National Technical University of Athens

Stress-weighted water footprint assessment of agricultural policies in a water scarce

Maria P. Papadopoulou, Z. Kalampaliki & V.K. Tsoukala

Naxos Island, June 2018

WATER Scarcity: A crucial problem that needs management

Water is one of the most important natural resources that affect humans' life both in terms of survival, but also as far as their development.

➡ Agriculture
➡ Industry
➡ Energy production
➡ Domestic use

<u>Current Situation</u>

- Climate change
- Overpopulation
- Modern lifestyle

\+ Overexploitation of water resources = Intense water scarcity phenomenon

⬇

Need for optimal water management

↙ Water Footprint

↘ Life Cycle Analysis

WATER FOOTPRINT CONCEPT

Water Footprint Concept

- Alternative indicator for freshwater consumption.
- Calculated for countries, particular geographical areas, consumers, products.
- Expressed in units of water per units of product or time.
- Calculation Methodologies according to **WF Network** (Hoekstra & Chapagain, 2008) and ***Equivalent*** **WF** (Ridoutt & Pfister, 2010).

Water footprint Network approach

Blue → fresh surface water or groundwater

Green → volume of rainwater

Grey → volume of freshwater that is required to assimilate the load of pollutants

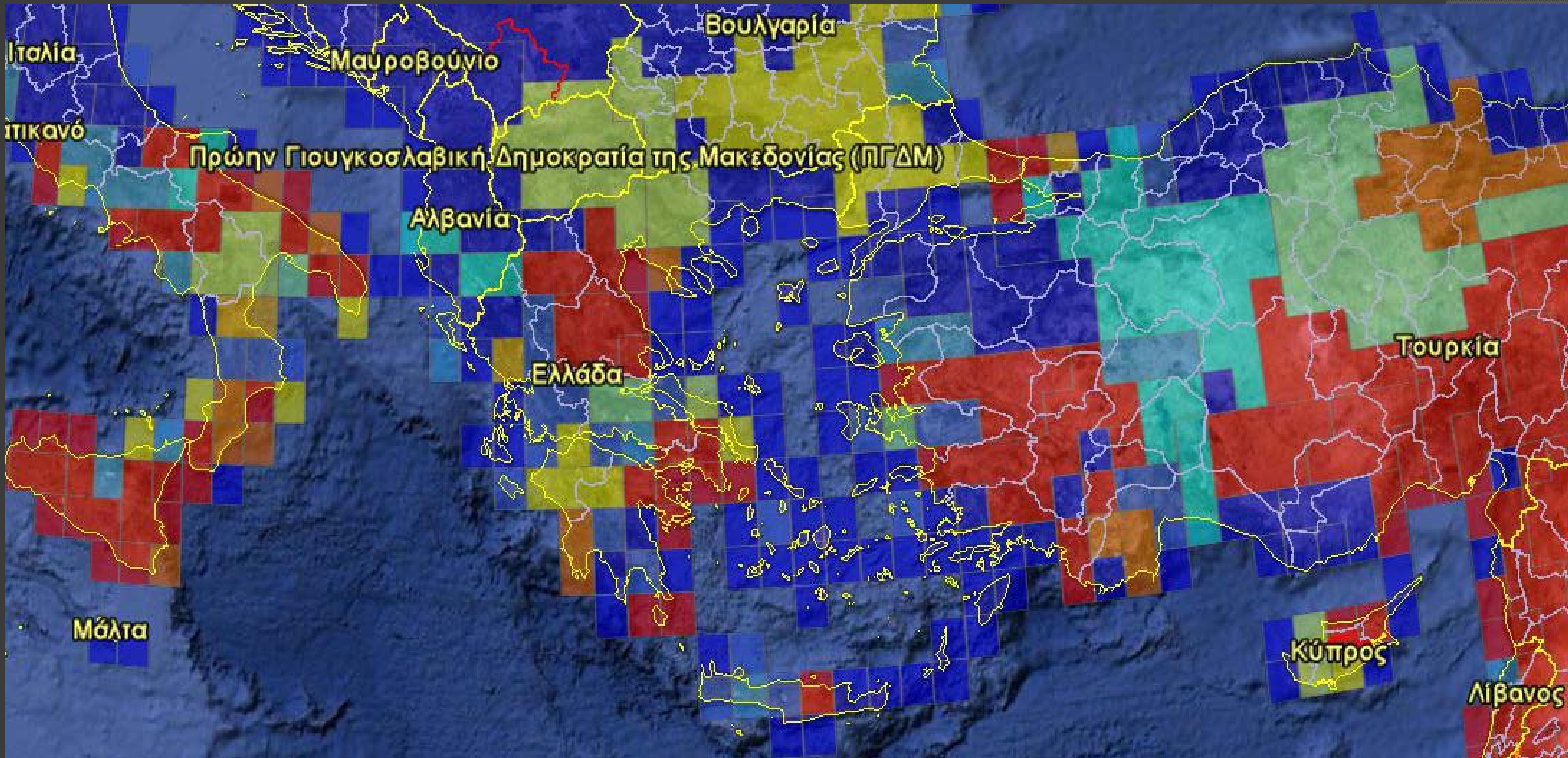
$$WF = WF_{green} + WF_{blue} + WF_{grey}$$

Stress-weighted WF (WFeqH2O) approach

- WF of a crop is estimated as the sum of: a) the blue water consumption, b) the grey water requirements and c) the impact of land use on blue water resources.
- WF can be calculated for a full product life cycle, from primary production to the use phase of a product, including intermediate stages like ingredient processing and product packaging.
- In order to account for different forms of consumption and local water scarcity, a water stress characterization factor, the Water Stress Index (WSI) a river basin-specific water scarcity indicator is used that combines: a) *the total available water resources*, b) *the total water use* and c) *the environmental water requirements (EWR)*

**According to Ridoutt & Pfister approach green WF does not contribute to environmental flows until it reaches the ground and becomes blue*

WSI Factor



Ιταλία
Βουλγαρία
Μαυροβούνιο
ατικανό
Πρώην Γιουγκοσλαβική Δημοκρατία της Μακεδονίας (ΠΓΔΜ)
Αλβανία
Ελλάδα
Τουρκία
Μάλτα
Κύπρος
Λίβανος

WFeqH2O Estimation

Step 1: The volumetric impact (V.I.) on blue water resources is calculated as the sum of blue water consumption, grey water requirement and impact of land use (L.U.) on blue water resources.

$$V.I. = WF_{blue} + WF_{grey} + L.U.$$

Step 2: For every river basin, V.I. is multiplied by the local water stress characterization factor (WSI) in order to calculate a stress-weighted water footprint (WFs-w):

$$WF_{S-W} = V.I. \times WSI$$

Step 3: The equivalent water footprint (WFeqH2O) is calculated by dividing the stress-weighted WFS-W by the average national WSI of the country.

$$WF_{eqH2O} = \frac{WF_{S-W}}{WSI_{nat}}$$

The WSI calculation follows an extremely complex procedure requiring systematic data collection. For the purposes of this analysis, WSI values were obtained on watershed level based on WSI global map (Pfister et al., 2009).

Equivalent water footprint is considered important because it describes the volume of direct water use which has an equivalent potential to contribute to water scarcity (Ridoutt and Poulton, 2010).

Area of Interest: Messara Valley

- Messara Plain (Municipalities of Tympaki and Mires) falling in the water district GR 13.
- Due to the intense land cultivation and groundwater overexploitation, the area faces serious challenges in order to meet its irrigation needs.
- Groundwater level has considerably declined causing serious water quantity and quality issues that are more severe towards the end of the irrigation season.
- 92% of the farmland is occupied by crops and pastures.
- The soil infiltration is estimated to be moderate to moderately slow and the available humidity high to moderate

- 13 different crops are cultivated such as olive groves, vegetables (e.g. tomatoes, potatoes), citrus fruits and grapes in open (87.6%) and covered (12.4%) cultivation systems.
- In the current crop scheme, the cultivation of several species (e.g. tomatoes) takes place under irrigation conditions in open and covered systems (81.5%) while 18.5% of the total area covering olive groves, grapes, wheat, barley and hay meadow crops are rainfed.
- The main crop in the region is olive groves (~48%).

Crop type	Current Scheme				Proposed Scheme			
	Open Systems		Covered Systems		Open Systems		Covered Systems	
	Area (acres)	% Total Area	Area (acres)	%Total Area	Area (acres)	%Total Area	Area (acres)	% Total Area
Wheat (rain.)	1000	3.76						
Barley (rain.)	1000	3.76						
Hay meadow (rain.)	1500	5.64						
Olives (rain.)	500	1.88						
Olives (irrig.)	12000	45.15			15000	56.43		
Grapes (rain.)	300	1.13						
Grapes (irrig)	800	3.01						
Legumes (irrig.)	120	0.45						
Medic (irrig.)	130	0.49						
Melons (irrig.)	750	2.82	750	2.82	1330	4.98	1320.5	4.98
Potatoes (irrig.)	1400	5.27						
Vegetables (irrig.)	750	2.82	750	2.82	1560	5.85	1550.5	5.85
Tomatoes (irrig.)	1800	6.77	1800	6.77	2060	7.73	2050.5	7.73
Citrus (irrig.)	950	3.57						
Fruits (irrig.)	280	1.05			171	6.43		

The irrigation system in the area is mainly supplied by groundwater pumping wells so actions related to upgrade the existing irrigation systems, and to modify and reform crop schemes are seriously discussed in authority level.

According to the finally adopted regional plan, in the proposed agricultural scheme the increasing irrigation water demand of the region is planned to be covered in three phases including:

a) construction of a water dam,

b) improvement of the irrigation system and

c) reduction of cultivated crops from 13 to 5

The **main goals** are to achieve:

a) an increase of farmers' agricultural income by producing of an appropriate quantity and quality products which will become available in the Greek and international markets and

b) a better management of the area's available freshwater resources.

Results Analysis

- In the present analysis, a reliable evaluation between agricultural schemes of WF based on stress-weighted water footprint approach (WF_{eqH2O}) that focuses mainly on water scarcity.
- The proposed agricultural scheme for Messara Plain that suggests re-constructuring of the crops from 13 to 5.
- Based on Pfister et al. (2009) classification of WSI, four scenarios considering the three diverse WSI values (0.1437, 0.9984, 0.0243) in the region and the mean WSI value of them (0.477) in order to obtain a representative estimation of the agricultural WF for Messara Plain are developed.

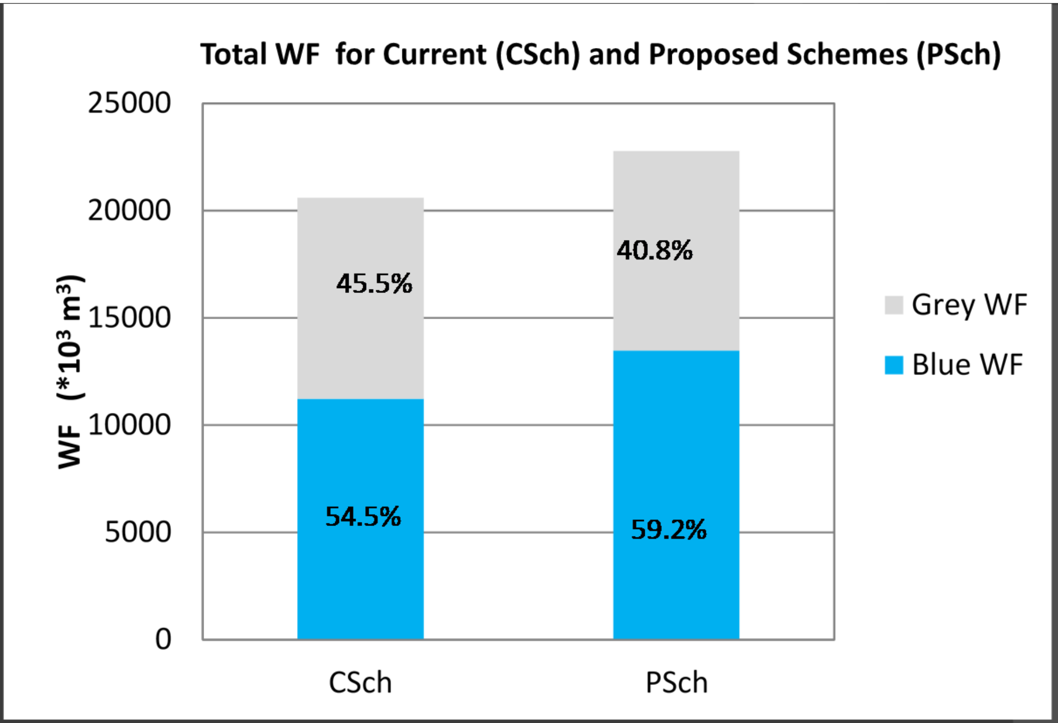
WF_{eqH2O} (m^3)	Current Scheme (CSch)	Proposed Scheme (PSch)	Change
Open systems	1332085	1389718	4.3%
Covered systems	236559	345209	45.9%
TOTAL	**1568644**	**1734927**	**10.6%**

For covered systems, the green WF component is zero whereas the grey WF component is lower in the proposed agricultural scheme than the current one.

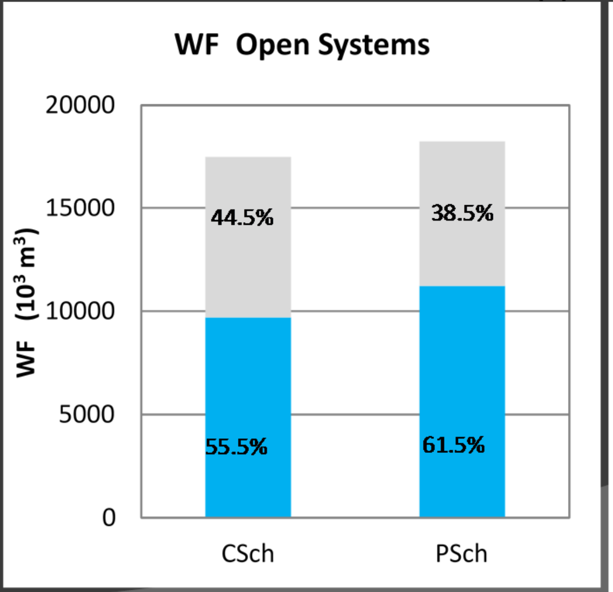
- Reliable results regarding crop restructuring could only be drawn by examining each crop separately due to major impact of crop yield in WF (m^3/tn) calculation.

- In this analysis a land use impact factor equal to zero. However, the inclusion of this factor in the WF estimation is important since the effects that land uses may have in water balance of the region should be considered

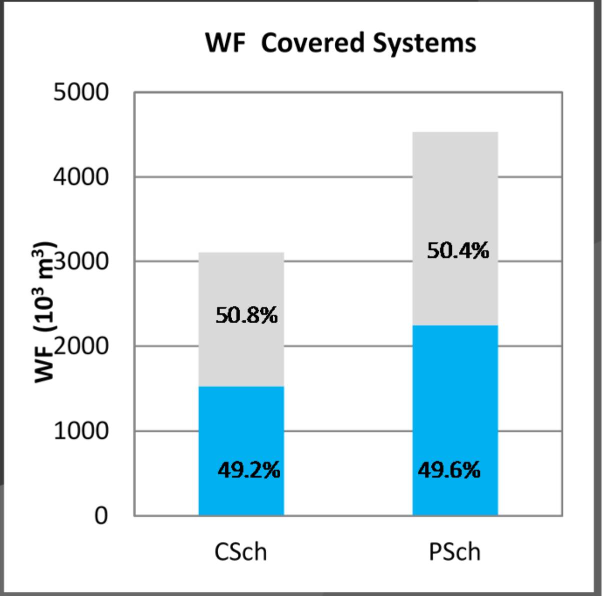
10,6% more water volume is needed to meet the needs of the proposed agricultural scheme than the current one



(a) Total WF



(b) Open Systems



(c) Covered Systems

Lessons Learnt

- Important decisions could be taken to ensure agricultural production mainly related to the implementation of modern irrigation infrastructure as well as on crops' restructuring and shifting agricultural production to less water-intensive crop types with significantly better agricultural yields

- In this paper, the possibility of using water footprint as a reliable indicator to assess different policies related to rural development.

- In the proposed agricultural scheme besides *the restructuring of agricultural crops from 13 to 5*, *the construction and operation of new irrigation infrastructure works* to obtain a better water resources management should be adopted.

- The assessment was based only on water requirements and effects to the agricultural production (crop yield) and not in the economical sustainability (cost and profit) of the proposed agricultural policies

- In order to propose a new agricultural scheme that will involve mainly crop restructuring, <u>a critical design parameter is the crop yield</u> that is directly correlated to agricultural water footprint.

- <u>The significant increase that is obtained in the crop yield of irrigated cropland that actually pays back the additional blue WF that is consumed.</u>

- Decisions related to irrigation infrastructure (associated with blue WF component) and protection of the environment (associated with grey WF component) could be only obtained based on the individual values of respectively blue and grey WF components and not the total water footprint.