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FOOD SAFETY AND WATER ALLOWANCE COEFFICIENT

FOGARASSY, Csaba*

NEUBAUER, Éva**

BÖRÖCZ BAKOSNÉ, Mária***

ZSARNÓCZAI, J. Sándor***

NAGY, László****

Abstract. *After global food price crisis in 2008, urgent importance of adequate safety nets, social programmes and needs of improvement of productivity and increase resilience are turned out. Most important indicators of the crisis were man-made; global water dilemma is appeared. Some of its main drivers are decreasing water supply rate per capita and the phenomenon of 'economic water scarcity'. Sustainable way out could be 'intensified hydro-solidarity, international legislation and its effective usage'. Practical solution can be the usage of water footprint estimation in decision making, since it is a measurement of expropriation of fresh water by humanity. It shows the absolute water need of producing a product or service along the whole supply chain. By this water need and responsibility of actors can be stated. Thinking forward, Water Allowance Coefficient could be a tool for decision makers to optimise water productivity. As a result of the primer estimations regional Water Allowance Coefficient values and regional and national freshwater values have been calculated. Average value of water used for agricultural production on a hectare is 1450 USD in Hungary. Rainwater has the highest value from it, 680 USD. The aggregated value in Hungary is over 7.765 billion USD.*

Key words: *water safety, water footprint, global water saving, water crisis, increase water productivity*

*Associate professor and head of Analysis and Research Centre of Climate Change Economics, Szent István University, Hungary.

**PhD-student at Analysis and Research Centre of Climate Change Economics, Szent István University, Hungary.

***Faculty of Economics and Social Sciences, Institute of Regional Economics and Rural Development Climate Change Economics Research Centre, Szent István University, Hungary.

****Faculty of Agricultural and Environmental Sciences, Institute of Crop Production, Szent István University, Hungary.

1. INTRODUCTION

The global food price crisis, followed by global financial crisis and economic recession, increased the number of starvation and undernourished people in the period 2007 and 2009. Estimations show, the number of undernourished people decreased in 2010, when food prices were reduced from the top and global economic conditions were improved. But level of undernourishment still stood high and still a top agenda at international political levels due to its connection to world economy and world agriculture. Experiences of shocks of this food price and financial crisis highly keep vulnerability of food safety in our mind. It is also showed how fast can uncertainty of food safety degenerate and overcome on different segments and occurrences. This emphasized the crucial and urgent importance of adequate safety nets, social programmes for support food security, improvement of productivity and increasing resilience against shocks of developing countries.

There is a wide range demand on increasing agricultural investments for environmentally sustainable productivity growth and production expansion, meanwhile agricultural contribution is enhanced to increase economy and decrease poverty. Significance of global food security and efforts on starvation-reduction is given, there is a need to identify governmental tasks in case of facing price volatility of global agricultural markets and avoid non-productive, beggar-thy-neighbour policy responses. "Necessary steps would include improved regulation of markets, greater market transparency, improved and timely statistics on food commodity markets, establishment of an appropriate level of emergency stocks and provision of adequate and appropriate safety nets. The recent food and financial crises, the uncoordinated policy responses, and continuing fears over global food market turmoil have underscored the urgent need for action by the international community" (FAO, 2011).

These problems must be solved not only by politicians, but by the support of scientists, researchers, governments, NGOs, consumers and all the elements of the economy, so by the cooperation the direct and indirect users of limited water resources. We assume that water footprint estimations are able to serve decision makers considering water allocation, use and consumption or reallocation, reuse and recycle. Will be water footprint one of the helpful tools?

3. MATERIALS AND METHODS

3.1. Global food price crisis and water dilemma – background analysis

The most important indicators of worldwide food crisis and their conjunctions, which became independent, are now identified. The only environmental effect can be mentioned here is extreme weather which caused decrease of crop export in many countries. This generated crop commodity absence in world market which finally led to food prices broke loose which later was increased by the need of accumulation savings. Besides, there were more anthropogenic elements added to this global historical crisis. Agricultural and trade policy of countries with specific weight and "*trade blocks*" like USA or EU acting at global food market played key role of which parts were, for example subsidized export, artificial low prices, or bad Common Agricultural Policy.

Increased global demand; according to increasing population due to change of social structure of certain countries like China. Because of urbanisation, people buy food in supermarkets, they are cut from agriculture, and demand for animal products is increasing with increasing life style which boosts prices of crop products (fodders). High level of climate risk and relative slow returns brought decreasing agricultural investments; states reduced their play in supporting commodities for world market and in the field of research. Besides, production of bio fuels instead of food commodity also well known phenomenon. Background of this is increasing prices of fossil energy sources, which drove world market demand hard to a cheaper alternative, like in connection of growing maize or colza which kept prices high. The unfavourable economic circumstance of significant weakness of US dollar was also added to the situation because this was many countries and businesses reserve currency. In addition, leaving the property market, USA speculative capital found his place on futures market of agricultural commodities (Burley - Bebb, 2010). This means that capital which flowed into this market had not supported production because trading and production were detached and what is more, it diverted resources in the middle of densification of liquidity problems. In addition to the factors above, modern colonisation must also be mentioned. Certain political administrations and private investors are buying or leasing land from other countries for producing food crops or bio fuel. According to this action they produce for their home land or other export with displacing locals. Supporting food sovereignty of countries and their internal market, creating sustainable and effective agriculture, building clear food trade system, making food reserves and supporting of growing landrace and popular cultures on local lands could be the suggested solution (Sarbu, 2011).

Global food safety, in addition to price volatility and the above ones, is also threatened by global water dilemma. According to Somlyody (2011) water is a global phenomenon considering to social and economic aspect, a unique resource which is not replaceable at many places of life. We can agree in worse case, renewable, available, and usable water resource is equal, in optimal case it should be greater than needs. One of the main drivers of water problems is decreasing water supply rate per capita. If values are approaching, presumably mainly because of increasing population, two main strategies may used (in case for example of China) stating that "*nutrition security is based on water security".* First is to enhance self-preservation for the increasing needs of nutrition, with enhancing own production, which finally causes enhanced increasing food price. Second is to build modern interregional and international relationships and choose import if it is possible. Impacts of these will appear also at the export area as growing water withdrawal.

Water supply is determined by geographical differentiation or volatility of weather by climate change, while needs are based on human activities like used agricultural and irrigation methods, customs, urbanisation and overgrowth of megacities, or wealth and culture of middle class. Conflicts arising from these can be feed by virtual-water trade which can lead to a unified regulator factor in product pricing.

Sustainable way out is "*intensified hydro-solidarity, international legislation and its effective usage*". Our water dilemmas are join forces of natural, economic and social sciences, are handled at both horizontal (agricultural, industrial or household level) and vertical way (micro, macro and global stage), not exclusively as hydro-engineering problem. Keys are recycling and closing circulations, which require also optimal infrastructure and political back ground. Lines of solution can be read out from both cases, which can be realised across institutional systems. So, it seems from scientific literature, that "*institutional pollution*" is key factor (Somlyody, 2008).

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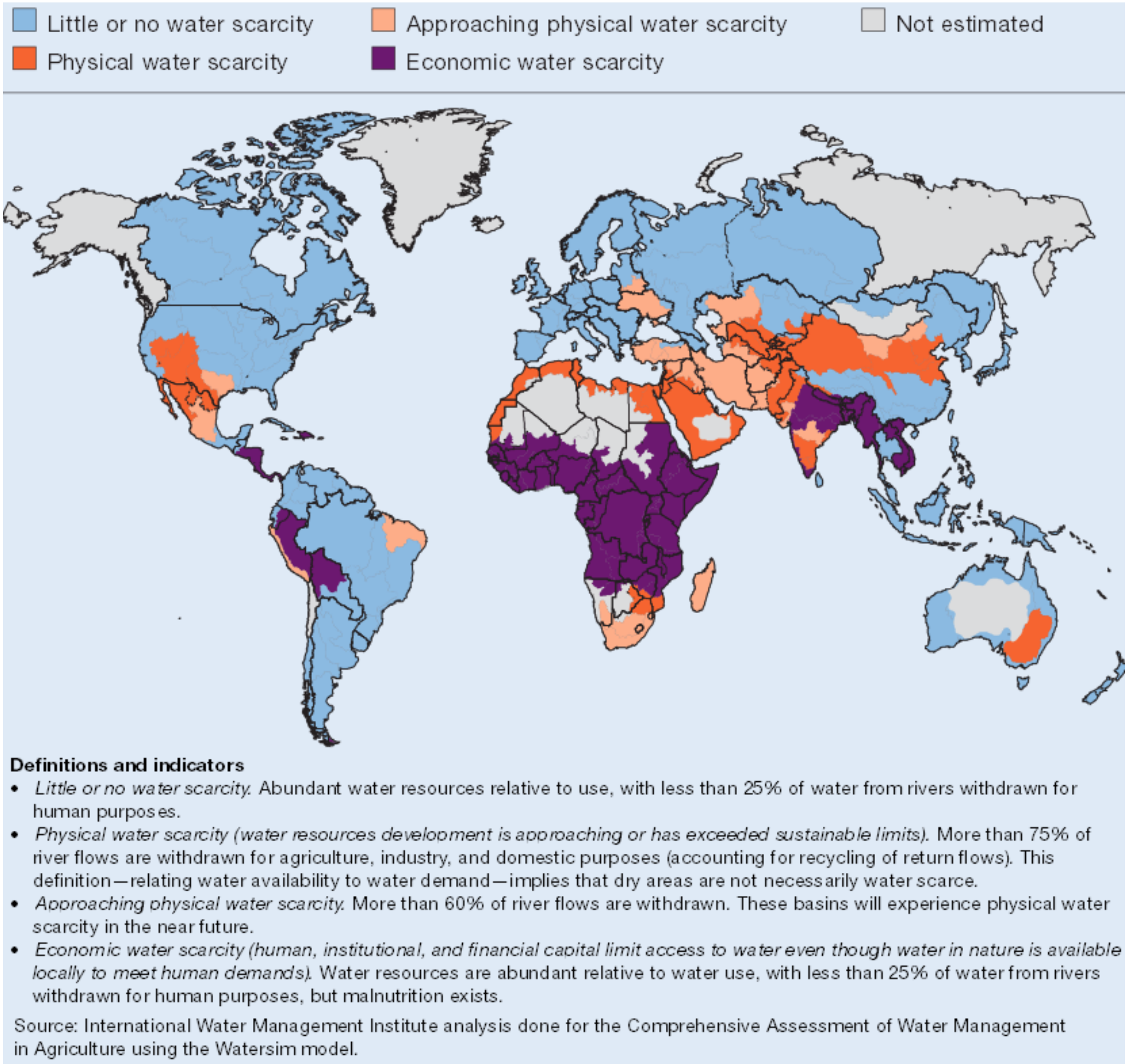
Figure 1.: *Areas of physical and economic water scarcity*



Source: IWMI, 2007/b, p. 63.

"*Institutional pollution*" is may confirmed by IWMI report. According to this, lack of water investments or human capacity for satisfying water demand causes economic water scarcity. Most of these cases, water scarcity is based on institutional operation – how do they favour a group over another and how don't listen to voices of women and disadvantaged groups. "Symptoms of economic water scarcity include inadequate infrastructure development, so that people have trouble getting enough water fluctuations, including floods and long- and short-term drought; and inequitable distribution of water even though infrastructure exists. Much of Sub-Saharan Africa experiences economic water scarcity, and there are many pockets across the globe where water resources are inequitably distributed (Figure 1.). Further water development could ease problems of poverty and inequality." (IWMI, 2007/a)

Economic water scarcity appears where lack of man-made institutional and financial sources restricts water availability, although there is enough resource in nature for local needs (IAASTD, 2009)

3.2. Water footprint

Water footprint is measurement of expropriation of fresh water by humanity. It has three contents. Blue water footprint refers to use of surface and ground water. Green water footprint refers to use of rain water, which is important especially at crop production. Grey water footprint refers to fresh water pollution what is diluted water need of water pollution determined by water quality standards (Mekonnen–Hoekstra, 2011). Water footprint is multi-sectoral, multi-dimensional water usage estimation. It shows the absolute water need of producing a product or service along the whole life cycle. An instantaneous estimation which considers water use and pollution of all elements of the supply chain. With this method, water need of actors can be stated, and also the weight of their water usage responsibility (Fogarassy–Neubauer, 2011). Water footprint is a geographically expressed index, which can show not only the quantity of water usage and pollution but its location also (Mekonnen–Hoekstra, 2011).

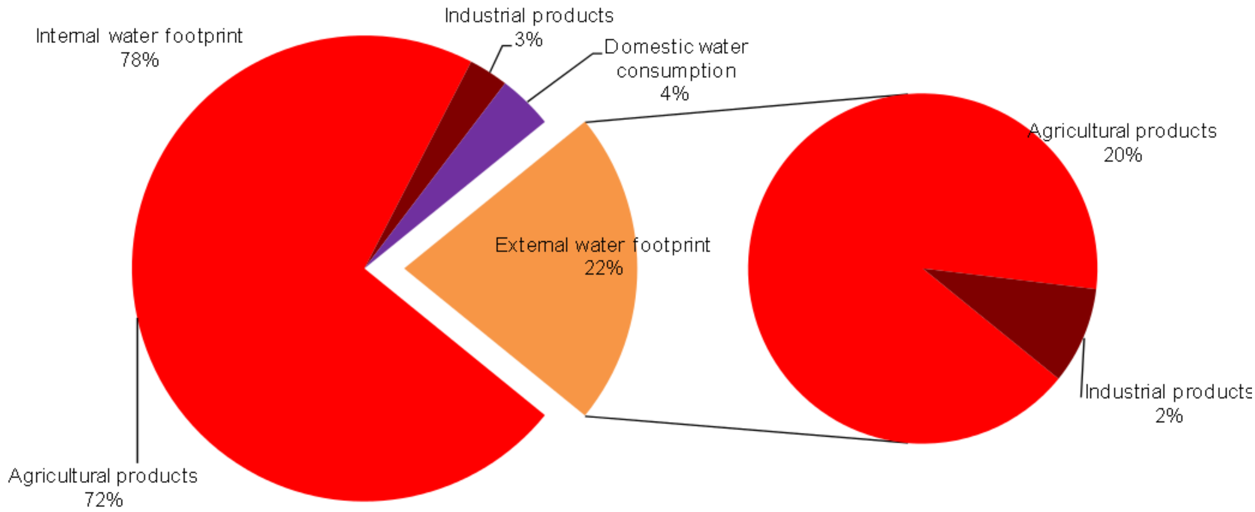
"Freshwater scarcity is a growing concern, placing considerable importance on the accuracy of indicators used to characterize and map water scarcity worldwide. We improve upon past efforts by using estimates of blue water footprints (consumptive use of ground- and surface water flows) rather than water withdrawals, accounting for the flows needed to sustain critical ecological functions and by considering monthly rather than annual values. We analyzed 405 river basins for the period 1996–2005. In 201 basins with 2.67 billion inhabitants there was severe water scarcity during at least one month of the year. The ecological and economic consequences of increasing degrees of water scarcity – as evidenced by the Rio Grande (Rio Bravo), Indus, and Murray-Darling River Basins – can include complete desiccation during dry seasons, decimation of aquatic biodiversity, and substantial economic disruption" (Hoekstra et al., 2012. p. 1.). Concern of water footprint of humanity is key question, water resources of the world are limited, thus it is important to measure how eligible can available water quantities be for producing certain products for certain people. Because water intensive goods are allowed to trade internationally, wise distribution of fresh water for alternative proposals is global question. Reducing aggregate water footprint of environmentally emphasized catchments deserves priority, but competition for fresh water of the world by increasing water productivity may serve the proposal at non-emphasized catchments. “Priorities to reduce water footprints of specific products, water footprints of nations as a whole, or water footprints within specific catchments need to be formulated in the context of a variety of considerations, including local environmental impact, global sustainability, equity, and economic efficiency. In addition, decisions on water footprint reduction need to be embedded in policy that considers the use and allocation of other finite resources as well” (Hoekstra–Mekonnen, 2012).

3.3. Water savings

Internal water footprint of a nation expresses water use from national resources which are used for producing products and services for consumption of inhabitants. External water footprint shows water quantity of products and services which are produced in different countries, but consumed by the inhabitants of the scanned country (Chapagain–Hoekstra, 2004). This is well shown at *Figure 2.*

Total water footprint of total origin of products times weighted distribution of incoming products from given country gains the amount of estimated average water footprint of a product of a certain country. For example tomato consumed by a German consumer: German tomato production was 47 000 ton/year with the average total water footprint of 36 $m^3/t/y$ over the period 1996-2005. At the same period, Germany imported 667 000 ton/year from which 252 000 ton/year arrived from the Netherlands with water footprint of 10 m^3/t, 244 000 ton/year arrived from Spain with water footprint of 83 m^3/t and 72 000 ton/year arrived from Italy with water footprint of 109 m^3/t. After weighting these different tomatoes, it turned out that at German markets water footprint of tomato is 57 m^3/t as an average (Mekonnen–Hoekstra, 2011). Step-by-step methods for different water footprint calculations can be found, for example, in Hoekstra et al. (2011) or at www.waterfootprint.org.

Figure 2.: *Distribution of global internal and external water footprint in connection to different consumption categories, 1996–2005.*



Source: Mekonnen–Hoekstra, 2011, p. 32.

As a result, international trading generates water savings for certain countries. Saving has physical, not economic meaning at this context. Besides, water saving does not mean that saved water is separated to other charitable purposes. At water-scarce countries this kind of water saving may cause positive environmental, social and economic effects. Many countries reduce usage of their national water resources by importing agricultural products. Japan saves 134 Gm^3/yr (80% green, 9% blue, 11% grey) from her domestic water resources. Mexico saves 83 Gm^3/yr (69% green, 26% blue, 5% grey), Italy saves 54 Gm^3/yr (83% green, 10% blue, 7% grey), the UK saves 53 Gm^3/yr (75% green, 15% blue, 10% grey) and Germany saves 50 Gm^3/yr (83% green, 14% blue, 3% grey). From the view of blue water saving, many countries are standing on the top of the list, like Mexico, Spain, Japan, the UK and countries from the Middle East. It turned out, that only below a certain water availability level can be defined a significant connection between water availability per capita of a country and her cereal import. Virtual-water import can be found at most cases of national water savings of countries like in North Africa, Middle East, South Europe and Mexico. But national water savings at North European countries can not be interpreted from the point of view of water-scarce. More than one fourth (27%) of global water savings are in connection to agricultural trade is blue water, which shows that virtual-water importer countries have generally higher dependency on blue water in their crop production than virtual-water exporter countries. Agricultural export products from the USA to Mexico and Japan (mainly maize and soybean products) contain the highest global water savings contributing with more than 11% to the total global water saving.

Cereal crops trade gain the highest water saving (196 Gm^3/yr) which is followed by oil crops (82 Gm^3/yr, mainly soybean) and animal products (56 Gm^3/yr). The highest water saving is due to maize trade from cereal crops trade (71 Gm^3/yr) which is followed by wheat (67 Gm^3/yr), rice (27 Gm^3/yr), barley (21 Gm^3/yr) and other cereals (10 Gm^3/yr). There is global water saving in relation of international trade of rice in connection to green, blue, and grey amounts, but in case of only the blue component there is global blue-water loss. From animal products, trade of poultry products (25 Gm^3/yr), milk products (16 Gm^3/yr), bovine products (16 Gm^3/yr) and swine products (2 Gm^3/yr) result significant global water saving, while trade of horse, sheep, and goat product cause 3 Gm^3/yr global water losses. Calculations of trade-related water savings are based on crop yield and linked water footprint values which exist at exporter and importer countries. Thus, one suggested being careful when water savings are extrapolated when trade flows are increasing. Scarce of water is going to stimulate countries to improve their water productivity especially at countries with low yield. Trade of water intensive products is going to be reduced from countries with high water productivity to ones with low (this causes present water savings) as soon as countries with low water productivity increase their productivity, efficiency.

Global water saving in connection to presented international trade seems significant: "the global water footprint of agricultural and industrial production would be 4% higher if countries would produce all commodities within their own territory based on existing domestic productivities instead of partially import them from other countries." Possibility of optimising international trade for more water savings is may slight once importers with low water productivity increase efficiency, productivity. Global water footprint can be significantly reduced globe wide by reaching high water productivity instead of optimising trade from areas with high productivity to low ones. This may result higher global water saving than the present one achieved by trade. That is why first step for water scarced countries would be to increase their water productivity as high as possible, thus they could solve their water problems with virtual-water import (Mekonnen–Hoekstra, 2011, p. 25.).

3.4. Water Allowance Coefficient

Thinking water footprint method forward, the methodology of Water Allowance Coefficient is worked out, which can be understood as the availability potential of freshwater resource. First estimations of water footprint based Water Allowance Coefficient is based on existing Hungarian wheat water footprint calculations of Neubauer (2010). According to these calculations green, blue and grey water footprint of Hungarian wheat has been calculated not only at national but also at regional level with the available national data of 2009 and with the help of free software of FAO, CropWat 8.0. With the help of CropWat almost all basic green and blue water footprint calculations were made considering the main equations of water footprint method (*Eq. 1–4.*). Results are shown in *Table 1.*

Table 1. Water footprint of wheat and its changes by regions and Hungary, 2009

Region	Water footprint (WF) (m^3/ton)				Water footprint changes (%)			
	WF*green*	WF*blue*	WF*grey*	WF	WF*green*	WF*blue*	WF*grey*	WF
Southern Great Plain	589	535	270	1 394	99	131	101	110
Northern Great Plain	675	432	309	1 417	114	106	116	112
Southern Transdanubia	569	329	216	1 114	96	81	81	88
Western Transdanubia	526	293	240	1 059	89	72	90	84
Central Transdanubia	527	422	257	1 206	89	104	96	95
Northern Hungary	574	279	290	1 143	97	69	108	90
Central Hungary	777	505	330	1 612	131	124	123	127
Hungary average	**593**	**407**	**268**	**1 268**	**100**	**100**	**100**	**100**

Source: Neubauer (2010)

$$WF_{wheat,green} = \frac{CWU_{green}}{Y} \quad \text{and} \quad WF_{wheat,blue} = \frac{CWU_{blue}}{Y}$$

(Eq. 1. and 2.)

where:

$WF_{wheat,green}/WF_{wheat,blue}$ = Green or blue water footprint of wheat (m^3/ton or l/kg).

CWU_{green}/CWU_{blue} = Green or blue water usage of wheat (m^3 or l).

Y = Yield (ton or kg).

It follows that:

$$CWU_{wheat,green} = CWR_{green} \times 10 \quad \text{and} \quad CWU_{wheat,blue} = CWR_{blue} \times 10$$

(Eq. 3. and 4.)

where:

CWU_{green}/CWU_{blue} = Green or blue water usage of wheat (m^3 or l).

CWR_{green}/CWR_{blue} = Green or blue water requirement of wheat (m^3 or l).

(Hoekstra et al., 2011)

In the case of grey water footprint estimation another method must be used. In agriculture environmental effects of nutrients, pesticides and herbicides, except fertilization, are little or not at all studied factors. Therefore, certain environmental standards should be applied. This, in the basic research, was the norm set by the U.S. EPA (United States Environmental Protection Agency). According to its assumption the amount of nitrogen flowing back into the water body is 10% of the applied fertilizer extent. Data, for calculation grey water footprint in connection with wheat production, were available from databases of national Central Statistical Office and FAO. According to the following equation and from Water Allowance Coefficient values the above results are at *Table 2*.

$$WAC_i = \frac{100}{WF_{wheat,i}\,\%}$$

(Eq. 5.)

where:

WAC_i = Water Allowance Coefficient, based on wheat water footprint changes at region *i*.

$WF_{wheat,i}$ = Changes of wheat water footprint at region *i*, %.

Table 2. Water Allowance Coefficient, based on water footprint change of wheat, by type and region, Hungary = 1.

Region	Water footprint change based Water Allowance Coefficient (WAC)			
	WAC*green*	**WAC*blue***	**WAC*grey***	**WAC*total***
	$\frac{100}{WF_{green}\%}$	$\frac{100}{WF_{blue}\%}$	$\frac{100}{WF_{grey}\%}$	$\frac{100}{WF_{total}\%}$
Southern Great Plain	1,01	0,76	0,99	0,91
Northern Great Plain	0,88	0,94	0,86	0,89
Southern Transdanubia	1,04	1,23	1,23	1,14
Western Transdanubia	1,12	1,39	1,11	1,19
Central Transdanubia	1,12	0,96	1,04	1,05
Northern Hungary	1,03	1,45	0,93	1,11
Central Hungary	0,76	0,81	0,81	0,79
Hungary average	**1,00**	**1,00**	**1,00**	**1,00**

Note: WAC*green*, WAC*blue*, WAC*grey*: green, blue and grey Water Allowance Coefficient

Source: self-calculation

4. RESULTS

Certain value must be assigned to the developed coefficient. Therefore, a basic consumer price of water consumption values of national users has been determined according to the database of CSO (2013/a), on 1.32 USD/m^3. Calculation results considering the irrigation volume is shown at *Table 3*.

Table 3. Values of adjusted, corrected Water Allowance Coefficient by regions and types (AWV) (USD/ha)

Region	Adjusted values of WAC (USD/ha) (AWV)			
	AWV*green*	**AWV*blue***	**AWV*grey***	**AWV*total***
Central Hungary	1221	1301	1301	**1269**
Central Transdanubia	1018	873	1054	**955**
Western Transdanubia	1193	1481	1182	**1268**
Southern Transdanubia	858	1014	1015	**1012**
Northern Hungary	1010	1422	912	**1089**
Northern Great Plain	1392	1487	1361	**1408**
Southern Great Plain	1515	1140	1485	**1365**

Note: AWV*green*, AWV*blue*, AWV*grey*, AWV*total*: green, blue, grey and total water value according to Adjusted Water Values of Water Allowance Coefficient values. The gained results may show little distortion due to rounding errors.

Source: self calculation (1 USD = 250 HUF)

4.1. Water Allowance Coefficient at national level

Because of the applied methodology the summary of the regional values is not giving the total national value. Thus, the Hungarian water value at national level looks different as regional level (see *Table 4.*).

Table 4. Calculation and types of Water Footprint based value of water used for agricultural production, Hungary (in USD)

Type of Water Footprint	Water Footprint values (m^3/t)	Changes of Water Footprint values (%) (WF*total*=100%)	Water Allowance Coefficient based on changes of Water Footprint (WAC) (100/WF%)	Value of water used for agricultural production on a hectare, based on average price of water consumption (USD/ha) (AWV)	Type of Adjusted Water Value
WF*green*	593	47	0,47	684	**AWV***green*
WF*blue*	407	32	0,32	465	**AWV***blue*
WF*grey*	268	21	0,21	305	**AWV***grey*
WF*total*	**1 268**	**100**	**1**	**1454**	**AWV*total***

Source: self calculation according to Neubauer, 2010, p. 43.

According to CSO (2013/b) data the cultivable territory of Hungary is 5 338 000 hectare. Completing the national, aggregated Adjusted Water Value with this the following estimation can be calculated (*Table 5* and *Eq. 6*):

Table 5. Aggregate value of water used for agricultural production, which is based on average price of water consumption, Hungary (in USD)

Type of **Adjusted Water Value**	**Water Allowance Coefficient** based on changes of Water Footprint (WAC) (100/WF%)	**Value of water used for agricultural production** on a hectare, based on average price of water consumption (USD/ha) (AWV)	**Aggregated adjusted value of Water** Allowance Coefficinent on Hungary (USD) (AWVagg).
AWV*green*	0,47	684	3 649 478 075
AWV*blue*	0,32	465	2 484 751 030
AWV*grey*	0,21	305	1 630 617 863
AWV*total*	**1**	**1454**	**7 764 846 968**

Source: self calculation according to CSO (2013/b)

$$AWV_{agg} = AWV \cdot T_{agr} \qquad \text{(Eq. 6.)}$$

where:

AWV_{agg} = Aggregated adjusted value of WAC on Hungary (HUF).

AWV = Adjusted value of WAC on Hungary (HUF/ha).

T_{agr} = Volume of agricultural territory (ha).

5. DISCUSSION

Global nutrition is determined by local factors, on the one hand, environmental facilities, as climate and on the other hand, socio-cultural frames, which are mainly determined by ownership of resources and institutional pollution. There were many proposals on resource optimization to solve international stress in connection to global nutrition also at agricultural, social, and political fields, but somehow these are not realized, thus concrete reasons of global nutrition stress must be found somewhere else. Right usage of water footprint, with the help of virtual-water flows, can draw up from water approach international trade relationships, dependencies and savings but final estimations must be used with caution. Unifying method and database at all levels are necessary to determine domestic relationships of actors and their responsibility at non-optimized, inequitable water resource distribution. If this existing regular use itself must be supported both centrally from the top and socially from the bottom to reach goals in time to optimize water productivity and identify and impeach responsible actors of water usage. There are many tools (also on the internet) available now for decision makers to increase water productivity.

Water footprint of agricultural and industrial water use per capita is determined by natural features, population, economic productivity, and consumption habits. During the calculation of an estimation, weight of these factors turn out which gives excellent opportunity to sustainable and optimized water resource distribution for decision makers. So, challenge is given at national level!

Water Allowance Coefficient is able to demonstrate the total value of water and its types with using a monetary co-factor. Furthermore, Adjusted Water Value itself as a correction co-factor of land valuation, at the right place, may change land prices regarding to the green, blue and grey components. Using AWV may also cause interesting, unexpected results at industry and the tertiary sector. Additional calculations for example on urbanisation, income or temporal effect calculations must be considered, which can be reflected, for example, by population density, average or gross national income data involvement as a limitation factor.

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