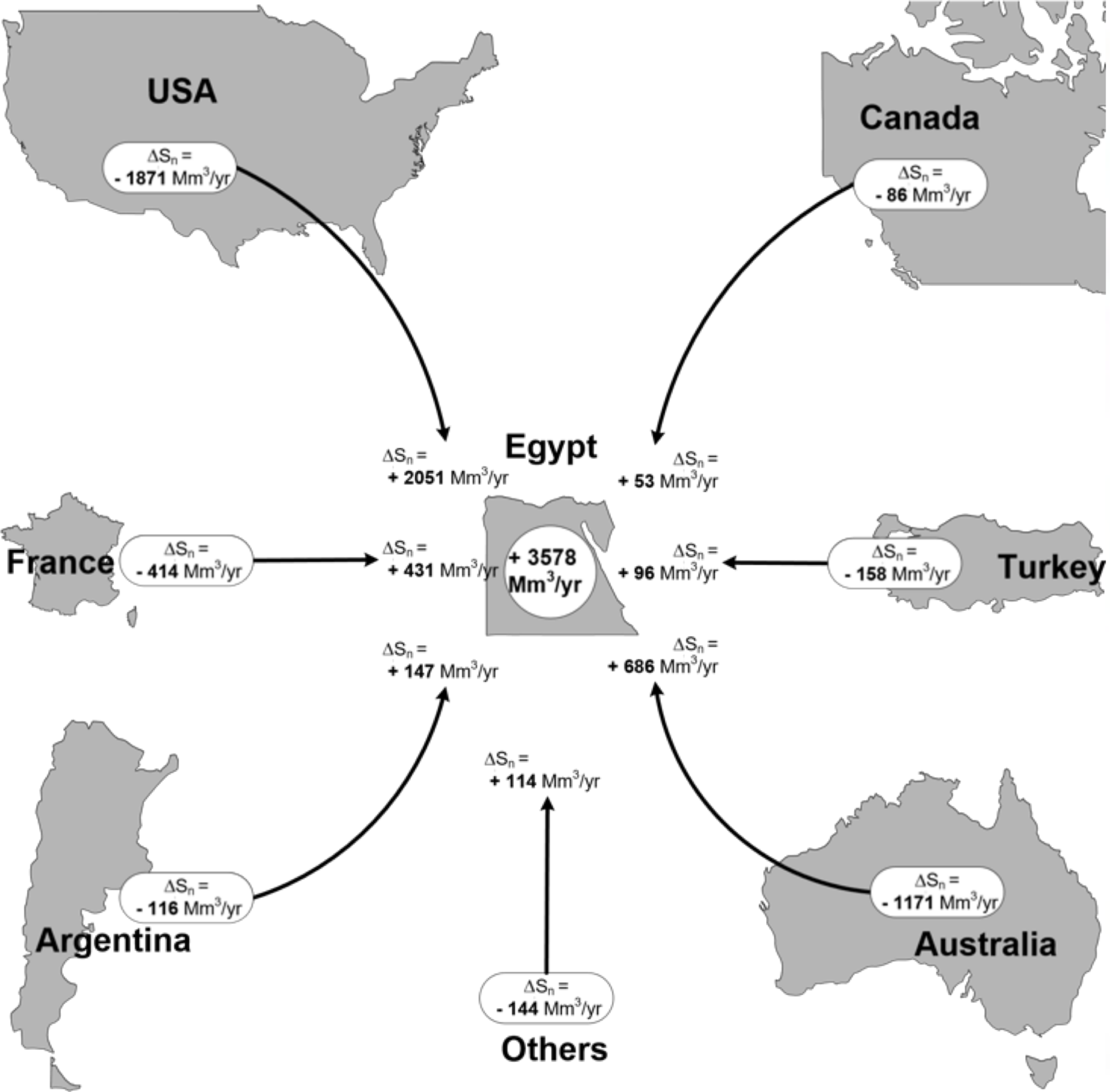
In 2010, the **cereal baseline <u>demand</u> is 29.982 × 10^6** tons with increase of **20.69% to 2007** situation where this baseline demand will be **33.887 × 10^6 tons** with increase of **36.41% in 2017.** Faced with this situation, a critical question that the country has **to face is how to <u>safeguard its long term food security</u>** with the **limited water resources**. The main concern, here, is to **apply the concept of virtual water, as a strategy**, in a way that **meets its interest and needs**, having in mind the main objectives of the National Water Resources Plan until 2017.

Countries with net **export**	Virtual water flows (Gm³/yr)			Countries with net **import**	Virtual water flows (Gm³/yr)		
	Export	Import	Net export		Import	Export	Net import
Australia	73	9	64	Japan	98	7	92
Canada	95	35	60	Italy	89	38	51
USA	229	176	53	United Kingdom	64	18	47
Argentina	51	6	45	Germany	106	70	35
Brazil	68	23	45	South Korea	39	7	32
Ivory Coast	35	2	33	Mexico	50	21	29
Thailand	43	15	28	Hong Kong	28	1	27
India	43	17	25	Iran	19	5	15
Ghana	20	2	18	Spain	45	31	14
Ukraine	21	4	17	Saudi Arabia	14	1	13

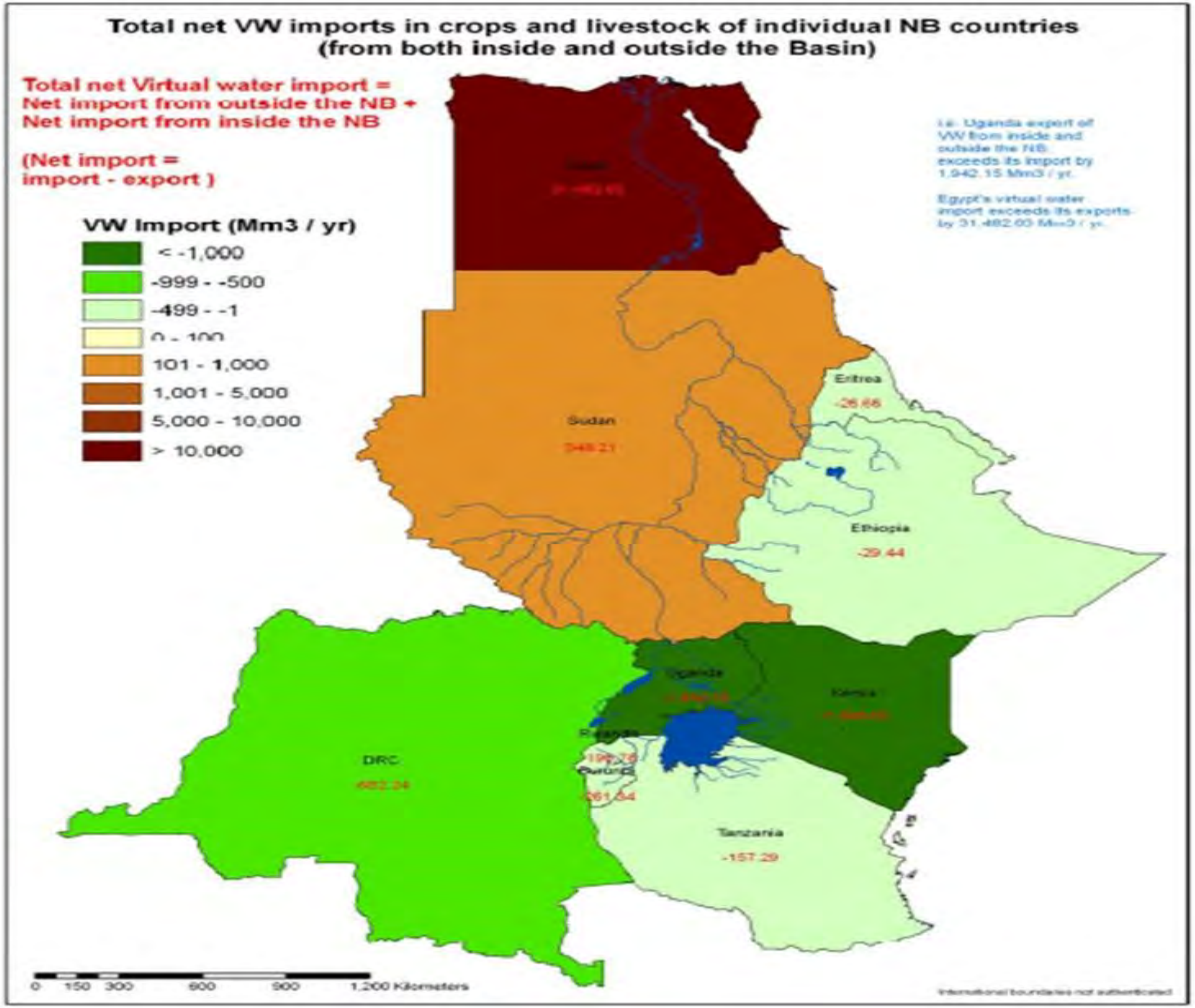


Global water savings (>5.0 Gm³/yr) associated with international trade of agricultural products.

Figure : Virtual water balance per country and direction of gross virtual water flows related to trade in agricultural and industrial products over the period 1996–2005.


USA
ΔS_n = - 1871 Mm^3/yr
Canada
ΔS_n = - 86 Mm^3/yr
Egypt
ΔS_n = + 2051 Mm^3/yr
ΔS_n = + 53 Mm^3/yr
France
ΔS_n = - 414 Mm^3/yr
ΔS_n = + 431 Mm^3/yr
+ 3578 Mm^3/yr
ΔS_n = + 96 Mm^3/yr
ΔS_n = - 158 Mm^3/yr
Turkey
ΔS_n = + 147 Mm^3/yr
ΔS_n = + 686 Mm^3/yr
ΔS_n = + 114 Mm^3/yr
ΔS_n = - 116 Mm^3/yr
Argentina
ΔS_n = - 1171 Mm^3/yr
Australia
ΔS_n = - 144 Mm^3/yr
Others


Egypt: virtual water imports in crops from other NB countries (1998-2004)
VW imports (Mm^3/ yr)
< 10
10 - 50
50 - 75
75 - 100
100 - 150
150 - 200
> 200
Blue water
Green water
Egypt
Sudan
Ethiopea
Uganda
Kenya
Tanzanya
DRC



Average annual total virtual water crop and livestock trade between Nile Basin states and the rest of the world, 1998-2004 (mm3/y).

Zeitoun et al. make the following observations about trade flows and water dependence:

The Nile Basin may be **divided into net importers and net exporters** .The figure shows that the **Southern Nile states as well as Ethiopia and Eritrea actually export more virtual water in crops and livestock than they import**. **Egypt and Sudan, by contrast, are net importers**. Virtual water imports from outside the basin appear to be of a great and growing significance to the lower Nile Riparians – Egypt and Sudan.

II - The National Water, Food, and Trade (NWFT) Modeling

The National Water, Food, and Trade (NWFT) modeling framework, consists of two parallel-running components The first component, **The national water-food (NWF)** model was built using the system dynamics approach (Ford, 1999).The NWF model runs with an annual time step and comprises three interlinked modules: ***(I) crop and animal production*, *(II) food consumption*, *and (III) water resources system.***

The second component, the **global virtual water trade** (**VWT**) model, characterizes the annual virtual water trade between **Egypt** and the **rest of the world**, which is here grouped into **nine regions**. The two models are not coupled, but rather running in parallel for the purpose of identifying discrepancies or issues at the global scale that might be worth attention from policy makers at the national scale

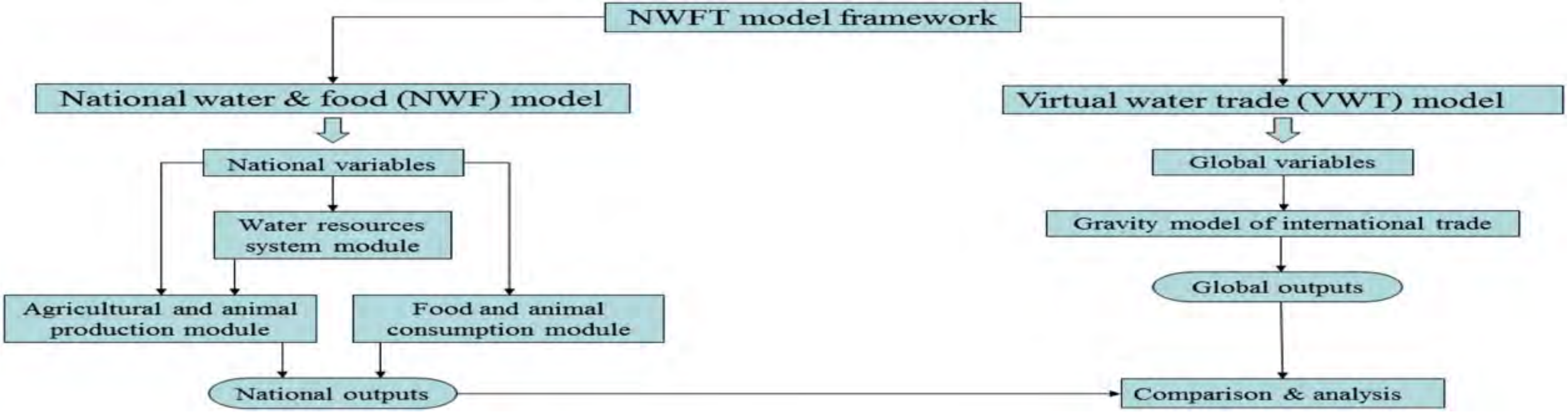


Figure Simplified schematic diagram of the NWFT modeling framework (A. Abdelkader, et al., 2018).

A- The National Water-Food (NWF) Component

The national water-food (NWF) model was built using the system dynamics approach (Ford, 1999), which uses stocks, flows, interactions and feedback loops to represent system elements and their relations. The NWF model runs with an annual time step and comprises three interlinked modules: ***(I) crop and animal production, (II) food consumption, and (III) water resources system.***

1- Crop and animal production module

For a total of **78 crops** (72 food crops, 3 non-food crops, and 3 fodder crops), harvested areas (ha) and yields (tonne/ha) were obtained per year for the period 1**986–2013** from (FAO 2017b). Egypt's **annual production** (tonne/y) per crop was calculated.

Production of animal products was calculated with a similar approach used for crop production. **Animal feed** is the major component that contributes to the total water footprint of animal production. **In Egypt, the major feed crop is berseem** (Egyptian clover), followed by concentrate feeds that are mainly composed of grains. In addition, animals and animal products require **drinking and service water** (m^3/ head), which was obtained for Egypt from (Chapagain and Hoekstra 2003). The production of food crops and animal products were added to get **national food production** (tonne/y).

2. Food consumption module

The food crops and animal **products** considered in the consumption module of the NWF model are **81 items.** This is more than those in the production module **because of imported food products**, which are consumed but not produced in Egypt. The consumed food mix (**kg/y/capita**) in Egypt was obtained from the food balance sheets by (FAO 2017b). The national food consumption (kg/y) for each food item is calculated .

Green and blue water footprints (**m^3/tonne**) of crops and animal products consumed and produced in Egypt were obtained from (Mekonnen and Hoekstra 2011, 2012), and then used to calculate the **water footprints of production and consumption** (**m^3/y**). **Surplus** or **deficit** were **calculated** and assumed to be equivalent to Egypt's exports and imports, respectively.

The **exports and imports** were calculated in terms of product trade (tonne/y) and virtual water trade (m^3/y). The modules of **production and consumption** were configured based on **Egypt's food balance sheet provided** by (FAO 2017b) over the historical record (**1986–2013**), and no calibration parameters were needed.

3. Egypt's water resources system module

The water resources system module is a national-scale water accounting and allocation model. The **annual municipal water** use was calculated based on the **population and the municipal water use rate** (**m^3/y/capita**). The irrigation system efficiency is known to range from **44%–66%** (IWMI, 2013), with improvement over time due to the improvement in irrigation methods and technologies.

National scenarios

Egypt's Ministry of Water Resources and Irrigation (MWRI, 2010) developed three future scenarios, **Critical, Balanced, and Optimistic**, regarding water resources supply and demand in Egypt till **2050**. The scenarios consider various water and socioeconomic combinations in their formulation. Variables considered are:

(1) Possible increase in Nile water inflow from projects of water saving in upstream countries,

(2) Different levels of internal water resources development of shallow and deep groundwater, reuse of drainage water, desalination, rainfall harvesting, and evaporation losses from the surface irrigation system,

(3) Socioeconomic variables, such as population and industrial growth, and

(4) Policy variables, such as agricultural land expansion and municipal water use reduction.

Reference scenario ***was added, which represents business as usual, with no significant changes relative to the past trends.***

	Reference[a]	Critical	Balanced	Optimistic	Uncertainty range
Annual population growth rate	2%	2%	1.8%	1.65%	±10%
Food consumption pattern	Unchanged	Unchanged	Increase in veg. & fruits (20%) and meat (26%), decrease in cereals (4%)	Increase in veg. & fruits (20%) and decrease in cereals (2.6%)	Unchanged
Increase in available water resources over the period 2013–2050 (10^9 m^3/y)[a]	+2.42 Nile flow + 0	+6.82 Nile flow + 0	+8.82 Nile flow + 2	+13.82 Nile flow + 4	±5%
	Shallow GW + 1.9	Shallow GW + 1.9	Shallow GW + 1.1	Shallow GW + 1.1	±10%
	Deep GW + 0	Deep GW + 1.63	Deep GW + 1.63	Deep GW + 1.63	±20%
	Reuse +0	Reuse +2	Reuse −2.3	Reuse +4.8	±20%
	Desalination + 0	Desalination + 0.77	Desalination + 1.27	Desalination + 1.77	±50%
	Rain harvesting + 0.02	Rain harvesting + 0.02	Rain harvesting + 0.02	Rain harvesting + 0.02	±30%
	Evaporation + 0.5	Evaporation + 0.5	Evaporation + 0.5	Evaporation + 0.5	±20%
Municipal water demand (m^3/y/capita)[a]	From 114 in 2013 to 79 by 2050	From 114 in 2013 to 79 by 2050	From 114 in 2013 to 82 by 2050	From 114 in 2013 to 82 by 2050	0% to −50% (114 to 57)
Annual growth in industrial water use (%)	0%	0.65%	1%	1.35%	±50%
Agriculture water consumption (m^3/Feddan)	4700 (unchanged)	From 4700 to 4500	From 4700 to 4400	From 4700 to 4300	±5%
Irrigation efficiency	63% (unchanged)	From 63% to 65%	From 63% to 70%	From 63% to 75%	±10%
Agriculture expansion (million Feddan)	No increase	Increase to 10	Increase to 10.8	Increase to 11.8	±20% for the target
Land productivity (tonne/Feddan)	Unchanged	Unchanged	Unchanged	Unchanged	±20%

National water-food (NWF) model results

NWF model simulates Egypt's **food production and consumption and its food and water gaps** for the baseline period **1986–2013** and the future up to **2050**. In all scenarios, the **increase of food production is projected to be slower than that of the baseline period** due to the limitation of fresh water availability (Figure).Under all scenarios, Egypt's food and water gaps are projected to widen with rates higher than those of the baseline period. This **occurs because the negative effect of the low rate of production and high population** growth rate.

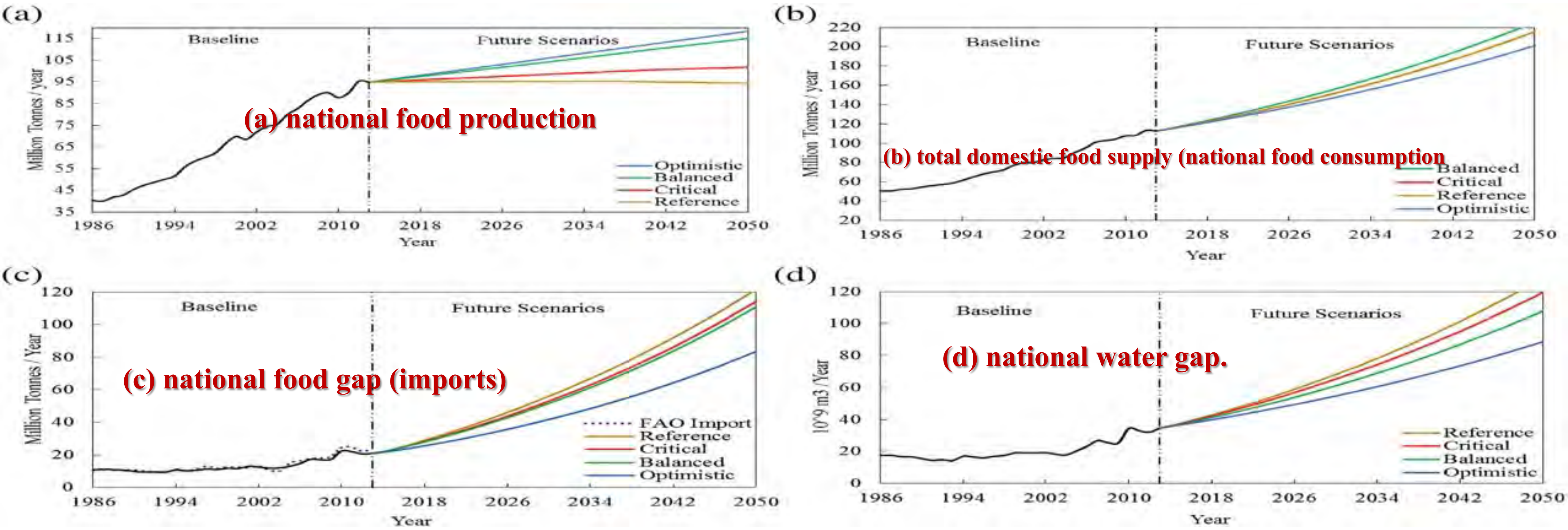


Figure Egypt's baseline and projected (a) national food production, (b) total domestic food supply (national food consumption), (c) national food gap (imports), and (d) national water gap (A. Abdelkader, et al., 2018).

As noted earlier, and shown in Figure , **population growth has a dramatic effect on Egypt's food and water gaps**. The **15 million tonne reduction in the food gap in 2050** can be achieved by lowering the population growth rate **from 2.0% to 1.79%.** Figure shows the extreme case **of lowering Egypt's annual population growth** to **the current level of some European nations (0.5%)**, and its huge impact on the national food gap. This is a strong indication **that investment in educational, health, and awareness programs** for lowering the population growth rate can be a major part of the solution of Egypt's severe water problems.

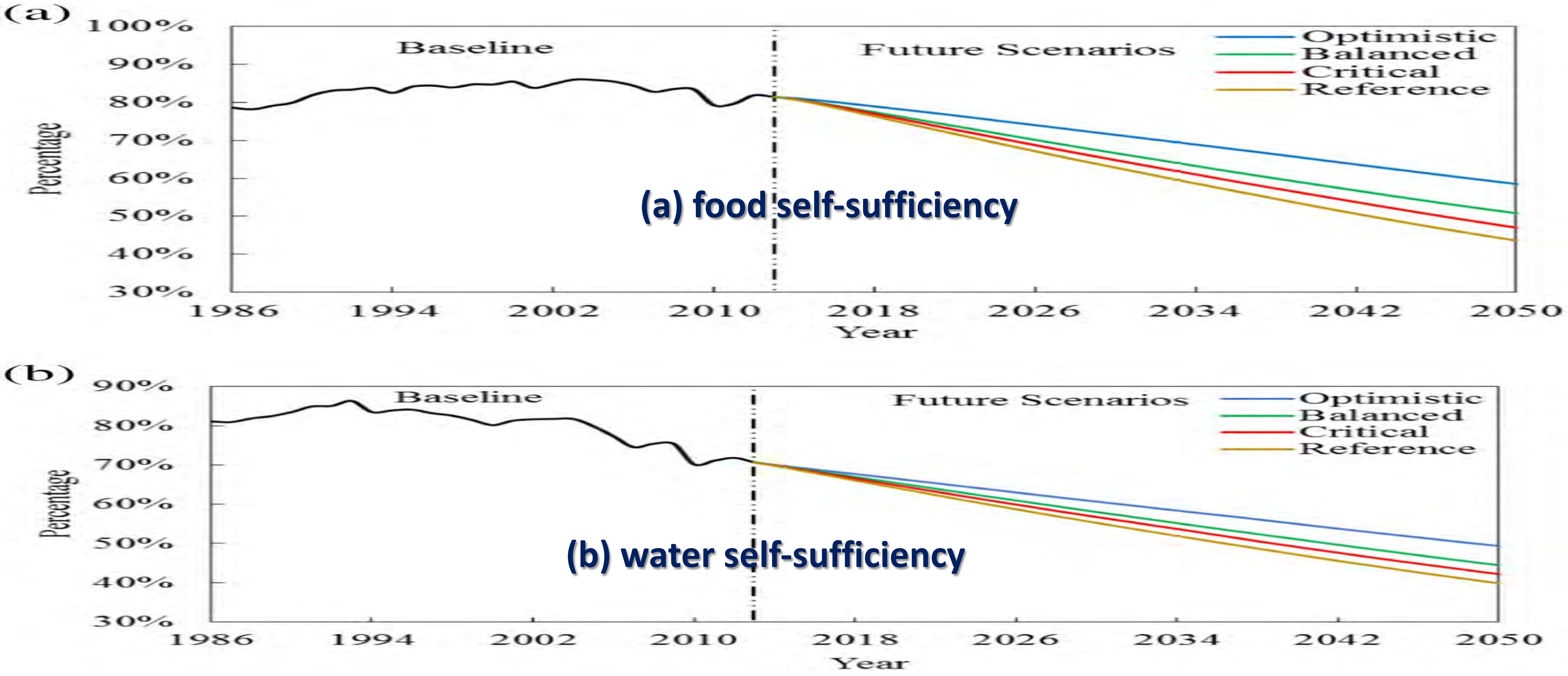


Figure Egypt's **(a)** food self-sufficiency, and **(b)** water self-sufficiency (A. Abdelkader, et al., 2018).

B- Virtual Water & Trade (VWT) model

The main purpose of this model is to characterize the **virtual water trade into and out of Egypt**. Therefore, there is less emphasis on individual countries, and thus, countries were integrated into **nine regions** to make the model and its links smaller and more parsimonious. The country under consideration, **Egypt** in this study, is kept as **an individual**. The nine regions are: Africa (**AF**), Middle East and North Africa (**ME**), East Asia and Pacific (**EA**), South Asia (**SA**), Central Asia (**CA**), Europe (**EU**), North America (**NA**), Latin America and Caribbean (**LA**), and Oceania and New Zealand (**OC**).

The data between **1986 and 2011** were used for the VWT model because it is the time frame within which all data were available. **Population and agricultural production and consumption-related** data are available publicly through the (FAO 2017b). The **blue and green water footprint** of each product (**m^3/tonne**) was obtained from (Mekonnen and Hoekstra 2011) and multiplied by the production quantity (tonne) to calculate the water footprint of each product (m^3). The water footprint of all food produced and consumed were summed up, then divided by the population to calculate **WF_P and WF_C**, respectively. The GDP data were obtained from the (UN 2017). The VWT model was developed and evaluated based on **the baseline period (1986–2011**), then it was used to project the future **VWT up to 2050** using the **future socioeconomic shared pathways (SSPs).**

Global scenarios / Shared Socioeconomic Pathways (SSPs)

The climate change research community **developed five scenarios** of global societal development, **called the shared socioeconomic pathways (SSPs)** (O'Neill et al., 2017). These SSPs consider changes in **demographics, economy and lifestyle, policies, technology, natural resources, and human development for distinguishing the five scenarios**.

IIASA (2016) provides **the population, gross domestic product and urbanization data of all SSPs for all countries for the period of 2000–2100**. **Data on population (P) and gross domestic product (GDP) were extracted for all countries up to year 2050 and processed to match the ten world regions distinguished in this study**.

The **future values of water footprint of agricultural production (WF_P)** are unknown for each region. These values depend on many factors that **vary by region**, like the **water resources availability, the agriculture policy and management decisions, and the degree of development and technology.** So, an ideal way to estimate WF_P is to **develop a model like NWF for every country in the world and simulate the future values based on assumptions for the controlling factors** T**wo different experiments were adopted**.

Experiment I, data on **WF_P per region** (expressed in m^3/y/capita) at the **end of the baseline period (2011) were assumed to remain constant up to the year 2050**. This implies that **each region** attempts to **keep the food production per capita at the level of 2011**, assuming that the water footprint of production in **every region keeps pace with regional population growth**.

Experiment II, even **if resources availability is not a problem for some regions** ,**other factors like water quality and socioeconomic factors** might make them fail to maintain 2011 levels of per capita food production. Hence, **some other regions would increase their per capita food production over 2011 levels to trade more food**. In this **experiment the per capita WF_p is assumed to be varying, for some regions it will increase while decrease for others.** The **annual WF_P series up to 2050** were generated **for all SSPs in the ten regions**. **Finally,** the **VWT model was used to generate the virtual water (food) imports of Egypt till year 2050 under the five SSPs**.

Virtual Water & Trade (VWT) model results

The VWT model was fed with the IIASA's SSPs to project Egypt's imports till 2050. **In experiment I**, when the WF_P (m^3/capita) was kept constant in the future in all regions, Egypt's virtual water import **increased from 76 up to 135 × 10^9 m^3/y by 2050**, with an **average value of 103× 10^9 m^3/y** (Figure a). This constant future value of WF_P implies a significant increase in Egypt's production over the years to match the pace of population growth, and thus, imports can be kept to the lowest possible level. However, **this future scenario may not be realistic** as the **VWT model generated unrealistically high or low waste and stock variations to keep the global food balance between exporting and importing regions**. **In experiment II**, the generated WF_P values (m^3/capita) **increased** in certain regions (e.g. Eastern Europe and North America) and **decreased** in others (e.g. **Middle East and South Asia**) in the future, and we find this to be **more realistic due to advancement in technology and the differences in population growth rates among the world's regions**. The new projections of Egypt's imports are shown in Fig. b. The imports range from **127 to 232 × 10^9 m3/y by 2050** with an average value of **195 × 10^9m3/y** in 2050.We also find the projections to be reasonable as the lowest imports projections of Egypt, in other words **exports to Egypt from the other nine regions**, happen in **SSP3 and SSP4**, characterized by global fragmentation and inequality **where policies are oriented towards security, including barriers to trade** . On the other hand, **the highest imports** are found for **SSP5**, the **conventional development scenario** .Egypt's **virtual water imports** are projected to **increase from all regions**.

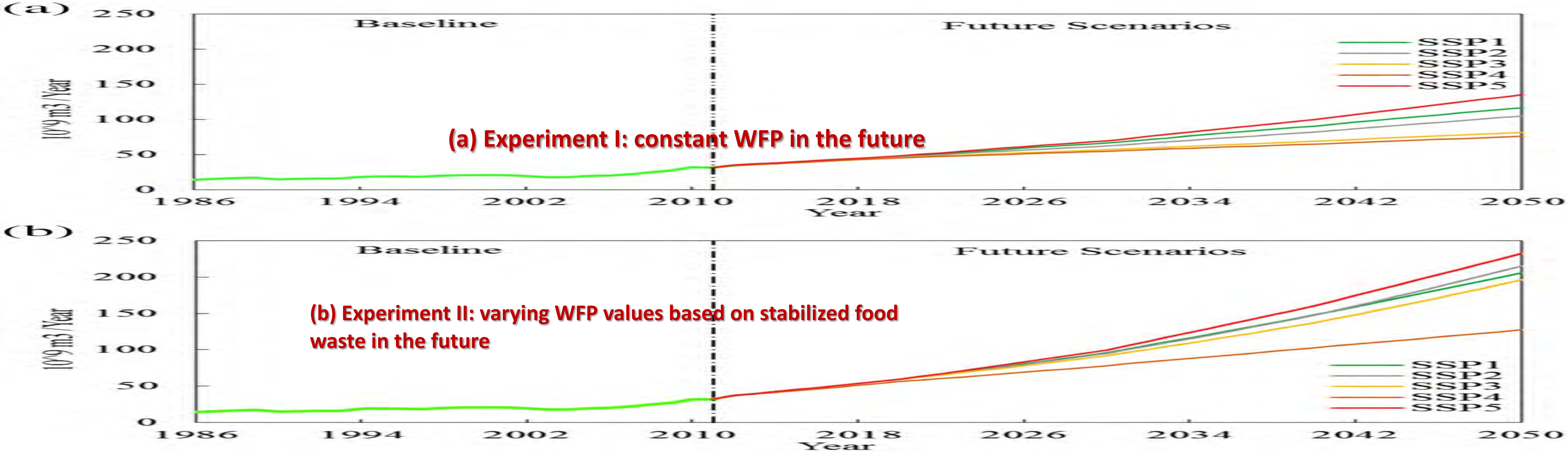


Figure . The baseline and projected future **virtual water imports of Egypt** under the five SSPs, **(a) Experiment I**: constant WF_P in the future and **(b) Experiment II**: varying WF_P values based on stabilized food waste in the future

The general pattern and trend of Egypt's food imports projected by both the global and national models in the NWFT modeling framework (Fig. 11). However, taking into consideration an average value of the five SSPs, the VWT model estimates Egypt's food import in year 2050 to be **150 million tonne, which is 39% higher** than the average estimate resulting from the **national model** (averaging the four national scenarios). **SSP4** provides a **close estimate to the national model**, with an estimated **food import in 2050 that is 8% lower than the average of the national scenarios**. In Egypt, it is useful and important to ensure that the **national 2050 strategy** and its associated future scenarios can be made **possible from a global perspective**, which can be assessed using the **VWT model** to a reasonable level. **If Experiment I (Fig. 11a) provides the realistic global picture**, it means that Egypt projected future food needs are far beyond what is anticipated based on the global food availability and trade network. In this case, it is an alarming situation that requires introducing **serious policy instruments** that can **change Egypt's food gap**.

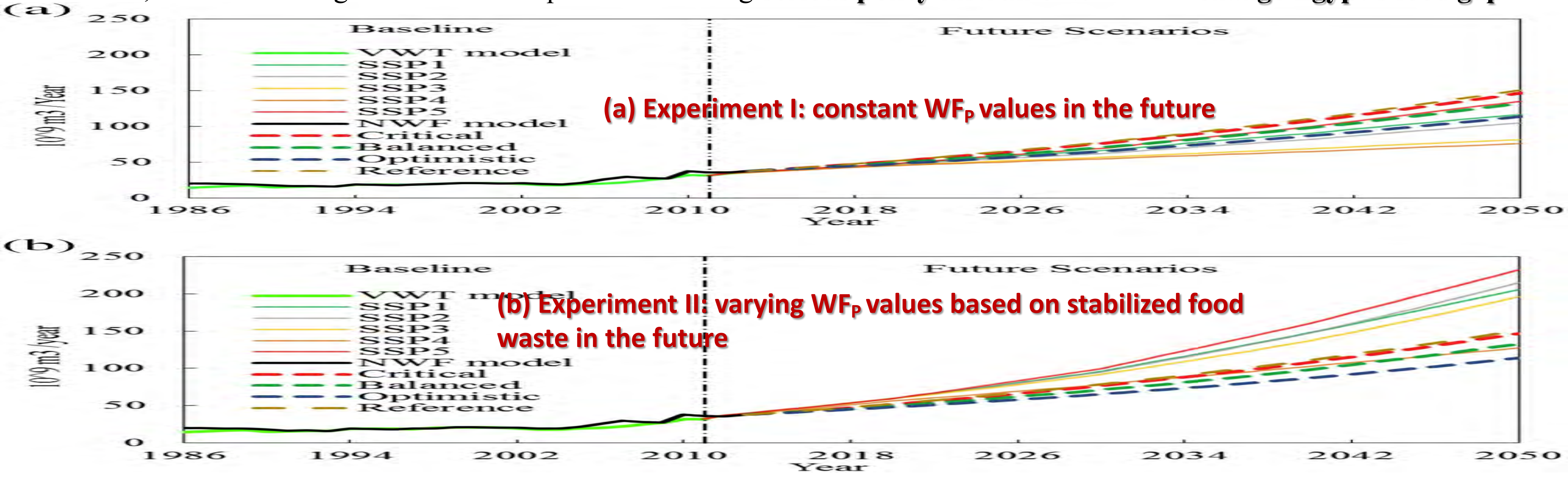


Figure. Virtual water (food) imports of Egypt over the baseline period and the projected future under various national and global scenarios, (a) Experiment I: constant WF_P values in the future and (b) Experiment II: varying WF_P values based on stabilized food waste in the future (A. Abdelkader, et al., 2018).

3- Conclusions

- A set of future scenarios of Egypt's water and socioeconomic conditions up to the year 2050 were evaluated using the national water-food (NWF) model, and they all revealed that **Egypt is facing the challenge of widening food and water gaps**. However, there are scenarios that were assessed to be more **optimistic** than others, and those ones require **investments to develop some internal water resources through desalination, the use of fossil groundwater, improving irrigation and municipal water efficiency , and lowering the population growth rate**. The sensitivity analysis revealed that the exceptionally **high population growth rate** in Egypt plays a critical role in pushing the national **water and food gaps to alarming levels**.

- **The NWFT modeling f**ramework can be easily adapted to other countries and also to expand the **nexus to other sectors, such as energy** This allows more integrated planning, development, policy-making, monitoring and evaluation of the nexus sectors. The same approach could be used to develop **national sustainability strategies** for multiple sectors.

- In Egypt, the water **shortage experience** is not related only to **increasing demand**, but rather also to **poor infrastructure and management practices**. The water sector in Egypt is facing many challenges including water scarcity and deterioration of water quality due to population increase and lack of financial resources.

- Agriculture in Egypt suffers from **low productivity**, **old technological**, **low incomes for farmers**, **low exporting vision**. Policy making should invest in **agricultural education and technology** (which in turn would increase productivity), and in turn influence the **agriculture water productivity** that influence **economic development** in the country.

- It is a strong indication **that investment in educational, health, and awareness programs** for lowering the **population growth rate** can be a major part of the solution of Egypt's severe water problems , also this is not enough alone but also awareness towards : (**Dietary energy** consumed (consume **fruits and vegetable** instead of **meat and wheat** , decrease the food waste is important for developed countries like Egypt .

4- Recommendations

- The NWFT modeling framework presented in this study has a few limitations that are worth further **improvements** in future studies. **First,** the NWF model can benefit from more including **more socioeconomic factors**, like for instance **food prices**. Explicit accounting of the **food prices, which might affect the national consumption** both in pattern and **quantity**, can affect the, **country's imports**. **Second,** the NWF model of Egypt's water-food nexus can be extended to include **energy**. Currently, because of the limited contribution of hydropower and the small amounts of cooling water for thermal power, relative to other water uses, and the **negligible use of Egyptian crops in bioenergy**, **the energy role in the nexus is limited**. Nonetheless, there is a considerable **input** of energy in water and food supply, mainly due to the use of **fertilizers and machinery** in agriculture and **pumping systems** in irrigation and water extraction. Also, an increase in desalination can enhance the need to include energy.

- It is recommend to take the **virtual water** as a major tool in **Egyptian national strategic plan 2050** also apply NWT framework with parallel to NWF and take into account the **energy , crop cost , benefit cost ratio , and food waste** scenarios

- There is some **agricultural water footprint and little to no industrial water footprint** in the **Egypt** it is recommended to Increase the **industrial component used in virtual water** to increase the water income as Egypt consume more than **86% of fresh water resources in agriculture** while **average water productivity from agriculture equal 3 USD** for cubic meter while it is 22 USD/m^3 in Algeria , 84 USD/m^3 in Bahrain , 37 USD/m^3 in Kuwait , and 137 USD/m^3 in Israel ..

- W**aste per capita** was studied and it is concluded that it will **increased 3 times in 2050** while water foot print decreases. It is recommended to study the capital waste and different Dietary Diets in **Egyptian strategic plan 2050** and to develop waste management technology ,**recycle techniques , and Biogas technology.**

- The **virtual water trade within the Nile Basin** is dominated by tea and coffee trade. Yet trade between the Nile Basin states is **small by comparison** to fresh water imports from **outside the Basin**. **Intra-basin virtual** water crop trade is about **2.3% of virtual water** imported by all states. Virtual water imported by the Basin states from other Basin states in the form of **livestock is about 1.1% of the amount imported** from the rest of the world. It is highly recommend to **increase the trade between** the basin countries **especially Egypt as the biggest importer** in the Nile Basin . Egypt should invest in the Nile Basin country specially in agriculture this investment would, in turn, lead to higher **agricultural outputs and decreasing water food gab.**


THANK YOU