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Opportunities of optimizing Hungary's water management using water footprint

Theses of Ph.D. Research

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TABLE OF CONTENTS

1. PRE-WORK THOUGHTS AND GOALS

Optimizing the requirements of water management, and defining an effective strategy has its roots in history, since the civilization, or in other words, cultural centers of humanity were always established in close proximity to some kind of water body throughout the years. The economic interpretation of water management is becoming more apparent nowadays. The rise in both humanity's numbers, and that of their needs, as well as the priority of sustainability in market mechanisms, which is on the rise, but still low, the global transformation of weather climate, and so on, all require us to make proper and responsible decisions for the future, from a water management point as well. When speaking of water usage, the effects of outer economic impacts, meaning presence of externalities in consumer habits, industrial water extraction, and agricultural watering and animal husbandry are also of note, with the importance of water usage also included.

This is a global phenomenon. In places, where the marginal costs of water extraction and usage - meaning, where they decide to extract or use water, in spite of the unfavorable costs - falls beyond the political borders of the country, a more economically sufficient water supply is imported. This may lead to fragile diplomatic relations and market connections, which showcase the international economic and social processes, even in case of dependence. However, this may be relevant in case of the connections of a country's own areas as well. As for the sectors, f.e. in case of agricultural watering, central subsidies, the taxing and regulatory system, and market motivators also have a big impact on water usage and pollution. Therefore, in the water's case, we can't disregard horizontal and vertical cross-connections either. This means that optimizations and effectiveness increases in relation to water management may show additional positive effects on f.e. reduction of energy usage, carbon emission, the spread of so-called *low-carbon* mechanisms, or advocating coping with the change in climate.

Therefore, it is imperative to not only view economic proficiency, but social and ecological benefits in greater detail, when related to water. Optimizing water management and water usage is always a must-do, and in cases where state measures are insufficient, we can allow the water management through market demand to have a greater influence. In this case, it's acceptable that values and costs surface between supply and usability.

Goals of my dissertation

Interpretation of calculating water footprints:
My first goal is to summarize the water resource-optimization opportunities, methods and shortcomings related to water footprints, through the associated international effects. The water footprint index is a relatively fresh index, since prof. Hoekstra, a scientist from the Netherlands, and his colleagues published their results of researching the index and its actual usage a mere 10-15 years ago. Therefore, it is logical and advised that we try to interpret water footprints from a social, and economic point of view. The actual estimation of water footprints is a process which requires high amounts of data and time. This is further elevated if the calculation doesn't only include a primary agricultural product. To more appropriately approximate these estimates, it's important to analyze their domestic applicability.

Domestic evaluation of water footprint index:
Domestic water management and water usage policies have unique challenges due to the quantity and quality of Hungary's water resources being sporadic time- and area-wise. My second goal is to introduce the thought, that by the water-related modeling of domestic phenomena - production, consumption, entrepreneurship, outer- and inner trade - water footprint research can be tailored to Hungary.

If further research can be widened to the critical showcasing of actual domestic water usage opportunities, both on the water usage levels of micro- and macro-economy, then this will offer the chance to balance the environmental and economic elements of water usage (and their society-related extra counterparts), by using the water footprint index. The goal is to introduce a decision-assisting, status-extracting, resource-optimizing and strategy-planning system, which may induce production-development processes accepted by both decision makers and market alike; meaning elevating the importance of actual applicability of scientific results.

My hypotheses:

H1: Water footprint results can showcase regions in terms of water demand.

H2: Based on domestic water footprint estimates, we can define a regional water-value measurement system.

H3: The water-value measurement system corrected with the market price gains a new function, and can therefore show the financial value of the water resource at disposal, thereby aiding in determining the true value of water.

H4: The correlation- and cluster- analysis of results shows inter-connections, and helps to gain a deeper understanding of domestic status.

Using water footprint calculations, we can determine areas where an optimization in water usage is necessary, and we can also find out the reasons for this. However, water footprint results in and of themselves aren't talkative, but using them, we can approach the social-economic portrait of life from a "water dimension". The analysis of my hypotheses may become quite informative, however, we cannot be satisfied with only this when researching the topic. Since water is a special, essential and crucial part and context of our lives, and the systems and processes maintained by us, we have to care for it both short- and long-term.

2. SOURCE AND METHOD

2.1. Source

To create a proper basis for my dissertation, I collected literature related to the field of research, both domestic and foreign, be it web-based or printed. The parts related to my goals and hypotheses, f. e. the economic attributes of water, the main perspectives of water as a macro-economic factor, and the water footprint index, with its related research documents publicized so far, were summarized, objectively evaluated, interpreted using my previous research material, personal knowledge and values, and logically ordered to be the goal of my work. The new results were based on the water footprint method, and were a proper scientific follow-up of my previous domestic wheat-water footprint research. Forming this was made possible by the markers laid out for me by my supervisor, and the personal interviews with professor István Szűcs, and another un-structured interview with Sándor Ress. I also used statistic data from KSH where I deemed necessary.

2.2. Method

The results I got in my dissertation were based on water footprint calculations, apart from the non-structural interview. These results were subjected to SWOT-based system evaluation, correlation calculations and cluster-analysis.

During the research, I could arrange the non-structural interview, because the method allows for the interviewee to share his/her personal professional experiences, which we can use as markers during the discussion, meaning that the questions we can talk about in more depth are the ones found interesting and important by the interviewee about the topic of research. The water footprint calculations were the main methodological basis of the research, which are the means of the complex, however, only water-related method of fresh water expropriation evaluation. All water footprint calculations are based on the water footprints of production and creation processes, which are furthered by the addition of the process water requirements of the steps. The water footprint index offers a wide area of understandability of man's economic activities from water's perspective, and therefore offers novel points of view which, if used more widely nationally, may help in making decisions which are more fair and rational for varied needs. The method can be flexibly applicable to domestic circumstances, and contains three different water types. Green water footprint refers to rainwater, blue water footprint to ground water, while grey water footprint to the freshwater needed to dilute polluted water. If need arises for deeper detailing, the green, blue and grey components can be divided into five categories for the prior two, and any number for the latter, depending on what kind of hazardous material is in the water. The data required for the method is usually present in the statistics (KSH, FAO, FertiStat, EuroStat, etc.), or if needed, can be estimated.

The results gained from the process of literature were summarized effectively via a SWOT-based system analysis. The knowledge regarding water resources, its macro-economic questions, and the water footprint index was organized into matrixes, which defined the attributes of the researched factors. The topics of the research are all complex, therefore, filling the matrixes via my professional expertise defined the most important processes for the various sub-topics.

I've analyzed my new research results with correlation calculations, due to the metric nature of the variables, for which I employed the SPSS software pack, since it's in the widest use, and has the greatest acceptance in education. After defining the metric variables, I analyzed the homogeny of their scatter via the size of the boxes on the box plots. Using the variables, I did Pearson's correlation coefficients with two-tailed tests. Furthermore, the results were organized into groups using cluster-analysis. Of the various categorization hierarchy models, I used Ward's. Where there was a need, I homogenized the data using standardization. I analyzed the results of the cluster analysis using summarization charts and their diagrams, icicle-diagrams, and dendograms. I deduced my final thoughts using cluster-centroids and scatter-square. Using the cluster analysis, I shed light on the applicability of data and methods required for the area-based optimized macro-economic borders and strategies related to water and water management. I did not have the goal of pitting regions against each other by water usage, water productivity and water accessibility criteria.

3. RESULTS

3.1. Water allowance coefficient

In my dissertation, further advancing the water footprint estimation system, I defined the water allowance coefficient (WaC), which can also be defined as the possibility of freshwater-resource availability. The basis of this for Hungary were mainly my national wheat-water footprint estimates (in: Neubauer, 2010).

During the water footprint evaluation, we can usually say that the lower the water footprint index, the more acceptable the water usage of the product's creation. Meaning that in certain regions, compared to national levels, the water footprints show more desirable values, while in other regions, they have a less desirable difference. We can estimate a water allowance coefficient using this, which can be based on existing wheat-water footprint calculations, mainly on a regional level. The Water footprint coefficient can be calculated as seen in *Equation 1*. below.

$$WaC_i = \frac{100}{WF_{wheat,i}\ \%} \tag{1}$$

where:

WaC_i = Water allowance coefficient by Wheat-water footprint in *i*-th region
$WF_{wheat,i}$ = Wheat production's water footprint value in *i*-th region (%)

WaC's value for any region falls between 0 and 1 ($0 < WaC_i < 1$), and if the wheat-water footprint is higher than the national value, it's less desirable altogether ($WF_{wheat,i} > WF_{wheat,nat}$). If the regional wheat-water footprint is lower, more desirable than the value of estimation nationally ($WF_{wheat,i} < WF_{wheat,nat}$), then it shows a value above 1 ($WaC_i > 1$). The lower the value of the water allowance coefficient in a region, meaning the closer it is to zero, the worse the evaluation of the region's water resources at hand are. In other words, a higher WaC value raises the monetary value of the region's water resources at disposal (*Chart 1*).

Since the regions have different water allowance efficient values, the differences in the various regions' values would diminish when ranked. To avoid this, we can continue working with the water allowance coefficients as they are. This means that the water allowance coefficient (WaC) based on the wheat-water footprints have a more desirable value compared to national levels for Southern Transdanubia, Western Transdanubia, Central Transdanubia, and Northern Hungary (*Chart 1, green background*). In these regions, the WaC mainly raises water value. However, we can meet unfavorable values compared to national levels in Southern Great Plain, Northern Great Plain, and Central Hungary (*Chart 1, red background*). In these regions, WaC will unfavorably effect the water value.

Chart 1.: Water allowance coefficient values based on wheat-water footprints by type and region, (Hungary = 1)

Region	Water Allowance Coefficient via Water footprint value			
	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	**1,00**	**1,00**	**1,00**	**1,00**

Source: personal calculations

We can define different WaC types by different water usage types. These are the rainwater in the ground, ground humidity (green water), according to its agricultural usage, can be named WaC_{green}. The water used to water plants (blue water) is WaC_{blue}, while the water required to dilute contaminated water is WaC_{grey}. It is important that these WaC types aren't in sync with the total coefficient value, meaning neither in ratio, nor in range do they affect water value equally.

3.2. Assigned water price

According to KSH's (2013/a) data, the average cost of water consumption was Ft/m^3 in 2012. Since it can be seen from older data, that as years went by, the value increased, at this time, we can use this value to measure the price by cubic meters of water, without calculating an average. Adding this value, and using KSH's (2013/b) data, we can assort *Chart 2*, which in essence is a technical guideline to calculating water values, using *Equation 2.* below.

$$\bar{X}_{p,wat,i} = \bar{X}_{wat,i} \cdot \bar{X}_{p,con} \qquad (2)$$

where:

$\bar{X}_{p,wat,i}$	=	Water's (used for watering) average market price in *i*-th region by hectare (Ft/ha).
$\bar{X}_{wat,i}$	=	Average watering in *i*-th region (m^3/ha).
$\bar{X}_{p,con}$	=	Average consumer price of water (Ft/m^3).

Chart 2.: Watering average for one hectare by region (m^3/ha) (2004–2012.) and the average consumer price of water (Ft/ha)

Region	Watering avg. (m^3/ha) (2004–2012.)	Price (AWP) (Ft/ha)
	$\bar{X}_{wat}$	$\bar{X}_{p,wat}$
Central Hungary	1 213	401 613
Central Transdanubia	687	227 287
Western Transdanubia	805	266 308
Southern Transdanubia	623	206 213
Northern Hungary	741	245 234
Northern Great Plain	1 195	395 508
Southern Great Plain	1 133	375 097
Hungary	**1 099**	**363 659**

Note: The average price of water used ($\bar{X}_{p,con}$) is 331 Ft/m^3.
Source: personal calculations, based on KSH data

The middle column of *Chart 2* shows the average watering of regions by hectare during the 2004-2012 period. If we multiply the values by the average consumer price of water (331 Ft/m^3), we get the third columns' values. By assigning these values to the various regions' water allowance coefficients, we can get the correctional factor of agricultural production's value modifiers. The average cost nationwide is almost 365.000 HUF by hectare, which varies according to the WaC values and types by region.

3.2.1. Calculations with WaC

Based on the main agricultural usage of water resources, the WaC's (*Chart 1*) and AWP's (*Equation 1* and *Chart 2*) results can be linked, where we get the regional values corrected by WaC as the results of *Equations 3-6*, and *Chart 3*, supplemented by the green-, blue- and grey-coefficient values.

$$WaC(av)_{green,i} = WaC_{green,i} \cdot \bar{X}_{p,wat,i} \tag{3}$$

$$WaC(av)_{blue,i} = WaC_{blue,i} \cdot \bar{X}_{p,wat,i} \tag{4}$$

$$WaC(av)_{grey,i} = WaC_{grey,i} \cdot \bar{X}_{p,wat,i} \tag{5}$$

$$WaC(av)_{tot,i} = WaC_{tot,i} \cdot \bar{X}_{p,wat}$$

(6)

where:

$WaC(av)_{green\,/\,blue\,/\,grey\,/\,tot,i}$, = WaC's assorted values by green, blue, grey and total water price values in *i*-th region (Ft/ha).

$WaC_{green,i}$, $WaC_{blue,i}$, $WaC_{grey,i}$, $WaC_{tot,i}$ = Green, blue, grey and total WaC values in *i*-th region.

$\bar{X}_{p,wat,i}$ = Average market price of water in *i*-th region by hectare (Ft/ha) (AWP) (*Equation 1*).

Chart 3.: Assorted and corrected values of water allowance coefficients by region and type (WaCav) (Ft/ha)

Region	Assorted values of water allowance coefficient (Ft/ha) (WaC(av))			
	$WaC(av)_{green}$	$WaC(av)_{blue}$	$WaC(av)_{grey}$	$WaC(av)_{tot}$
Central Hungary	305 226	325 307	325 307	**317 275**
Central Transdanubia	254 561	218 195	236 378	**238 651**
Western Transdanubia	298 265	370 168	295 602	**316 906**
Southern Transdanubia	214 462	253 642	253 642	**235 083**
Northern Hungary	252 591	355 590	228 068	**272 210**
Northern Great Plain	348 047	371 778	340 137	**352 002**
Southern Great Plain	378 848	285 073	371 346	**341 338**

Note:

Rounded results may show slight distortion in value.

Source: personal calculations based on *Chart 1* and *Equations 3-6*

The data of *Chart 3* differs from the water footprint values regionally. The good and critical regions aren't the same as the values of the pre-calculations suggest. The reasons for this lie in the assorted values inserted between water footprint values and water allowance coefficients, and their regionally different weights, f. e. the average watering by hectare values.

The above chart shows additional WaC-related values, which were derived from the average consumer prices by hectare. This shows us, that f.e. the value of rainwater is lowest in Southern Transdanubia, and highest in Southern Great Plain. We can also see that if we calculate with the average consumer price, Central Transdanubia has an exceptionally favorable watering-purpose water value compared to other regions, which is 218 195 Ft/ha. The next most favorable value in this segment is about 35.000 Ft/ha more expensive, with Western Transdanubia and Northern Great Plain having the highest values for the WaC of watering-purpose water (370 168 and 371 778 Ft/ha). We can also see from the chart that the water needed to dilute hazardous water, which in essence is an indirect water demand, has its lowest and highest values in Northern Hungary and Southern Great Plain respectively. These are the colored values in *Chart 3.*

The following full equation can be used to calculate region-wise, using the water footprint as a basis (*Equation 7.*):

$$WaC(av)_i = \left(\frac{100}{WF_{wheat,i}\ \%} \right) \cdot \left(\bar{X}_{wat,i} \cdot \bar{X}_{p,con} \right) \tag{7}$$

where:

$WaC(av)_i$ = Assorted value of water-allowance coefficient in *i*-th region (Ft/ha).

$WF_{wheat,i}$ = Wheat-water footprint in *i*-th region, %.

$\bar{X}_{wat,i}$ = Average watering in *i*-th region (m^3/ha).

$\bar{X}_{p,con}$ = Water's average consumer price (Ft/m^3).

3.2.2. Agricultural water value in Hungary

Due to the nature of the methodology, the national water resource cannot be calculated as a sum of the various regional water resources' sum. Therefore, Hungary's water value is as follows (*Chart 4.* and *Equations 8-10*):

Water footprint type	**Water footprint values** (m^3/t)	**Water footprint values** (%) (WF*total*=100%)	**Water allowance coefficient** based on water footprint (WaC) (100/WF%)	**Value of agricultural use water** by hectare, based on water consumption market price (Ft/ha) (WaC(av))	**Type of assorted water value**
WF*green*	593	47	0,47	170 920	**WaC(av)***green*
WF*blue*	407	32	0,32	116 371	**WaC(av)***blue*
WF*grey*	268	21	0,21	76 368	**WaC(av)***grey*
WF*total*	**1 268**	**100**	**1**	**363 659**	**WaC(av)*total***

Source: personal calculations based on Neubauer, 2010, p. 43.

Calculating with *Chart 4.'s* data, we can define the value of water used by agriculture for one hectare, including its green, blue, and grey components. We can say that the highest national value is that of rainwater, 170 920 Ft for each agriculturally usable hectare. This is almost half of the total WaC(av) value. Next up is watering-purpose water, which is nearly one-third of the total value. The lowest share is held by water used for diluting hazardous water, with 21%. The values of *Chart 4.* are as follows (*Equations 8-10*):

$$WaC(av)_{tot,HU} = WaC(av)_{green,HU} + WaC(av)_{blue,HU} + WaC(av)_{grey,HU} \quad (8)$$

where:

$WaC(av)_{tot,HU}$	=	WaC's assorted value for Hungary (Ft/ha).
$WaC(av)_{green,HU}$	=	WaC's assorted green value for Hungary (Ft/ha).
$WaC(av)_{blue,HU}$	=	WaC's assorted blue value for Hungary (Ft/ha).
$WaC(av)_{grey,HU}$	=	WaC's assorted grey value for Hungary (Ft/ha).

or:

$$WaC(av)_{HU} = \bar{X}_{p,HU,WFgreen} + \bar{X}_{p,HU,WFblue} + \bar{X}_{p,HU,WFgrey} \quad (9)$$

where:

$WaC(av)_{HU}$ = WaC's assorted value in Hungary (Ft/ha).

$\bar{X}_{p,HU,Wfgreen}$ = The price by hectare for agricultural use greenwater based on national average market price (Ft/ha).

$\bar{X}_{p,HU,Wfblue}$ = The price by hectare for agricultural use bluewater based on national average market price (Ft/ha).

$\bar{X}_{p,HU,Wfgrey}$ = The price by hectare for agricultural use greywater based on national average market price (Ft/ha).

or:

$$WaC(av)_{HU} = [(\frac{WF_{green}}{WF_{tot}}) \cdot (\bar{X}_{wat} \cdot \bar{X}_{p,con})] + [(\frac{WF_{blue}}{WF_{teljes}}) \cdot (\bar{X}_{wat} \cdot \bar{X}_{p,con})] + [(\frac{WF_{grey}}{WF_{teljes}}) \cdot (\bar{X}_{wat} \cdot \bar{X}_{p,con})] \quad (10)$$

where:

$WaC(av)_{Mo}$	= WaC's assorted value in Hungary (Ft/ha).
$WF_{green,\ blue,\ grey}$	= National green, blue and grey water footprint (m^3/t).
WF_{tot}	= Hungary's water footprint for wheat (m^3/t).
$\bar{X}_{wat}$	= Average national watering (m^3/ha).
$\bar{X}_{p,con}$	= Water's average consumer price (Ft/m^3).

According to KSH's 2012 data (2013/c), Hungary's agricultural area total is 5 338 000 hectare. If we include this data, we get the following estimation for national aggregated WaC value (*Equation 11.* and *Chart 5.*):

$$AWaC(av) = WaC(av) \cdot A_{ac} \qquad (11)$$

where:

AWaC(av) = WaC's aggregated assorted value for Hungary (Ft).
WaC(av) = WaC's assorted value for Hungary (Ft/ha).
A_{ac} = Size of agricultural area (ha).

Chart 4.: Value of agricultural use water based on water's average market price nationally

Water footprint type	**Water allowance coefficient** based on water footprint (WaC) (100/WF%)	**Value of agricultural use water** by hectare, based on water consumption market price (WaC(av))	WaC's **aggregated assorted water value** for Hungary (Ft) (AWaC(av)).
WF*green*	0,47	170 920	912 369 518 740
WF*blue*	0,32	116 371	621 187 757 440
WF*grey*	0,21	76 368	407 654 465 820
WF*total*	**1**	**363 659**	**1 941 211 742 000**

Source: personal calculations based on KSH data and *Chart 4.*

We can see in the results of Hungary's national water values, based on the water footprint calculations, and corrected with the assorted values of the water allowance coefficient, regarding the agricultural water usage. According to these results, the value of rainwater (greenwater) is close to 912,5 billion HUF. The value of watering-purpose water is over 621,18 billion HUF, while that of water needed to dilute hazardous water is over 407,65 billion HUF. Summarizing this estimate, the national aggregated water value is over 1941,211 billion HUF.

3.3. Correlations

Using this method, I searched for an answer to the following question: is there any connection between wheat-water footprint (WF_{wheat}), water allowance coefficient (WaC) and its assorted value types (WaC(av)) regionally. If there is, what kind of a connection is it?

During my research, I didn't create any criteria for extreme cases, since I used the total data table, meaning all of Hungary's statistical regions, instead of trying to model it with a sample. The boxplots show the homogeny of the various factors with their sizes. The blue wheat-water footprint ($WF_{wheat,blue}$) and bluewater allowance coefficient (WaC_{blue}) show a lower level of homogeny regionally, compared to the other values, while the assorted values of water allowance coefficients (WaC(av)) are heterogeneous in all three cases.

According to the results of the correlation tests, the water footprint of wheat (WF_{wheat}), the water allowance coefficient (WaC) and the assorted values of said water allowance coefficient by types (WaC(av)) are 'different', excluding four cases. There are four significant, stochaistic connections, where there is a definite statistic connection between the average values of the factors, but their deterministic connection, or its absence is not proven:

1. With a two-sided asymp. significance of 0,01, the connection between the assorted values of green- and grey-water allowance coefficients is strong positive ($WaC(av)_{green}$ and $WaC(av)_{grey}$) (r = 0,922, sig. = 0,003).
2. With a two-sided significance of 0,01-0,05, the connection between the green- and greywater footprints of wheat production is strong positive ($WF_{wheat,green}$ and $WF_{wheat,grey}$) (r = 0,823, sig. = 0,023).
3. With a two-sided significance of 0,01-0,05, the connection between the blue-water allowance coefficient (WaC_{blue}) and the grey-water footprint of wheat production ($WF_{wheat,grey}$) is strong positive (r = 0,778, sig. = 0,039).
4. With a two-sided significance of 0,01-0,05, the connection between green- and greywater allowance coefficients is strong positive (WaC_{grey} and WaC_{green}) (r = 0,762, sig. = 0,047).

Due to the low quantity of analyzed samples, the high correlation values might not mean strong significance in cases where they could, if the analyzed sample's quantity were sufficient.

3.4. Cluster analysis

During the cluster analysis of the wheat-water footprint (WF_{wheat}), the water allowance coefficient (WaC) and its assorted values (WaC(av)), I discarded the first step of the usual process, which is to exclude extreme cases, because the analyzed sample is the entirety, instead of a smaller sample. During the cluster analysis, I used the *Ward-method* exclusively. The only time variables were taken into consideration was the summarization process.

Cluster analysis by water-wheat footprint types of regions

I defined either two or three clusters when calculating with wheat-water footprints. Since the three-cluster solution offered groupings with higher homogeny in this case, this was used instead of the two-cluster solution. Using the calculated results, the first cluster's regions are average, or close to average water footprint-wise, while the third cluster has high water footprint values.

The regions:

1. cluster – High watering-purpose water demand regions: Southern Great Plain, Central Transdanubia;
2. cluster – Low water demand regions: Southern Transdanubia, Northern Hungary, Western Transdanubia;

3. cluster – High water demand regions: Northern Great Plain, Central Hungary.

Cluster analysis by water allowance coefficients of regions

We can also determine for water allowance coefficients, that we can either group the regions into two or three clusters. Since in this case, the two-cluster solution provides a greater level of homogeny, this was the one I chose. According to the calculated results, the first cluster's regions have a low, while the second's regions have a high water allowance coefficient.

The regions:

1. cluster – Regions lowering water value: Southern Great Plain, Southern Transdanubia, Central Transdanubia, Western Transdanubia;
2. cluster – Regions raising water value: Northern Great Plain, Northern Hungary, Central Hungary.

Cluster analysis by assorted values of water allowance coefficients of regions

Regarding the assorted values of the water allowance coefficient, we can say that there are once again two-, or three-cluster solutions for grouping regions. The only main difference between the two solutions is whether Central Transdanubia forms a separate region, which in case of a two-cluster solution causes the heterogeneous nature of the second cluster due to the blue factor. In spite of this, since it's not advisable to use a single region as a separate cluster, I chose the two-cluster solution. According to the calculations, the first cluster has high, and the second has low assorted values.

The regions:

1. cluster – Regions with high assorted value: Southern Great Plain, Northern Great Plain, Central Hungary, Western Transdanubia;
2. cluster – Regions with low assorted value: Southern Transdanubia, Northern Hungary, Central Transdanubia.

Cluster analysis by summaries of regions

To summarize all regions, I standardized the different variables for the cluster analysis. Calculating with these results, we can say that the regions can be organized into either two, three or four separate clusters. Out of these options, I discarded the one with four clusters, due to its heterogeneous nature. Of the remaining two options - them being two- or three-cluster solutions - I chose the two-cluster solution, because the homogeny was broken by the same variables in both cases, but in case of the three-cluster solution, I ended up with an extra cluster with one region.

In the first cluster, all variables are close to the average apart from the low greenwater footprint, while in case of the second cluster, the values of the water allowance coefficients are varied by type, and the assorted value of the bluewater allowance coefficient is low. This therefore means that the rainwater used for wheat production is lower than the average in case of the regions of the first cluster, while all other variables are average. In case of the second cluster, the water allowance coefficient values and the monetary value of watering-purpose water are low compared to the other variables, which are all average.

The regions:

1. cluster – Low greenwater footprint, average regions: Southern Great Plain, Southern Transdanubia, Northern Hungary, Central Transdanubia, Western Transdanubia;
2. cluster – Varied water allowance coefficient, and low watering purpose water-value regions: Northern Great Plain, Central Hungary.

3.3. New scientific results

1. Based on the national wheat-water footprint, I defined the water allowance coefficient's (WaC) equation, which shows both regional and by-type results as follows:

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

where:

WaC_i = Water allowance coefficient by Wheat-water footprint in *i*-th region

$WF_{wheat,i}$ = Wheat production's water footprint value in *i*-th region (%)

This index can be defined as the availability of freshwater. Its results add to the evaluation of rainwater, watering-purpose water and water required to dilute hazardous water (blue-, green- and greywater), not only in the entirety of Hungary, but the level of statistic regions as well. The lower the value of the water allowance coefficient, meaning the closer it is to zero, the less favorable the evaluation of available water resources in the region are.

2. WaC can be further supplemented by co-factors. By grouping it with the monetary values, I defined a water resource evaluation method. The results from this method are the assorted values of the water allowance coefficients (WaC(av)), which can show the water value by hectare of agricultural use area, both in regional and by-type division. These values are dependent on the WaC values, the agricultural use areas, the average watering by hectare, and the market price of water.

$$WaC(av)_i = WaC_i \cdot \bar{X}_{p,wat}$$

where:

$WaC(av)_i$ = Assorted value of water-allowance coefficient in *i*-th region (Ft/ha).

WaC_i = Water allowance coefficient in *i*-th region.

$\bar{X}_{p,wat,i}$ = Price of watering-purpose water in *i*-th region by hectare (Ft/ha).

3. I analyzed the estimated results of my new, personal methods with research-evaluation methods. Using my correlation tests, I deduced that the wheat-water footprint (WF_{wheat}), the water allowance coefficient (WaC) and its type-assorted values (WaC(av)) are 'different' excluding four cases, meaning there are four significant stochaistic connections:

- the connection between the assorted values of green- and grey-water allowance coefficients ($WaC(av)_{green}$ and $WaC(av)_{grey}$);
- the connection between the green- and greywater footprints of wheat production ($WF_{wheat,green}$ and $WF_{wheat,grey}$);
- the connection between the blue-water allowance coefficient and the grey-water footprint of wheat production (WaC_{blue} and $WF_{wheat,grey}$);
- the connection between green- and greywater allowance coefficients (WaC_{grey} and WaC_{green}).

4. Using my estimated values, I also did a cluster-analysis. As the results of the by-type analysis of the wheat-water footprint (WF_{wheat}), the water allowance coefficient (WaC), its assorted values (WaC(av)) and the by-type analyses of their standardized summaries, I assorted the regions into one three-, and three two-cluster systems:

- Cluster analysis of wheat-water footprint (WF_{wheat}):
  1. cluster – High watering-purpose water demand regions: Southern Great Plain, Central Transdanubia;
  2. cluster – Low water demand regions: Southern Transdanubia, Northern Hungary, Western Transdanubia;
  3. cluster – High water demand regions: Northern Great Plain, Central Hungary.

- Cluster analysis of water allowance coefficient (WaC):
  1. cluster – Regions lowering water value: Southern Great Plain, Southern Transdanubia, Central Transdanubia, Western Transdanubia;
  2. cluster – Regions raising water value: Northern Great Plain, Northern Hungary, Central Hungary.

- Cluster analysis of assorted value of water allowance coefficient (WaC(av)):
  1. cluster – Regions with high assorted value: Southern Great Plain, Northern Great Plain, Central Hungary, Western Transdanubia;
  2. cluster – Regions with low assorted value: Southern Transdanubia, Northern Hungary, Central Transdanubia.

- Summarized cluster analysis:
  1. cluster – Low greenwater footprint, average regions: Southern Great Plain, Southern Transdanubia, Northern Hungary, Central Transdanubia, Western Transdanubia;
  2. cluster – Varied water allowance coefficient, and low watering purpose water-value regions: Northern Great Plain, Central Hungary.

4. CONCLUSIONS, ADVICES

I believe that the economic processes outsourced beyond national borders due to water-efficiency or marginal water sources should be lowered to the absolute required level, by optimizing the national water usage. Furthermore, the boundless flow-energy source of the movement of national rivers would suffice as sustainable opportunities from an energy resource view. We have to exploit investments which supply social needs, and are in accordance with reality, while devoid of social, economic and environmental extremities, and include natural resources in their calculations. Water, and its infrastructure cannot be exposed to speculation. Though for decision makers who are rigorously monetary thinkers, usage of water resources as economic factors is more easily optimisable. However, we must work to actualize an economic system, which is sustainable and fair from either an environmental, social and economic perspective. The effective cooperation of actors regarding water-related problems can also be achieved through the cooperation of the various fields of science. I believe that the criteria for this is that the institutions backing the actors offer a helping hand in establishing water-workgroups which discuss the various, f.e. agricultural, food safety and welfare problems and goals, and define strategies and operative programmes. Publishing results can come after that, on various conferences, seminars, and for a wider audience, webinars and free universities. The goal of this would be to make hydro-solidarity more conscious. I agree that these solutions can most efficiently be implemented between the boundaries of institutional systems. Also, when defining national water strategy and making decisions related to it, I believe the conclusions of the 2008-2009 economic and food-price slump should be incorporated. Our own safety nets should not only be re-thought, but remade to be even more effective both on a national and a regional level, while defining specific social plans locally to protect the citizenship. Food safety is closely related to water-policy questions. Increasing agricultural investments results in an environmentally sustainable rise in productivity, and extra production rates, while we can simultaneously raise agriculture's share in economic growth and fighting against poverty. However, agricultural investments are by no means small or insignificant, so I think that to actualize them, we need either a backing group of capital holders, or a decent and fair subsidy system, or perhaps a cooperation of actors starting from the base, rather than the top. I believe that the latter would exclude results which lower welfare with a higher margin of success. To make this possible, we have to clearly define the duties of the government nationally as well, while also implementing impeaching. The goals of this are to avoid political instructions which are non-productive, the complete transparency of markets, and the establishment of various safety nets. We also need to assist national markets, the actualization of a sustainable and productive national agriculture and a transparent food-trade system, the creation of food reserves, and assistance to producing local foodstuffs on local fields. I believe that for this, creating local cooperation, and using examples of implementation is necessary to reform grounding or non-productive central decisions.

The national water footprint calculations offer a chance to peek into our freshwater-extraction. For this, I believe that the main objective is to develop a calculation walkthrough for Hungary, which will help and combine calculations in case of questions regarding methodology popping up. Its goal, parallel to an international walkthrough, is to establish an intelligent water footprint database, ratifying simplifications, combining the time-wise changes in situation, combining the depth of detailing calculations, creating policies for hazardous material inclusion for all different hazmats, numerification of various environmental values, and spreading awareness and information for our country. Domestic enterprises and educational, or research institutes entering the water footprint network is in my view a most welcome thought, due to them expanding their knowledge, and building relations beyond borders by entering workgroups. There are numerous developments to be made in water footprint theory, f.e. linking it to footprint methods, or other methods evaluating impact on the environment. International connections may bring forth a more productive result, since water flows both above and beyond ground, and their usage demand decisions which transcend national borders. As a reference, according to the performance of some producers, we could also work out water footprint reference bases for domestic products as well, however, they should not be used for quota-trade in my opinion, due to the water footprint sorely lacking. Beyond providing domestic water footprint calculations with data, they should also offer sustainability evaluations and definite answers, for the sake of water footprints becoming a decisive factor included in water-policy decisions. Also, the water footprint index yields domestic results, which have to be used and maintained in a correct fashion, since basing decisions upon this exclusively might become dangerous, due to it being in close proximity with Gross National Income, consumer habits, weather climate, and most notably evaporation requirements and agricultural practice. I believe that as an addition to the water bills managed by KSH, water footprint calculations could become a part of national reports, and could thereby appear in national statistics as well, which are open to all interested parties. And in case of some specific enterprises, it could become an element of sustainability analyses. Furthermore, proper calculations need to be done, to determine if it has a role in establishing our dependences due to its import-export habits and policies. If it does, we have to decide what we will do with this problem further on, since this role can lead to diplomatic relations that are to be handled with care. Therefore, in my opinion, we need to scan our domestic import-export habits, in a way that it reflects virtual water streams, which make others dependent on our country, or our own country dependent on others without sound reason. The water footprints resulting from consumer habits, which are mostly undue, can be shaped through widening knowledge base, and spreading awareness. It is therefore preferable that water consumers create a lower water-sensitivity threshold. I believe that for this to actually happen, Hungary also has to take part in establishing international, ratified protocols regarding sustainable water usage, a fair international water pricing protocol, and an international water footprint enablement system. Furthermore, our specialists have to take part in the actual planning of these systems, so that the various stakeholders are favored not by having an unfavorable effect on each other. To make this possible, we have to analyze the virtual water-savings related to the trade of products from our own database, and level them rationally, in a way that it doesn't unreasonably hinder other nations. We also have to inspect if there is a nation that irrationally outsources its water footprint or one of its types to our nation. If this comes into play, we have to research its reasons, and take steps to handle these unfair advantages. We have to decide, and occasionally overview if the local, regional, national or global level is the sufficient one regarding virtual water-savings, since all of them have different impacts on national water resources. I believe that we have to evaluate water productivity regarding our homeland on two different levels. One of these is the national level, where the rise in regional and local water productivity may surface. The other is the international level, where the rise in our nation's total water-productivity might become more important. The demands have to be evaluated, and if they're well-reasoned, measures must be taken to achieve them. If they are poorly conceived ideas, then we have to protect ourselves from needs for detrimental changes, most notably on a national level. Both methods require thorough supervision from time to time. Using the water footprint method is in my opinion also something which cannot be taken out of context. Usage of the water footprint index has to be exploited in all possible ways, but its results and method has to be further advanced for the sake of development, and has to be balanced with the other factors of society, economy and environment contexts.

In this dissertation, the method worked out and employed is based on my old research calculations. Actualizing the already obtainable national water footprint calculations is in my opinion offering an opportunity, and creates a context of comparison, by which we can gain further results useful in creating deductions towards optimizing domestic water usage. Water footprints also offer the opportunity to work out other methods. For the sake of these based on well-conceived cornerstones, we have to contribute to make the water footprint method clear as soon as possible, and have to increase the quantity of domestic water footprint research projects. I believe that critically appraising the water allowance coefficient (WaC) is required, so that it bestows an index as effective as it can get upon us. If there are apparent problems, then those have to be solved. The water allowance coefficient's assorted value (WaC(av)) offers a chance to f.e. inform decision-makers with the reference values of some of its components, how the value of the water resource's agricultural usage is. However, according to my opinion, using this as a basis of quota-trade may become an irresponsible decision. It offers extra information to evaluate the green-, blue- and greywater sorted assorted values beyond the regional division (WaC(av)), and the reasons for their values, or their connections, their level and direction to certain variables, like economic indexes, population density, time indexes, demographic data, or material costs. Furthermore, I believe that the assorted values of water allowance coefficients (WaC(av)) need to be further evaluated by using other side-factors, f.e. population density, income, investments, or some other time factor. Also, the water allowance coefficient (WaC) coupled with other natural resource-evaluating methods may become a correctional side-factor f.e. evaluating soil.

The water footprint, the water allowance coefficient (WaC) and its assorted values (WaC(av)) have to undergo correlation analysis, since it offers opportunities for further research. For this, I believe we need to include as many externalities as possible, f.e. precipitation, duration of sunshine, income by person, agricultural soil by person, population density, age brackets of population, watering technology implemented, or other various factors. Due to the low quantity of the sample, when we look at the results of the regional correlation tests and cluster analysis, it might come as natural that it's different to f.e. researching on a county or sub-region level, even over borders. However, this also has the inherent criteria of the standardized water footprint calculations, and the availability of the database. However, we have to see in this case that water's properties as a natural resource aren't bound by administrative borders, meaning during either its usage, or evaluation of usage, we have to include this as a factor which has an impact on results. The further evaluation of clusters may shed light on additional, nationally unique connections beyond the inclusion of factors outside of the summarization process and reliability tests, as was seen in the correlation analysis' case. I believe that segmenting the values related to water footprints in many possible ways may simplify the establishment of border systems aiming at increasing water usage efficiency, and implementing them in a manner required by the actual area, which may be possible beyond national borders, if the calculations are harmonized.

Since the water footprint results depicted regions from a water-policy demand, and opened the way to new domestic research, analysis and changing national water consumption habits, my hypotheses H1, H2 and H3 stand true, since when including the pros and cons of the water footprint, a national water footprint estimation system was established on the regional level, which obtained a new function when corrected with market price, and was therefore able to provide a momentary outlook on the monetary value of water usage, contributing to understanding the true worth of water. However, my H4 hypothesis holds true only partly, since the correlation- and cluster analyses proved to be implementable research methods in evaluating the final results, but due to the low quantity of the sample between our national borders, their results are not reliable, and therefore need further research.

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