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Water footprint based water allowance coefficient

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ABSTRACT

In our work, we tried to determine the asset value of water from natural resources. During the research we decided that a method based on allowance capitalization can be the most effective. Thus, the developed method is able to estimate water property value in a nationally uniformed system by utilizing final products. It has been decided that the determined method of Water Allowance Coefficient (WAC) is based on water footprint results of domestic wheat production. Water footprint was chosen because it is able to refer to water availability by also considering both direct and indirect usage of water. It covers absolute volume of our freshwater needs, which also can be determined as the availability potential of freshwater resources.

Methodological statement, because changes in AWVs (Adjusted Water Value) vary among regions, the distances of regional values would disappear by ranking. To eliminate this, the WAC values were directly used.

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1. Introduction

Water is classified among common goods, its place is among boundaries – fixed, its transportation and storage are complicated and costly (rather happens in the form of a product even at a national or regional level – for example grains, fruits, meat, etc.). In addition its substantive value is large (often not expressed in money), as it is related to life, beauty, wealth and health. People like the proximity of water. The economic consequence is that we should use it when and where it is available considering that it gravitates, leaks downward. There is always the threat of market failures in water supply as it has no homogeneous market because it is too expensive – pricing and water rate determination (can) cause extreme social conflicts and tensions. There is no other economic good that has such a complicated combination of characteristics like water [9].

We can agree with Professor Somlyódy [10] when he writes that water is a global phenomenon considering social and economic aspects, a unique resource which is not replaceable at many places of life. Water supply is determined by geographical differentiation or volatility of weather by climate change, while needs are based on human activities like agricultural and irrigation methods, customs, urbanization 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 regulatory factor in product pricing.

Sustainable way out is "*intensified hydro-solidarity*, *international legislation and its effective usage*". Water dilemmas are joint forces of natural, economic and social sciences, that are handled in both horizontal (agricultural, industrial or household level) and vertical ways (micro-, macro- and global-stage), not exclusively as hydro-engineering problem. Keys are recycling and closing circulations, which also require optimal infrastructure and political background.

Present appointed target of this study is monetary valuation of the link between human economic activity and water. Evaluation of water as natural resource could raise numerous questions at theoretical level. We will not consider moral, ethical or philosophical views, in this study only an economic aspect and method and its needs will be discussed. Within a research project at Szent István University, Hungary [5], monetary valuation of water as an agricultural natural resource could take place by oriental calculations related to water price. This value is linked to the regional average irrigation rate on a hectare, which is finally corrected by the Water Allowance Coefficient (WAC). WAC is built on Water Footprint (WF) of domestic wheat production, because WF is the method, which is able to refer to water availability that also considers direct and indirect water use and it can explore the absolute amount of our fresh water need.

According to our main results, the value of agricultural water use on a hectare is 363,659 HUF (approx. 1200 EUR) in Hungary. Rainwater has the highest value from it, 170,920 HUF (approx. 550 EUR), which is almost half of the total AWV. The next is irrigation water, which is almost one-third of the total value. The lowest value is for dilute polluted water with 21%, 76,368 HUF (approx. 246 EUR). WAC based aggregated AWV in Hungary is over 1941.211 billion HUF (approx. 6.262 billion EUR). Value of rainwater (green water) is close to 912.5 billion HUF (approx. 2.943 billion EUR). Value of irrigation water (blue water) is over 621.18 billion HUF (approx. 2.003 billion EUR); the value of dilute polluted water (grey water) is more than 407.65 billion HUF (approx. 1.315 billion EUR).

2. Materials and methods

Water resource valuation as a national natural resource is hardly defined as it is difficult to estimate the value of all usage directions of surface, ground and waste water because of the lack of data and their borderless characteristics both in spatial and temporal dimensions. We decided to work out a model based on agricultural water usage direction, which is mainly irrigation. We have also decided to work with wheat production data as the national land valuation system (AK) is also working with it. That is why in our case water footprint of wheat is relevant.

Based on Water Footprint of domestic wheat production, Water Allowance Coefficient (WAC) has been developed as a correction factor, which can also be described as the availability potential of freshwater resource. Its practical application is achieved through regional agricultural water resource valuation.

Water footprint is the measurement of expropriation of fresh water by humanity. It has three contents. Blue water footprint refers to the use of surface and ground water. Green water footprint refers to the use of rain water, which is important especially for crop production. Grey water footprint refers to fresh water pollution, which is diluted water required for water pollution, determined by water quality standards [6]. Water footprint is multi-sectoral and multi-dimensional water usage estimation. It shows the absolute water need for producing a product or service along the whole life cycle. It is an instantaneous estimation which considers water use and pollution of all elements of the supply chain. With this method, the need for water by actors, and also the weight of their water usage responsibility can be stated [4]. Water footprint is a geographically expressed index, which can show not only the quantity of water usage and pollution but also its location [7].

3. Results and discussions: water footprint

Water footprint is a relatively new environmental economic index, which shows new side of processes related to water consumption, use, and virtual water flows both at the national and the international levels. Development of the methodology is linked to the Dutch Professors Hoekstra and Chapagain [11]. The structure, the composition of water footprint is different from casual water withdrawal indicators, since it has three main factors. Green water footprint refers to the consumption of the total rainwater evapotranspiration, from fields and plantations, and the water incorporated into the harvested crop or wood. Blue water footprint shows the consumption of surface and groundwater. Grey water footprint refers to pollution with the quantity of water required to dilute pollutants. During the water footprint calculation these are combined and completed with the basic processing water needs of each step of the production process. "*Water footprint is the absolute amount of freshwater which is used during the production of a product or a service*, *and also includes the measurement of polluted water. This indicator makes integrated complex*, *horizontal and vertical sectoral data multifactorial assessment procedures possible. With its application previously unknown*, *sometimes even unsuspected economic*, *social and political correlations could come to light*, *which are approaching our personal and social attitudes related to water in a new way*" [8]. The index shows the actual, direct and indirect water usage measured on the whole value chain – only valid for the given area and period. It can be calculated for a product, a consumer, a company, a nation or group of these and a geographic area.

So, water footprint of a product is the volume of freshwater expropriated during its production, taking also into account the used and polluted volume of water in the different steps of the supply chain (www.waterfootprint.org). Numerous studies and researches have been worked out to highlight water need for our consumption and production habits through water footprint calculations. These reasons also turn out during the calculations; thus water productivity can be increased to high efficiency by appropriate decisions.

3.1. Water Allowance Coefficient

Water Allowance Coefficient (WAC), which can be described as the availability potential of a freshwater resource has been worked out by further thinking the estimation system of water footprint. With respect to Hungary, it is based and foregone by national water footprint estimations of wheat production in [8]. Results of calculations and estimations can be seen in Table 1.

During the water footprint assessment generally we can say, *the lower the value of water footprint*, *the better the water resource usage of the production of the product*. This is suggested by the underlined italicized values of the last column in Table 1. (Southern Transdanubia, Western Transdanubia, Central Transdanubia, Northern Hungary), which are compared to the national result that have better values, while the others (Southern Plains, Northern Plains, Central Hungary) show unfavourable difference. Based on these a Water Allowance Coefficient (WAC) was concluded which can be determined on the basis of the existing wheat water footprint calculation [8] mainly at a regional level. WAC is formed

Table 1
Water Footprint of wheat and its changes by regions and Hungary, 2009.
Source: [8] p. 43.

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	1394	99	131	101	110
Northern Great Plain	675	432	309	1417	114	106	116	112
Southern Transdanubia	569	329	216	1114	96	81	81	*88*
Western Transdanubia	526	293	240	1059	89	72	90	*84*
Central Transdanubia	527	422	257	1206	89	104	96	*95*
Northern Hungary	574	279	290	1143	97	69	108	*90*
Central Hungary	777	505	330	1612	131	124	123	127
Hungary average	**593**	**407**	**268**	**1268**	**100**	**100**	**100**	**100**

according to Eq. (1) and Table 1.

$$WAC_i = 100/WF_{wheat,i}\% \tag{1}$$

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,%.

The lower the WAC in a region, which is closer to zero, the more unfavourable the assessment of water resources availability is. In other words, larger values of WAC increase the monetary value of available water resources in a given region (Table 2).

Since changes of WAC vary among regions, setting up ranking values would cause the disappearance of the distances between the regions. We work directly with the Water Allowance Coefficient values to eliminate this.

3.2. Adjusted water value

Water assessment as natural resource starts, at this point, to connect to market price of water, because certain monetary 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 Central Statistical Office of Hungary [1], in the year 2012, the average consumer price of water consumption was 331 HUF/m^3 (approx. 1.06 EUR/m^3). Because the retrospective data show increasing values year-by-year, the price of water fee per m^3, in our case, is measured on that price without any average calculations. Following Table 3 can be tabulated by supplementing CSO [2] data with the average consumer price, which is actually a technical auxiliary table for calculating water values according to the following equation:

$$\overline{X}_{p,irr,i} = \overline{X}_{irr,i}\overline{X}_{p,cons} \tag{2}$$

where

$\overline{X}_{p,irr,i}$=average price of irrigation water at region i on a hectare (HUF/ha or EUR/ha).
$\overline{X}_{irr,i}$=average volume of irrigation at region i (m^3/ha).
$\overline{X}_{p,cons}$=average consumer price of water (HUF/m^3 or EUR/m^3).

The second column in Table 4 shows the average irrigation by hectare of regions in the period 2004–2012. Values of the third column are gained by multiplying values of the middle column and the average consumer price of water consumption (331 HUF/m^3 – approx. 1.06 EUR/m^3). Values in EUR

Table 2
Water Allowance Coefficient, based on Water Footprint change of wheat, by type and region, Hungary = 1.
Source: own calculation according to Table 1.

Region	Water footprint change based on Water Allowance Coefficient (WAC)			
	WAC_{green} 100 WF_{green}%	**WAC_{blue} 100 WF_{blue}%**	**WAC_{grey} 100 WF_{grey}%**	**WAC_{total} 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, respectively.
WF_{green}, WF_{blue}, WF_{grey}, WF_{total}: green, blue, grey and total Water Footprint, respectively.

Table 3
Average volume of consumed irrigation water by regions (m^3/ha) (2004–2012.) complemented by the average consumer price of water use (HUF/ha).
Source: own calculation according to [1,2].

Region	Average irrigation (m^3/ha) (2004 – 2012.) $\overline{X}_{irr}$	Average price (HUF/ha) $\overline{X}_{p,irr}$	Approx. in EUR/ha 1 EUR = 310 HUF
Central Hungary	1213	401,613	1295
Central Transdanubia	687	227,287	733
Western Transdanubia	805	266,308	859
Southern Transdanubia	623	206,213	665
Northern Hungary	741	245,234	791
Northern Great Plain	1195	395,508	1276
Southern Great Plain	1133	375,097	1210
Hungary average	**1099**	**363,659**	**112,734**

Note: Average water fee price ($\overline{X}_{p,con}$) is determined on the price 331 HUF/m^3.

Table 4
Values of adjusted, corrected Water Allowance Coefficients by regions and types (AWV) (HUF/ha).
Source: own calculation according to Tables 2 and 3 and Eqs. (3)–(6).

Region	Adjusted values of WAC (HUF/ha) (AWV)				EUR/ha 1 EUR = 310 HUF
	AWV_{green}	**AWV_{blue}**	**AWV_{grey}**	**AWV_{total}**	**AWV_{total}**, EUR
Central Hungary	305,226	325,307	325,307	**317,275**	1023
Central Transdanubia	254,561	*218,195*	236,378	**238,651**	770
Western Transdanubia	298,265	*370,168*	295,602	**316,906**	1022
Southern Transdanubia	*214,462*	253,642	253,642	**235,083**	749
Northern Hungary	252,591	355,590	*228,068*	**272,210**	878
Northern Great Plain	348,047	*371,778*	340,137	**352,002**	1135
Southern Great Plain	*378,848*	285,073	*371,346*	**341,338**	1101

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, respectively.
The gained results may show little distortion due to rounding errors.

are shown in the last column. Value modifying factors of agricultural production are gained by the assignment of these data to the Water Allowance Coefficient of the region as a correction factor. The value of Hungary average on a hectare is almost 365,000 HUF (approx. 1177 EUR), which can change by regions according to WAC changes and types.

3.3. *Results by regions*

Following results are gained based on agricultural usage direction of water resource. By linking Water Allowance Coefficient results (Table 2) and its water value to be adjusted (Eq. (2) and Table 3), regional values corrected by Water Allowance Coefficient, and complemented by green, blue and grey coefficient values, can be calculated as results of the following Eqs. (3)–(6) and Table 5.

$$\mathrm{AWV}_{green,i} = \mathrm{WAC}_{green,i}\overline{X}_{p,irr,i} \tag{3}$$

$$\mathrm{AWV}_{blue,i} = \mathrm{WAC}_{blue,i}\overline{X}_{p,irr,i} \tag{4}$$

$$\mathrm{AWV}_{grey,i} = \mathrm{WAC}_{grey,i}\overline{X}_{p,irr,i} \tag{5}$$

$$\mathrm{AWV}_{total,i} = \mathrm{WAC}_{total,i}\overline{X}_{p,irr} \tag{6}$$

where

$\mathrm{AWV}_{green,i}$, $\mathrm{AWV}_{blue,i}$, $\mathrm{AWV}_{grey,i}$, $\mathrm{AWV}_{total,i}$=adjusted green, blue, grey and total water value of Water Allowance Coefficient (HUF/ha or EUR/ha) at region *i*, respectively.
$\mathrm{WAC}_{green,i}$, $\mathrm{WAC}_{blue,i}$, $\mathrm{WAC}_{grey,i}$, $\mathrm{WAC}_{total,i}$=green, blue, grey and total Water Allowance Coefficient at region *i*, respectively.
$\overline{X}_{p,irr,i}$ =average market price of irrigation water on a hectare at region *i* (HUF/ha or EUR/ha) (Eq. (2)).

Changes in data in Table 4 are different from the direction of changes of regional Water Footprint values. Favourable and critical regions are different from the results of foundational calculations. Its reasons are the inserted values, and their different regional weights, in Water Footprint values and Adjusted Water Values of Water Allowance Coefficients, just like differences of volume of average irrigation on a hectare. Further values in relation to AWV types appeared from the table above, which are determined by average consumer prices on a hectare. From these it turned out *that the value of rain water at Southern Transdanubia* (*S-Transdanubia*) *is the lowest while Southern Great Plain* (*S-Great Plain*) *the highest*. It also turned out that the value of irrigation water measured on average consumer price

Table 5
Calculation and types of Water Footprint based values of water used for agricultural production, Hungary.
Source: own calculation according to [8] p. 43.

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 (HUF/ha) (AWV)	**Value of water used for agricultural production** on a hectare, based on average price of water consumption (EUR/ha)	Type of **Adjusted Water Value**
WF*green*	593	47	0.47	170,920	551.35	$\mathbf{AWV}_{green}$
WF*blue*	407	32	0.32	116,371	375.39	$\mathbf{AWV}_{blue}$
WF*grey*	268	21	0.21	76,368	246.35	$\mathbf{AWV}_{grey}$
WF*total*	**1 268**	**100**	**1**	**363,659**	**1173**	$\mathbf{AWV}_{total}$

Note: the gained results may show little distortion due to rounding errors.

Table 6
Aggregate value of water used for agricultural production, which is based on average price of water consumption, Hungary. Source: own calculation according to [3] and Table 5.

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 (HUF/ha) (AWV)	**Aggregated adjusted value** of Water Allowance Coefficient on Hungary (HUF) (AWV_{agg})	**Aggregated adjusted value** of Water Allowance Coefficient on Hungary (EUR)
AWV*green*	0.47	170,920	912,369,518,740	2,943,127,500
AWV*blue*	0.32	116,371	621,187,757,440	2,003,831,500
AWV*grey*	0.21	76,368	407,654,465,820	1,315,014,400
AWV*total*	**1**	**363,659**	**1,941,211,742,000**	**6,261,973,400**

Note: the gained results may show little distortion due to rounding errors.

compared to the other regions and their values is very favourable at Central Transdanubia, 218,195 HUF/ha (approx. 703.85 EUR).

The next favourable value of this type is about 35,000 HUF/ha (approx. 113 EUR/ha) higher, and the most expensive Adjusted Water Values of irrigation water are at and Northern Great Plain (370,168 and 371,778 HUF/ha – approx. 1194 and 1199 EUR/ha respectively). From the table it is also clearly seen that the value of water need for dilute pollutant water, which is actually an indirect water need, is the lowest in Northern Hungary and the highest in Southern Great Plain. These are the underlined italicized values in Table 4.

3.4. Results 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 looks as follows. According to CSO [3] data the cultivable territory of Hungary is 5,338,000 ha. Completing the national, aggregated AWV with this the following estimation can be calculated (Eq. (7) and Table 5):

$$AWV_{agg} = AWVT_{agr} \quad (7)$$

where

AWV_{agg} = aggregated adjusted value of WAC on Hungary (HUF or EUR).
AWV = adjusted value of WAC on Hungary (HUF/ha or EUR/ha).
T_{agr} = volume of agricultural territory (ha).

From the results in Table 6 the corrected total water values of Hungary, on the basis of agricultural water use, by water footprint calculations based on adjusted values of Water Allowance Coefficient can be seen. According to these values, rain water (green water) is close to 912.4 billion HUF (approx. 2.943 billion EUR). The value of irrigation water (blue water) is more than 621.18 billion HUF (approx. 2.004 billion EUR) and the volume of dilute water need (grey water) is over 407.65 billion HUF (approx. 1.315 billion EUR). According to this estimation, the national aggregate water value is more than 1,941,211 billion HUF (approx. 6.262 billion EUR).

4. Conclusion and further opportunities

According to our orientation calculations monetary valuation of water as an agricultural natural resource is connected to the consumer price of water. This is in relation with the average regional irrigation volume on a hectare, which is finally corrected by WAC. The name of the gained value is Adjusted Water Value (AWV).

In case of further valuations, WAC provides the opportunity for calculating water values at different sectors. As a correction co-factor of land valuation, at the right place, it may change land prices with respect to the green, blue and grey components. Using AWV may also cause interesting, unexpected results at industry and the tertiary sector. However, urbanization effect calculations must be considered, which can be reflected, for example, by population density data involvement as a limitation factor. It also could be interesting to make calculations not only with the water footprint of wheat production but with different bases of WAC which could be based on water footprint data of either primary or secondary or tertiary sector.

WAC is able to demonstrate the total value of water and its types. Scaling with other regional water usage data or even economic indexes is also important. Working out and giving the best response by understanding it are further tasks. These opportunities are challenging, it is expected to meet them as results of further researches.

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