4. WATER VALUE AND WATER RESOURCE EVALUATION IN HUNGARY

Csaba Fogarassy – Éva Neubauer

„All natural resources, especially agricultural land, forests and drinking water supplies, biodiversity – in particular native plant and animal species – and cultural assets shall form part of the nation's common heritage, and the State and every person shall be obligated to protect, sustain and preserve them for future generations."

The Constitution of Hungary

Introduction

Present appointed target of this study is monetary valuation of 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 the economic aspects and methods and their needs will be discussed.

European Union is undoubtedly one of the most influential factors on the present state of our domestic economy, and it is not different in case of water resource management either. The EU determines in its Water Framework Directive for all member states the condition in which this important natural resource must be. The European Union taking into consideration the concerning contracts and Commission opinions justifying the necessity of its establishment has adopted in 53 points the 2000/60/EC directive on 23rd October, 2000, the definition and framework of community action in water politics (EU VKI, 2000). The alignment to Water Framework Directive (WFD) at national level required many years of research and consultation to conduct a qualitative and quantitative survey and classification of the water resources of Hungary. Of course, it is required to continue this work, to conduct monitoring, and to make necessary corrective decisions in the future.

It can be accepted that the mentioned research results and their attachments of National River Basin Management Plan (NRBMP) are the main pillars of national water resource evaluation. At this approach, NRBMP, which was prepared in accordance with the requirements, can serve as the basis of future evaluations of water resources. This vision could be welcomed by us, because for this reason water resource evaluation methodology can be performed with increasing security and the possible comparison of the resulted values could be more established.

In this study, we try to explore the economic aspects of water resource and determine which the most acceptable versions are for us. In addition, we strive to describe water resource evaluation methods in a wider range rather than selecting or developing one, which can best illustrate the estimated value of water resource of Hungary with current available knowledge and data.

4.1. Economic approach of water resource

Decision makers in water resource management take certain driving forces into consideration during their strategic planning, which can determine our competitiveness within Europe. These driving forces are, in broad sense, for example demographic, technological, economic, social, environmental and institutional or even changing attitudes and international processes. These factors can be external factors, on which we have no influence, internal factors, which are the present conditions and traditions, and the mixed ones (Somlyódy, 2011). From these factors, we can conclude that hydrological resources can be strategical environmental and social factors, while the result of water resource evaluation can be considered as an economic driving force. In our case, all the three can be considered as mixed driving force, because each environmental, social and economic ones has elements both beyond and depending on our control.

The economic definition of water resource can be accepted from Ress (1988, p. 9.), who considers it as the elements and attributes of the natural resource, which can be used for satisfying the needs of a society at given or expected technological state of development. This concept assumes two axioms:

- „physical, chemical, biological characteristics of water determine advantageous and disadvantageous attributes for society, of which carrier is the material of water. This is the value of water recourse potential."
- „Satisfaction of human, economic and environmental needs are related to valuable attributes
  - quality, quantity,
  - energy,
  - maintenance of living space of biological movements,
  - effort on risk minimizing in economic, environmental approach."

In the economic development process induced by the changing needs, economic value of water is formed by different structure of elements. Namely, the development level of productive factors in a given period, the environmental, economic and human water demand and the need for water use are the main determining economic factors of water resources. The historically changing structure of the use of these resources is determined by three value factors: value of resource, value of utilization chain and used external cost. From the natural side it is determined by resource balances, capacity balances and the satisfaction balances (Ress, 1988).

According to Marjainé (2005) economic approaches of natural resource valuation are estimations to express in money the social value of quantitative change and to reduce the advantages and disadvantages from many areas into one dimension.

In other words, this is the evaluation of spatially and temporally defined, advantageous and disadvantageous characteristics and the positive and negative effects of physical, chemical and biological attributes of water. It is based on objective determinations, and appoints the directions of utilization. Each attribute can be shared by multi level categorization. This can be, for example according to utilization (such as material, energy, and living space), spatial appearance, temporal changes, risk, etc. Adjusted to the changing needs, the presence of water as a potential value system can be determined in monetary units, score, dimension, etc (Ress, 1988).

4.2. Economic approach to define characteristics of water resource

Water is a natural resource that can be found all over the country. There are spatial and temporal differentiation in its quality and quantity thus demand appears differently in these dimensions (Ress, 1988).

Beside the fact that water is classified into the group of natural resources according to its features, it can also be described with specific characteristics. In general aspects, as a natural resource, it has life sustaining function, a natural condition that a human being or the society use for satisfying their material needs at a given technological level. Water is a renewable, namely a flow type natural resource. That means that in spite of its use it can be regenerated by the laws of nature in a perceptible time by humans (Bora, 2001). But renewable resources can be used until exhaustion if the rate of usage [or pollution] is higher than the rate of reproduction [or purification]. Among the renewable resources, this group is called the critical zone. Typically, those natural resources are included here where the recovery of supply processes does not take place even after the usage of the resource stopped (Rees, 1985).

Table 1: Classification of natural resources (part)

Renewable (flow) resources	
Without of risk of critical zone	**With the risk of critical zone**
solar energy	flora
geothermal energy	forests
atmospheric energy (wind)	fauna
water (hydropower)	aquatic ecosystems
tidal	part of water resources
waves	soil
marine currents	
biomass	

Source: Bora (2001, p. 16.)

Table 1. suggests that the natural kinetic activity of water cannot be exhausted by any over usage or over pollution according to our present knowledge. In addition, although one part of water resources and aquatic ecosystems are able to regenerate, but they can reach their limit of capacity of regeneration with over usage or over pollution and if this is exceeded, they become non-renewable ones. Well known examples for this are over-fishing, over-withdrawal of karst water, leaching of chemicals into shallow lakes or certain river sections which reduces assimilation and can causes algae, siltation or decease (Bora, 2001).

With a few exceptions, water as a natural resource is part of the national wealth. Without claiming completeness, the following laws are in order:

- Act CXCVI. of 2011. on national wealth, **Chapter II. Property types belonging to the category of national property**, 1. State property, 4. § (1) d) - e) paragraphs, and: Enclosure 1. to act CXCVI. of 2011., **Exclusive property of the state**, A) Rivers, streams, backwaters, tributaries and their river bed, and register of water establishments.
- Act LVII. of 1995. on water management, **Chapter III. Provisions of property and operating of property,** 6. § (4) a) - c) paragraphs

4.3. Methodological background of water resource valuation

Considering the renewal rate of water resource in total, it can be interpreted as a limited natural resource. This is an absolute limit, which suits to Malthusian limits, therefore quantity and renewal rate are constant. In our case, synthetically produced water is not taken into consideration. In addition, the relative limit, which determines consumption, appears at a certain level that is determined by place, time and purpose of usage. Relations among these determinants are represented by transport and storage costs. Finally, limits can be permanently static or variable dynamic ones (Ress, 1988).

During our research, we try to calculate the value of water as a natural resource. By this aspect, we mean that it is part of the national water resource, which is used or can be used considering usage directions of multi-dimensional human activities. This, in itself, assumes that this part of water resource is known and (can be) used at given level of needs and technology. This study does not include those elements of life cycle, which are connected to exploitation and subsequent levels of being, like costs of construction and maintenance of infrastructure, storage, redistribution or managing pollution. These factors are evaluated typically at market-base.

Considering the task, in system-based approach, following Tyteca (2001), economy can be considered as it is implanted in social and natural systems, so these systems are interrelated with each other.

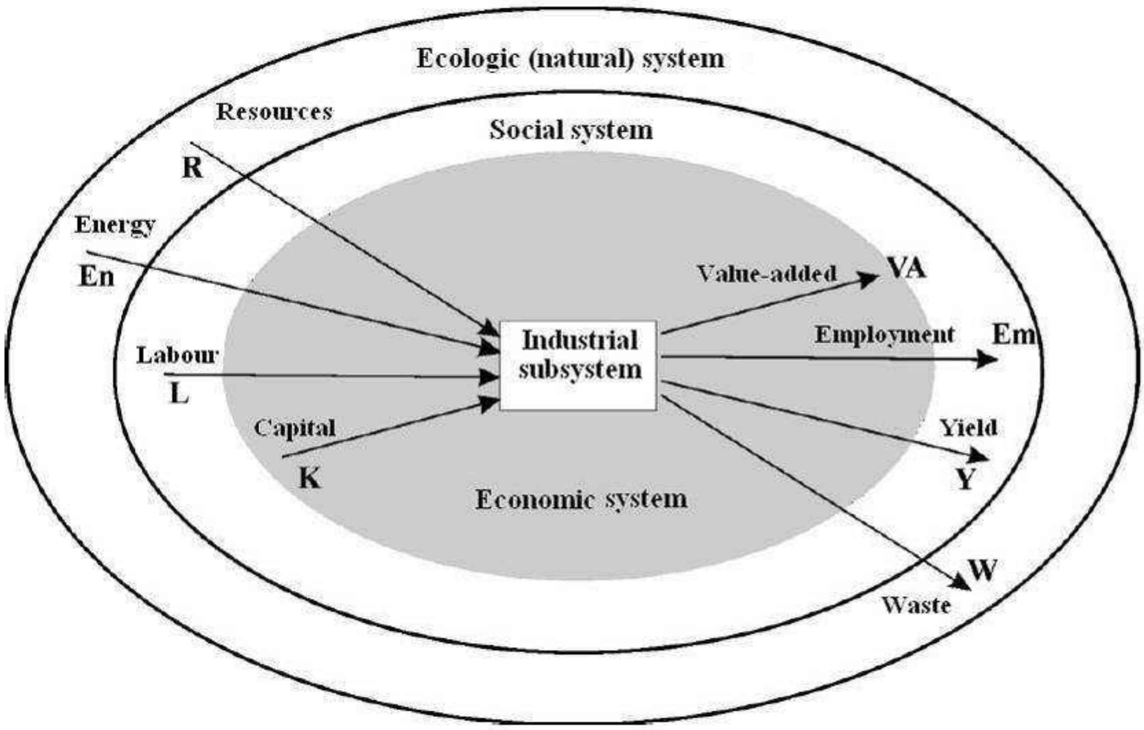

Figure 1: Implantation of economical, social and ecological systems
Source: Tyteca (2001) cited by Kerekes-Fogarassy (2007, p. 47.)

Water appears in all the three systems; in the ecologic one water cycle is essential as a transfer medium and living space at macro and micro level. Human settlements have always been established near main water streams and culture and economy has also been developed there. Economy was built on water usage, because all the economic sectors basically use water both in a direct and indirect way.

In addition to the mutual relationship the existence of these systems is depending on each other: typically from inside out as it is illustrated by Figure 1. Thus, our social system is built on the ecologic system; the former cannot exist without the latter one. Our economic system is built on our social system, but this in turn, cannot exist without the presence of both social and ecologic systems. In our opinion, these conditions must be taken into consideration in the method.

An interview with Dr. Sándor Ress[15] appointed the practical part of water resource valuation, and the diversity of elements used as the basis of evaluation as well as the responsibility accompanies defining these elements. According to his experiences, the random variable is actually the availability rate, and water need is not equal to water demand, because when price appears the value of the difference narrows down.

Labour theory of value in the case of water is not working even not in the sense of water exploiting. The only exception is when water is artificially produced.

Relatively new factors appear in the calculation of potential value, namely the *value of existence* and the *value of heritage*. A good example can be as follows: the value of a granny would represent the former one and the next generation(s) is represented by the latter one.

We must determine during the evaluation what water as a natural resource is mainly suitable for, but the exact factors cannot be defined at this stage of the evaluation process. For example quantifying of changing of biological processes is very difficult, expensive and inexact or mostly impractical. Evaluation should be restricted to welfare factors because the biological needs of humans cannot be specifically accounted.

Expenses must be defined with the consideration of correcting, value-reducing factors. These features in general are known that the more costly is less valuable. It can be interesting to consider the case of water that for example we have to pay at drought, but not at flooding though with intervening in conditions of drains we have to face with economically invested objectified capital. However, for example, in relation to maintenance costs at infinite time horizon this cannot be evaluated.

The starting point of one-by-one evaluation is the principle of cardinal utility, in other words it means that certain composition of properties cannot be replaced with each other. A good example for this is the therapeutic value and energy of thermal water. Separately both of these properties can be replaced with certain costs. But these two replaced parts will never give the utility as original thermal water, because the whole is always more than the sum of its parts. Take for example thermal water at Parád[16]. Valuation of bottled Parádi sulphurous thermal water is market-based, but Parád spa represents cardinal utility, because it cannot be replaced, there is no other like that. In addition, in case of replacement its value need to be corrected by travel cost or benefit transfer and remediation or cleaning cost must also be accounted. These vectors must be evaluated both individually and in groups. In connection to water resource, it can be evaluated for the present or future. According to Ress (1988), present valuation is the valuation of water resource as part of the national resource. This can be the basis of both water management decisions and future valuations.

"When the well is dry, we learn the true value of water."
Benjamin Franklin

4.3.1. Non-use value

Existence, intangible value

In this case, following the opinion of Kerekes−Szlávik (1996), value of existence can be understood as the value of being itself. At this approach, water resource has value if

[15] Dr. Sándor Ress is present chairman and CEO of Hungarian ÖKO Inc. After many years of research his results on water resource evaluation was published in 1988, which is one of the bases of present study. The interview was in 27. August 2012.

[16] At Parád there is one of the greatest thermal spas of Hungary.

society takes care of its long-term existence in this value. The formula can be written like this:

$$\text{Existence value} = \text{multitude of organisms} \cdot \text{intangible value} \quad (1)$$

where:

multitude of organisms = biocoenosis can be found at the area,
intangible value = nature protection value of elementary object.

It follows that:

$$\text{Intangible value} = K \cdot [R + T \cdot (A+e)] \quad (2)$$

where:

K = category multiplier (0,1–1,0)
R = rarity (0–50 point)
T = type multiplier (0,1–1,0)
A = base value (5–45)
e = unique index (-10 – +5).

The natural value of elementary object must be assessed with careful objectivity. Following the thought of existence value, Equation 1. can be used in our case at sub-unit, sub-basin and country level.

Heritage value

Citing Marjainé (2001) "there are numerous explanations on the existence of heritage value which summarized by Freeman III [1994] as follows: 1. the intention is to leave certain resources by will for our descendants and for future generations; 2. feel responsibility for conservation of natural resources or their certain properties; 3. the desire to keep the opportunity of usage of natural resource in question by others." In our opinion heritage value comes from the value of "being" and has to express that given water resource might be the reflection of thousands of years. This is the value of which benefits are respected, enjoyed by present society, but which is available after thousand years with the same technical conditions.

4.3.2. Use value

Calculation of benefits based on imputation

With mathematical economic methods it can be shown how effectively the unit elements of a supply proportion to be valued are utilized at direct or final consumers. In our case it is calculable how much the benefit, which was generated during the production process, is included by a unit of the quantity of water resources. The bases of the calculations are modified Cobb-Douglas production functions, in which elasticity coefficient relate to water can constitute a basis for the evaluation of water resource (f_{ij}).
Value of water resource:

$$E = \sum_i \sum_j x_{ij} \cdot f_{ij} \quad (3)$$

where:

E = Value of used water, utilized hydrological conditions. Annual outcome attributed water resource.

x_{ij} = Volume of water resource can be utilized by *j*th consumer related to *i*th supply component. So, volume of water resource used from *i*th water quarry by *j*th consumer.

f_{ij} = Benefit attributed to one unit element of supply proportion, elasticity coefficient related to water.

This method is mainly suitable at those water usage directions, where correlation relationship can be quantified and defined between benefit and used water as production factor.

Benefit calculation set out from principle of substitution

Substitutability of each supply unit at any consumer can be revealed and by this way, proportional numbers of substitution (h_{ij}) can be defined regard to the examined substitution alternatives. Evaluation can be accomplished by quantifying cost-savings or demonstrable surplus outcomes compared to outcomes or costs of substitution variables.

In case of one substitution variable, if the result, which can be attributed to the variable can be valued according to *calculation of benefits based on imputation* the relation below can be used.

Correlation in case of one single substitution variable:

$$E = \sum_{i} \sum_{j} x_{ij} \cdot H_{ij} \; (i, j = 1, 2, \ldots) \tag{4}$$

where:

H_{ij} = Surplus outcome shown against substitute variable on unit of used water resource.

It follows that:

$$H_{ij} = h_{ij} \cdot (g_{ij} - k_{ij}) \tag{5}$$

where:

h_{ij} = Substitution proportion rate indicator. Denotes how many unit elements of substitution variable of given usage are able to replace one unit element of the examined *i*th type water resource (generally smaller than one).

g_{ij} = Net annual outcome attributed to one unit element of substitution variable of *i*th type water resource unit element at *j*th consumer.

k_{ij} = Production, withdrawal cost of utilization of *i*th type water resource unit element at *j*th consumer.

If the result attributed to one single unit of substitution variable (g_{ij}) cannot be concretized, that costs of one single unit of variable must be considered. In this case, therefore, g_{ij} represents expenditures.

In case of more substitution variables compared surplus outcome (H_{ij}) can be calculated as:

$$H_{ij} = \min_{k} \left\{ h_{ij}^{k} \; (g_{ij}^{k} - k_{ij}) \; (i, j, k = 1, 2, \ldots) \right\} \tag{6}$$

where:

k = Number of variables.

This method is mainly suitable in those cases where water utilization can be compared to other solution alternatives.

Benefit calculation deducted from formation of differential allowance

D_{ij} proportion of real costs of one single unit of water production, obtaining can be received with defining real costs of water production, obtaining in case of all utilization directions (*j*) and quarries (*i*).
Context:

$$D_{ij} = \max_{j} \left\{ D_{ij}\ (i, j, k = 1, 2, \ldots) \right\} \tag{7}$$

where:

D_{ij} = Maximum cost at which acquisition costs of water are also refunded at social level. (Costs of marginal water quarries.)

Annual outcome attributed to water resource can be written from these as the following equation:

$$E = \sum_{i} \sum_{j} x_{ij} \cdot (D_i - D_{ij}) \tag{8}$$

where:

$D_i - D_{ij}$ = Differential allowance on water usage type (*i, j*).

Any of the methods based on quantified benefits can be used depending on aim and feasibility of research and data availability (Ress, 1988).

The basis of property, resource valuation of components with positive effect are given by outcome proportion of usage of produced water resources at a given level of development.

On the other hand, the basis of property, resource valuation of negative, threatening components are given by value of damage of non-built protection capacities also at a given level of development. These are for example, *lost production values*, additional costs of *rescue and damage control* and *value of damaged components of national property*. Extents of these negative components are depending on type, presence and appearance of damage, extent of protection, economic and geographic structure of a given area. Internal waters just like rainfall conditions are mostly calculated in land evaluation (Ress, 1988).

4.3.3. Cost-based valuation methods

According to Marjainé (2005), the initial assumption of these methods is the value of natural resource; in our case water, is equivalent to the extent of utility it provides for humans, which is equivalent to the extent of costs of conservation or/and restoration.

Marjainé also accepts two assumptions in national resources evaluation. According to the first one, people's income and changes in natural resources are replaceable with each other, so people accept decrease of environmental conditions, if they get compensations, and vice versa, with decreasing income they can live in better environmental conditions. According to the other assumption, the only thing is worth, for which people are willing to pay (Marjainé, w.y.[17])

[17] w.y.: without year

Failure of **cost-based valuation methods** is that they cannot make real difference between alternatives, since extents of benefits of natural resource are considered to conservation costs. Real benefit by natural resource is probably not equivalent with the costs of maintenance, therefore this group give significantly distorted result (Marjainé, 2005).

This group includes the following methods: *productivity change method, defensive expenditure method, shadow project method, cost recovery method and the method of substitute goods.* These methods are very similar to each other. Their advantages are that they can be accomplished relatively easily, data is relatively easily available, and forming of the value of a change takes relatively short time (few months). In contrast with these, they are suitable only for determining values related to usage; their usage is not recommended in case of dominance of non-use values; the resource values estimated by costs or benefit can be distorted (two times higher expense do not mean two times higher benefit; the value of the underlied natural resource is often only in indirect relation with the valuated goods (Marjainé, 2005).

Besides these, the methods that estimate by demand curves can be used. One of the large group of them is called **revealed preference methods**. A main feature of these methods is that their inductions on demand of natural resource connected to product or service are related to changes in consumption, so these are rather ex post than hypothetical. Here the aim is to identify events at which behaviour of market participants and prices are affected by the change of natural resource (Marjainé, 2005).

Dr. Sándor Ress revealed that the extent of economic utilization of each water body could be analysed. The higher this value is the more preferable of using of given water body as natural resource is.

Its most commonly used methods are *travel cost method* and *hedonic price method*. These two valuations are more suitable for determination of certain value parts, and not for the whole natural resource evaluation and research where results meets with the fundamental difficulties of qualitative research, and therefore distortion must be expected at these cases (Marjainé, 2005).

The third group of methods, which is called **revealed preference methods** also belongs to methods estimated by demand curves. Their characteristic is that they outline hypothetic situations where respondents do not express their preferences by their behaviour at market. Methods of this group are *contingent valuation method*, *contingent choice method*, and *contingent ranking method*. These methods can also be false due to their hypothetic way, they require professional skills and practise, and are often expensive and time-consuming. However, they suit for water resource evaluation, since value judgement of those who are not directly involved can turn out, and allow exploration of value of conversions (trade-off), thus monetary definition (Marjainé, 2005).

In summary, these methods are typically used in a mixed way by experts, at certain cases in order to obtain more complete values which are closer to reality (Marjainé, 2005). In our opinion, these methods should have been calculated with value of water as natural resource. This would exclude the assumption that only that is worth something what people are willing to pay for.

4.4. Interactions considered

4.4.1. Dependence of system constituents

For the construction of methodology, independence axiom of Edgeworth is considered. This, after Berde-Petró (1995), is the following: "total utility can be very rarely broken down to the sum of separate utilities of each good.” In our view, this is supported by the statement that the whole is always more than the sum of its parts.

4.4.2. Mutual effects

It is acceptable, that there is mutual relationship between water resource and its directions of usage at water resource evaluation in which controlling mechanisms are in action. At this context, these directions can be probably split into two groups. Factors of effects, which have impact on water resource at a given knowledge and at a given level of technological development, are in one group. And those factors on which water resource has an impact on are in the other one (Figure 2.).

Figure 2: Schematic representation of mutual relationship between water resource and its usage directions
Source: own editing

4.4.3. Summary of variables, factors

The European Union’s Water Framework Directive (EU WFD) provides a strong national framework at domestic level for present water situation. Therefore, in our opinion, sub-basins and their sub-units are defined in National River Basin Management Plan (NRBMP) of which smallest units are water bodies can be extent at water resource evaluation of Hungary. These are as follows:

Sub-basins (4 pcs)

Sub-units of sub-basins (42 pcs)

Water bodies (185 surface water and 953 groundwater) (VKKI, 2009)

The factors of evaluation which are taken into consideration in this work are classified into three groups. For each of the factors typically according to the groups different weight have been given in the evaluation.

Group of factors of sustainability

Value of these factors can be weighted more heavily, because all the others, natural conditions and social usability are formed from this. Values belonging here areas follows:

– *existence value*,
– *uniqueness value* and
– *heritage value*.

Group of natural characteristics of water

This group is typically about classification which system is worked out in EU WFD, which is completed by requirements of socio-economic needs of properties of water resource. Features are included in this group are less weighed than factors of sustainability. These are:

– volume and surface area of the water resource,

– quality according to WFD: excellent, good, moderate, poor and bad.

WFD is “serving for determination of biological indicators requiring detailed, species listed survey, furthermore for determination of morphologic and hydrologic features of water body and its environment, and for determination of specific pollutants to characterise water status. ... must be examined during the qualification process if biological classification is supported by physical-chemical state or not. ... WDF requires “wrong one wrong all” principle during aggregated classification, i.e. result of worst classification is the reference in all case” (Clement–Somlyódy, 2011).

Conditions determining social consumption

This group includes those factors which arise from our culture or which have influence on our economic decisions. From these, by rearranging, the value of certain directions can be differentiated which then show with add up representative value considering the water resource. These factors, because they can be influenced by anthropogenic factors, are less weighed than factors of natural characteristic:

– needs,
– prices,
– social utilization direction.

At this point value modifying factors can be mentioned which can build into all the three elements. These can be, according to Mizseiné (2010) for example position, location (distance from inhabited area, food processing plant), accessibility, road conditions, use inhibitory landmarks, demographic conditions, farming traditions, aesthetic impression, economic environment, infrastructure, public utilities, natural protection of area, et cetera. These factors can be interpreted as contingency allowance elements determining water as natural resource allowance. In our case, we must account in water resource evaluation with three factors in socio-economic system at given technologic level. Interconnection of these, parts can be seen in Figure 3.

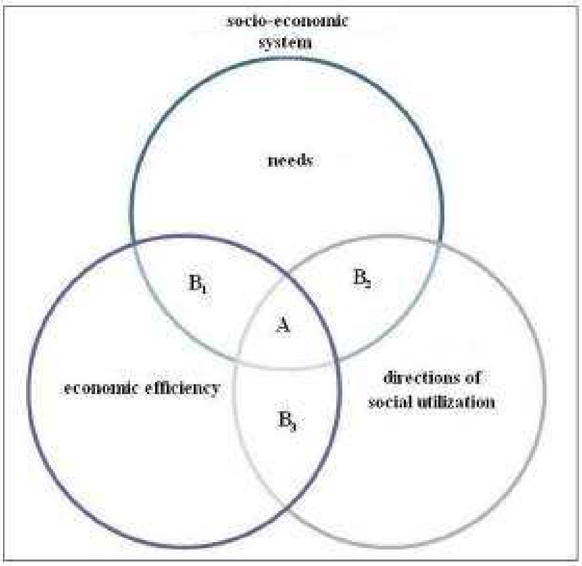

Figure 3: Schematic representation of merging of socio-economic conditions established to natural resources
Source: own editing

Figure 3. displays the following factors:

– needs: requirements, needs considering to water usage,
– economic efficiency: considering to practical satisfaction of needs,
– direction of social utilization: practical applications.

The overlapping sets according to Figure 3., can be interpreted as all three factors are present in *Section A* in sufficient quantities for existence or implementation. It means that practices and utilization directions exist to satisfy emerging needs and market prices do not hinder them. (This part of the figure can be closest to practical issues of water management.) There might be a need which would meet the effective demand, i.e. need and economic effectiveness are presented (*Sub-section* B_1), but certain activity cannot be classified into any current utilization directions, practical background of realization is absent. Furthermore, there are needs which are too expensive and cannot be satisfied even with the presence of current utilization directions (*Sub-section* B_2). And it is also possible that prices and current utilization directions would allow certain kind of utilization of water resources, but need does not appear for it (*Sub-section* B_3).

Social utilization directions of *Section A* are listed at this present research. For further calculations this group is enlargeable. In light of quality and quantity, completed by Ress (1988), these are as follows:

– communal sector,
– industry,
– agricultural irrigation,
– production of water products,
– pollutant disposal,
– shipping,
– recreation,
– hydropower generation,
– thermal water utilization.

Each utilization direction is considered as consumer goods, utilization final products that target satisfaction of needs. In our view, each of the utilization directions has rent proceed on which water resource valuation can be clearly based.

4.4.4. Interpretation of water rent

During the interpretation of water rent we proceeded from the fact that producer price of final water product (V_{up}) is depending not only on the average profit of producer but on the access cost of marginal quarry, too. It follows that:

$$\text{Water rent} = V_{up} - \text{access cost of better quarry than marginal one} + \text{average profit} \quad (9)$$

In other words, production costs of marginal quarries and their components, as well as average cost per water unit from one unfavourable water quarry can be understood as utilization final product, which were the bases of water rent calculation.

Rent according to utilization directions interprets and evaluates water resource in one system at national (even international) level. According to this, asset value of water as utilization final product (V_u) is:

$$V_u = \frac{\text{water rent} \pm \text{externalities} \pm \text{potential rent}}{\text{capitalisation real interest rate}} \quad (10)$$

Total asset value of national water is:

$$V = \sum g_u \cdot V_u \qquad (11)$$

where:

g_u = relative weight rate of each water utilization directions.

4.5. Water Allowance Coefficient

4.5.1. 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 international level. Development of the methodology is linked to the Dutch professor Hoekstra. 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. Whit 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" (Neubauer, 2010. p. 2). Researches of this direction may reveal the absolute water need throughout the total product life-cycle. 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 different phases of the supply chain (www.waterfootprint.org). Numerous studies and researches have been conducted to highlight water need of our consumption and production habits through water footprint calculations. These reasons also turn out during the calculations, thus water productivity can be increased with high efficiency by appropriate decisions.

It turned out from the estimations that, for example from aspects of national water footprint of productions, globally China, India and the USA have the highest total water footprint (1 207, 1 182, and 1 053 Gm^3/year[18]). About 38% of the global total production takes place in the territory of these countries. The next on the list is Brazil with 482 Gm^3/year, which is just a fraction of the preceding ones. India has the highest blue water footprint with 243 Gm^3/year, which is 24% of the global total blue water footprint value. Responsible for this are the irrigation of wheat in 33%, of rice in 24% and of sugarcane in 16%. China has the highest grey water footprint, 360 Gm^3/year, which is 26% of the total global grey water footprint value. It also turned out, that agricultural production has the highest water footprints in all countries. In industrial production, the USA and China have the highest water footprints with 22% and 18% from the total global industrial water footprint. The water footprint of industrial production of Belgium can be interesting with

[18] Gm^3: giga cubic meter. 1 Gm^3 = 1 000 000 000 000 000 000 000 000 000 m^3, with other words 1 $Gm^3 = 10^{27}$ m^3.

its 41% of the total national water footprint, while the agricultural is 53% and the remaining six percent responsible for the household consumption.

The global annual average water footprint during the period 1996-2005 in relation to agricultural and industrial production and household water consumption is 9 087 Gm^3/year. 74% of this is green, 11% is blue and 15% is grey water footprint. Water footprint of agricultural production is significant 92% of the total global value. Industrial production is taking only 4,4% and households are 3,6%.

Global water footprint of products produced for export is 1 762 Gm^3/year. In agricultural sector, 19% of the total water footprint is the value of export products. In industrial sector this is 41%. As the average of the three sectors it is seen, that 19% of the total global water footprint of production is not for domestic consumption but for export, thus generating international virtual water flows.

The global sum of international virtual water flows related to the trade of agricultural and industrial products is on average 2 320 Gm^3/year in the period 1996-2005. 68% of this is green, 13% is blue and 19% is grey water footprint. 76% of the total global value is related to trade of crops and crop products. Responsibility of trade of livestock and industrial products are 12-12% of the international virtual water flows. It is concluded from the results and background calculations that export goods are more strongly related to surface and groundwater consumption and pollution than goods which are produced for local consumption.

"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."

Leaders of gross virtual water export countries, which are together responsible for half of the value of total global virtual water export, are the USA, China, India, Brazil, Argentina, Canada, Australia, Indonesia, France and Germany. The USA, Pakistan, India, Australia, Uzbekistan, China and Turkey are the responsible for 49% of total global virtual blue water trade. Because these countries have to struggle partial drought, it raises the question of whether the implicit or explicit use of this scarce national resources into blue water export production is the most efficient and sustainable choice or not. Closely related matter is how much is the reflection of water scarcity in water prices in these countries. The fact is that externalities hardly appear in water prices and it is more typical in agriculture. We cannot expect that production and trade patterns are also automatically counted with the regional scarce patterns of water.

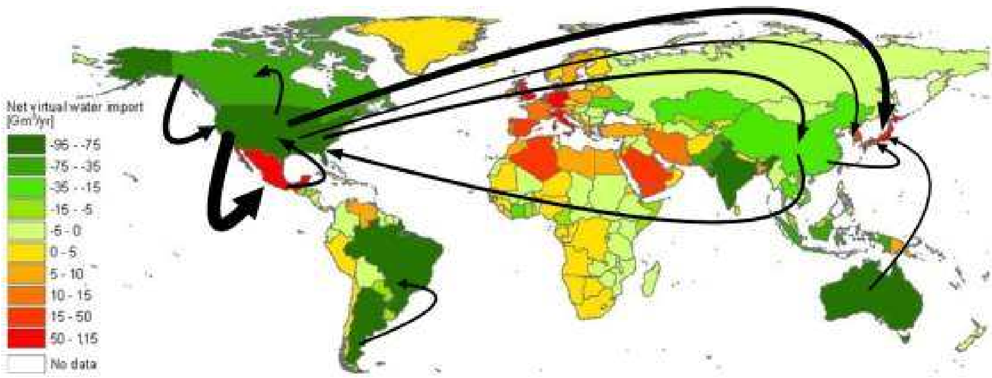

Figure 4: Virtual water balance per country and direction of gross virtual water flows related to trade in agricultural and industrial products over the period 1996-2005.
Note: Only the biggest gross flows (> 15 Gm^3/yr) are shown; the fatter the arrow, the bigger the virtual water flow.
Source: Mekonnen-Hoekstra, 2011, p. 21.

International water dependency of certain countries can be concluded from these estimations (Figure 4.). Total external water footprint[19] of nations is 22% of the total global value, although it varies by country. At some European countries, such as Italy, Germany, the UK and the Netherlands, external water footprint constitutes 60-95% of the total. On the other hand, in some countries such as Chad, Ethiopia, India, Niger, DR of Congo, Mali, Argentina and Sudan, this value is very low, less than 4%. Countries with high external water footprint are seemingly dependent on the freshwater resources of other countries. Countries with high water scarcity, which have extremly strong water dependency are Mali (dependency 92%), Kuwait (90%), Jordan (86%), Israel (82%), the UAE (76%), Yemen (76%), Mauritius (74%), Lebanon (73%) and Cyprus (71%). Not all of the water dependent countries have large external water footprint. Many northern European countries are like this, such as the Netherlands and the UK. Freshwater resource dependencies of other countries in these cases are not necessary, because agricultural production could be extended within the areas of the countries and thereby reduce their dependence on external water (Hoekstra-Mekonnen, 2012).

A recently conducted study shows the virtual water balance of agricultural products of the hydrologic regions, which are greater than 1000 km^2, of the Union (EU28 and Croatia). The result is net virtual water import of agricultural products, which is shown in Figure 5.

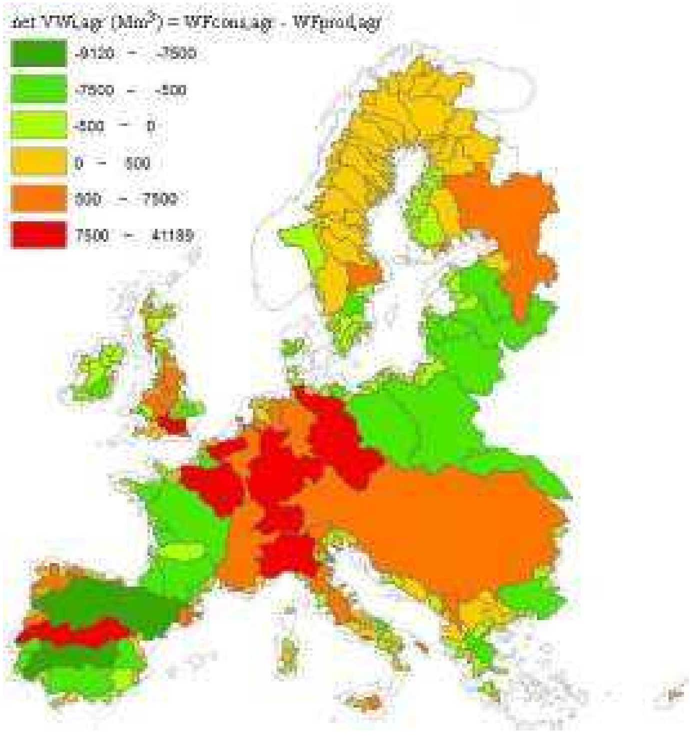

Figure 5: Virtual water balance of agricultural products of hydrologic regions, which are greater than 1000 km^2 in the EU (Mm^3)[20]

Note: net VW*i,agr*: net virtual water import of agricultural products

WF*cons,agr*: water footprint of consumption of agricultural products

WF*prod,agr*: water footprint of production of agricultural products

Source: Vanham, 2013, p. 55.

[19] The part of the water footprint of national consumption that falls outside the nation considered. It refers to the appropriation of water resources in other nations for the production of goods and services that are imported into and consumed within the nation considered (www.waterfootprint.org / a).

[20] Mm^3: mega cubic meter. 1 Mm^3=1 000 000 000 000 000 000 m^3, with other words 1 Mm^3=10^{18} m^3.

Net virtual water import of agricultural products is the difference between water footprint values of producing and consuming agricultural products. Overall, considering agricultural products the EU is a net virtual water importer, so more virtual water is imported due to the trade of agricultural products than exported.

However, there are enormous differences between regions in the EU. Net virtual water import values of basins of densely populated and industrialized regions of Western Europe are high, therefore, they are virtual water importers according to the virtual water balance. Such catchments are the Rhine, the Elbe, the Po, the Seine, the Thames and the Scheldt. On the other hand, rural and sparsely populated catchments, such as the Iberian Peninsula, Western France and the Eastern Baltic countries, have negative net virtual water import values; they are virtual water exporters (Vanham, 2013).

Previous researches have also highlighted the water footprint of wheat production. Based on water footprint estimations, freshwater need of wheat production in the period of 1996-2005 was 108 billion cubic meters. The majority of this (70%) was green water (rainwater, soil moisture), approximately 19% was blue water (irrigation of surface and groundwaters), and 11% was gray water (water need for dilute polluted water). The global average water footprint of wheat was 1 830 m^3/ton in the same period. Approximately 18% of it was devoted for export and not for local residents to consume. In addition, global average water saving from international trade of wheat products was 65 Gm^3/year. It turned out that blue water footprint is relatively high of water stressed Ganges and Indus river basins. These two basins were responsible for 47% of total blue water footprint of global wheat production.

It was also revealed that 93% of wheat consumption in Japan was coming from other countries, partly from the USA, Australia and Canada. In Italy about 44% of water footprint of average 150 kg/year/person wheat consumption, which was more than twice the world average, was outside the country mainly in France and the USA. Estimated data for Hungary also turned out form the study. For example, our country contributed to the total wheat production of the examined countries with 0,7%. This rate was 0,6% in the Czech Republic and 1,5% in Poland. Domestic total water footprint of wheat production for the period was 5 476 Mm^3/year (green 4 078 Mm^3/year, blue 8 Mm^3/year and gray 1 389 Mm^3/year). In the Czech Republic it was 3 734 Mm^3/year (green 2 834 Mm^3/year, blue 0 Mm^3/year and gray 900 Mm^3/year), and in Poland it was 14 517 Mm^3/year (green 9 922 Mm^3/year, blue 4 Mm^3/year and gray 4 591 Mm^3/year). The total water footprint of a ton of wheat in Hungary was 1 306 Mm^3/year (green 973 Mm^3/year, blue 2 Mm^3/year and gray 331 Mm^3/year). In the Czech Republic this value was 957 Mm^3/year (green 726 Mm^3/year, blue 0 Mm^3/year and gray 231 Mm^3/year) and in Poland was 1 639 Mm^3/year (green 1 120 Mm^3/year, blue 0 Mm^3/year and grey 518 Mm^3/year) (Mekonnen–Hoekstra, 2010). Generally, certain conclusions can be drawn regarding a given time period, that the domestic wheat production was typically demanding green water, which refers to the free falling rainwater, and, compared to this, required much less irrigation water (blue water). The value of related water pollution was relatively high, which would require a more careful investigation, this fact can have many reasons from incorrect support system to inadequate fertilization and pesticide use. While green and blue water footprints can only be decreased until the plant keeps the maximum yield, the gray water footprint can be reduced to zero by appropriate measures and prudent decisions.[21]

[21] See more definitions, interesting studies and scientific researches at www.waterfootprint.org.

4.5.2. Water Allowance Coefficient (WAC)

Water Allowance Coefficient (WAC), which can be described as availability potential of freshwater resource, has developed from thinking the estimation system of water footprint further. In the case of Hungary, it is based and foregone by national water footprint estimations of wheat production by Neubauer (2010). The results of this research were achieved by the following methodological steps by making some necessary simplifications, by CropWat 8.0[22] software.

The data required by the software to calculate the water need of wheat was gained from several information sources. The climatic data was obtained from the closest synoptic meteorological stations of the wheat growing regions. Other factors, such as humidity estimation, root depth, crop coefficient and soil data, was based on existing FAO database in the software. The received results were the value of reference evapotranspiration (ETo), solar radiation rate (Rs), and wheat water requirement (CWR). Data source of production of wheat was the national Central Statistical Office. It was necessary methodological assumption that during the cultivation of wheat crop water requirements were fully satisfied, so the conditions were ideal in order to not have any restriction of its growth and yield. Thus, the green and blue evapotranspiration of wheat can be equivalent to the total water requirement of the plant (ETgreen+ETblue=ET=CWR). Further calculations for the estimation of green and blue water footprint of wheat are based on this crop water requirement data, because:

$$WF_{wheat,green} = \frac{CWU_{green}}{Y} \quad \text{and} \quad WF_{wheat,blue} = \frac{CWU_{blue}}{Y} \tag{11 and 12}$$

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:

$$CWU_{wheat,green} = CWR_{green} \times 10 \quad \text{and} \quad CWU_{wheat,blue} = CWR_{blue} \times 10 \tag{13 and 14}$$

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 it is not possible to rely on the software, thus 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

[22] CROPWAT 8.0: Decision supporter software developed by FAO Land and Water Development Division. A tool that is used to calculate the water and irrigation needs of plants with certain soil, climate and crop data. By using it watering schedule of different crops can be determined and irrigation practices of farmers can be evaluated (FAO, 2010).

with wheat production, were available from databases of national Central Statistical Office and FAO.
Results of calculations and estimations can be seen in Table 2:

Table 2: 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, p. 43.

Based on the water footprint assessment we can state generally that a lower value of water footprint is accompanied with a more efficient water usage of production. This is suggested by the green values of the last column of Table 2. (Southern Transdanubia, Western Transdanubia, Central Transdanubia, Northern Hungary), which are compared to the national result have better value, while the red ones (Southern Plains, Northern Plains, Central Hungary) show unfavorable difference. Based on these a Water Allowance Coefficient (WAC) was concluded that can be determinated on the base of existing wheat water footprint calculation mainly at regional level. Water Allowance Coefficient is formed according to Equation 15 from Table 2. above.

$$WAC_i = \frac{100}{WF_{wheat,i}\ \%} \tag{15}$$

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 regional value of WAC is between zero and one ($0 < WAC_i < 1$), if value of water footprint of wheat produced in the region is higher, it is less favorable than the national value ($WF_{wheat,i} > WF_{wheat,nat}$). If regional wheat water footprint is less, it is more favorable than the national estimation ($WF_{wheat,i} < WF_{wheat,nat}$), and it shows a value above one ($WAC_i > 1$). The lower the Water Allowance Coefficient in a region, which is the closer to zero is, the more unfavorable 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 3).

Table 3: 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***
	$\frac{\mathbf{100}}{\mathbf{WF}\mathit{green}\%}$	$\frac{\mathbf{100}}{\mathbf{WF}\mathit{blue}\%}$	$\frac{\mathbf{100}}{\mathbf{WF}\mathit{grey}\%}$	$\frac{\mathbf{100}}{\mathbf{WF}\mathit{total}\%}$
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: own calculation according to *Table 2.*

Since changes of Water Allowance Coefficients vary between 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.

This means that Water Allowance Coefficient, based on the wheat water footprint change, has favorable values at the regions of Southern Transdanubia, Western Transdanubia, Central Transdanubia and Northern Hungary (see green background at Table 3). In these regions WAC reduces the value of water resource on the whole. Compared to the national average, we face unfavorable values in the regions of Southern Great Plain and Central Hungary (see red background in Table 3). In these regions WAC changes are unfavorable.

According to directions of water usage various types of WAC can be distinguished. Conforming to these, agricultural usage of rainwater stored in soil, soil moisture (green water) is interpreted as WAC_{green}. Irrigation water (blue water) is WAC_{blue} while water need of dilute pollutants (grey water) is WAC_{grey}. It is important, that these WAC types are not synchronized with the total coefficient value, therefore they do not change water value neither the same proportions nor the same direction. This can be seen later in values (Table 5.).

„The part systems of a complex organic whole exist in a state of such intimate interaction that it is hard to draw a line between their several functions, none of which in its normal form is conceivable without all the others."

Konrad Lorenz

Civilized man's eight deadly sins

4.5.3. Adjusted Water Value

Water assessment as a natural resource starts, at this point, to connect to the 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 HCSO (2013/a), in the year 2012, the average consumer price of water consumption was 331 HUF/m^3. Because the retrospective data shows 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 4. it can be drawn up by supplementing HCSO (2013/b) data with the average consumer price, which is actually a technical auxiliary table for calculating water values according to Equation 16.

$$\bar{X}_{p,irr,i} = \bar{X}_{irr,i} \cdot \bar{X}_{p,cons} \tag{16}$$

where:

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

Table 4: Average volume of consumed irrigation water by regions (m^3/ha) (2004-2012.) complemented by the average consumer price of water use (HUF/ha)

Region	Average irrigation (m^3/ha) (2004–2012.)	Average price (HUF/ha)
	$\bar{X}_{irr}$	$\bar{X}_{p,irr}$
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 average	**1 099**	**363 659**

Note: Average water fee price ($\bar{x}_{p,con}$) is determined on the price 331 HUF/m^3.
Source: own calculation according to HCSO (2013/a, 2013/b).

The middle column of 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). 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 national average value of Hungary is about 365 000 HUF/hectare, which can vary by regions according to WAC changes and types.

4.6. Results by Water Allowance Coefficient

The following results, based on agricultural usage direction of water resource are gained. By linking Water Allowance Coefficient results (Table 3) and its water value to be adjusted (Equation 16. and Table 4), regional values corrected by Water Allowance

Coefficient, complemented by green, blue and gray coefficient values, can be calculated as results of the following Equation 17–20. and Table 5.

$$AWV_{green,i} = WAC_{green,i} \cdot \bar{X}_{p,irr,i} \tag{17}$$

$$AWV_{blue,i} = WAC_{blue,i} \cdot \bar{X}_{p,irr,i} \tag{18}$$

$$AWV_{grey,i} = WAC_{grey,i} \cdot \bar{X}_{p,irr,i} \tag{19}$$

$$AWV_{total,i} = WAC_{total,i} \cdot \bar{X}_{p,irr} \tag{20}$$

where:

$AWV_{green,i}$, $AWV_{blue,i}$, $AWV_{grey,i}$, $AWV_{total,i}$ = Adjusted green, blue, grey and total water value of Water Allowance Coefficient (HUF/ha) at region *i*.

$WAC_{green,i}$, $WAC_{blue,i}$, $WAC_{grey,i}$, $WAC_{total,i}$ = Green, blue, grey and total Water Allowance Coefficient at region *i*.

$\bar{X}_{p,irr,i}$ = Average market price of irrigation water on a hectare at region *i* (HUF/ha) (Equation 16.).

Table 5: Values of adjusted, corrected Water Allowance Coefficient by regions and types (AWV) (HUF/ha)

Region	Adjusted values of WAC (HUF/ha) (AWV)			
	AWV*green*	**AWV*blue***	**AWV*grey***	**AWV*total***
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:
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: own calculation according to Table 3. and 4. and Equation 17-20.

The changes of data in Table 5. 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, into 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 Adjusted Water Value types appeared from the table above, which are determined by average consumer prices on a hectare. It turned out, that the value of rain water in Southern Transdanubia is the lowest and it is highest in the Southern Great Plain. It also turned out, that the value of irrigation water measured on average consumer price compared to the other regions and their values, is very favourable in Central Transdanubia, 218 195 HUF/ha. The next favourable value of this type is about 35 000 HUF/ha higher and the most expensive Adjusted Water Value of irrigation water are in Western Transdanubia and Northern Great Plain (370 168 and 371 778 HUF/ha). 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 coloured values in Table 5.

The following Figure 6., illustrates the AWV results by regions. Values of the lightest areas are the lowest and they are growing toward the darker regions. The lowest AWVs are in Southern Transdanubia and Central Transdanubia. The value of water in Northern Great Plain is outstanding.

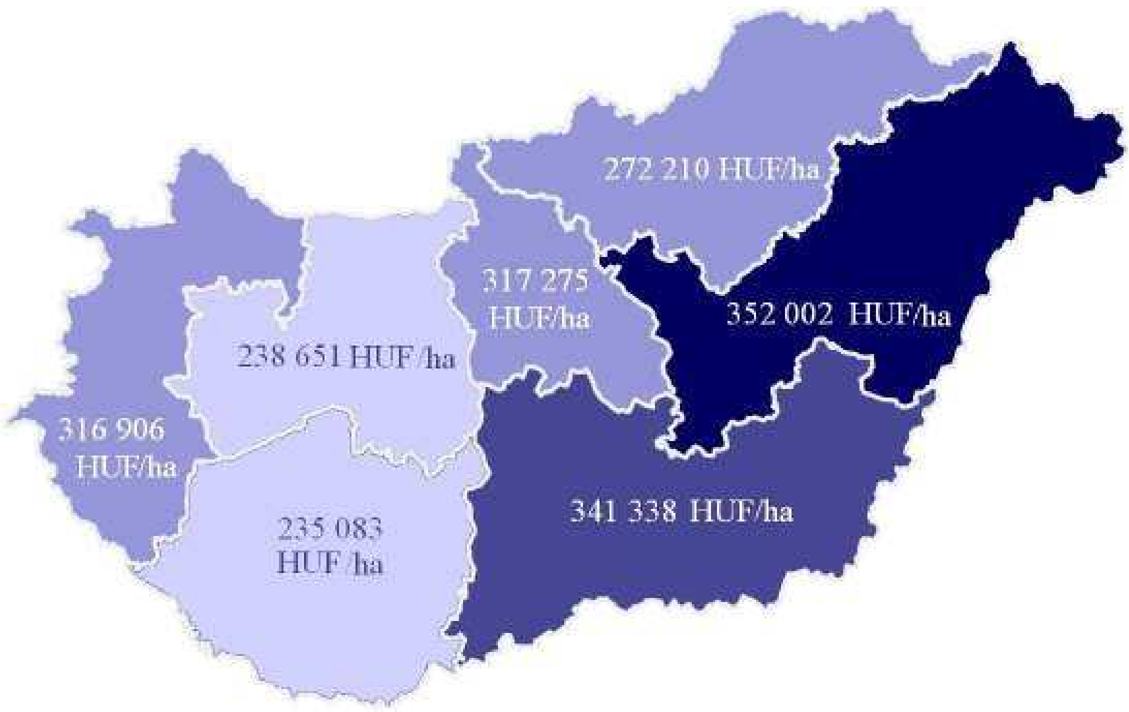

Figure 6: Schematic illustration of Adjusted Water Values of Water Allowance Coefficient by regions

Source: own editing according to own calculations

Equation for regional level calculation based on Water Footprint is as follows (Equation 21.):

$$AWV_i = \left(\frac{100}{WF_{wheat,i}\ \%} \right) \cdot (\bar{X}_{irr,i} \cdot \bar{X}_{p,cons}) \tag{21}$$

where:

- AWV_i = Adjusted Water Value of Water Allowance Coefficient at region *i* (HUF/ha).
- $WF_{wheat,i}$ = Changes of Water Footprint of wheat production at region *i*, %.
- $\bar{X}_{irr,i}$ = Average volume of irrigation at region *i* (m^3/ha).
- $\bar{X}_{p,cons}$ = Average price of consumer water fee (HUF/m^3).

4.6.1. National agricultural water value

Because of the applied methodology the sum of the regional values is not giving the total national value. Thus the Hungarian water value looks as follows (Table 6. and Equation 22-23.):

Table 6: Calculation and types of Water Footprint based value of water used for agricultural production, Hungary

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)	Type of **Adjusted Water Value**
WF*green*	593	47	0,47	170 920	**AWV***green*
WF*blue*	407	32	0,32	116 371	**AWV***blue*
WF*grey*	268	21	0,21	76 368	**AWV***grey*
WF*total*	**1 268**	**100**	**1**	**363 659**	**AWV*total***

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

The value, with its green, blue and grey components, of water used in agriculture on a hectare of Hungary is determined by calculating with the data of Table 6. As a national average it is shown that rain water has the highest value, 170 920 HUF on a cultivable hectare. This is almost half of the total Adjusted Water Value. The next is the irrigation water which is almost one third of the total value. The smallest part is the value of water need for dilute pollutant water with 21%. Values of Table 6. are in equation are as follows (Equation 22-24.):

$$AWV_{total,Hun} = AWV_{green,Hun} + AWV_{blue,Hun} + AWV_{grey,Hun} \quad (22)$$

where:

$AWV_{total,Hun}$ = Adjusted value of WAC on Hungary (HUF/ha).
$AWV_{green,Hun}$ = Adjusted value of green WAC on Hungary (HUF/ha).
$AWV_{blue,Hun}$ = Adjusted value of blue WAC on Hungary (HUF/ha).
$AWV_{grey,Hun}$ = Adjusted value of grey WAC on Hungary (HUF/ha).

Another way:

$$AWV_{Hun} = \bar{X}_{p,Hun,WFgreen} + \bar{X}_{p,Hun,WFblue} + \bar{X}_{p,Hun,WFgrey} \quad (23)$$

where:

AWV_{Hun} = Adjusted value of WAC on Hungary (HUF/ha).

$\bar{X}_{p,Hun,WFgreen}$ = Value of green water used for agricultural production on a hectare, which is based on average domestic price of water consumption (HUF/ha).

$\bar{X}_{p,Hun,WFblue}$ = Value of blue water used for agricultural production on a hectare, which is based on average domestic price of water consumption (HUF/ha).

$\bar{X}_{p,Hun,WFgrey}$ = Value of grey water used for agricultural production on a hectare, which is based on average domestic price of water consumption (HUF/ha).

Also another way:

$$AWV_{Hun} = [(\frac{WF_{green}}{WF_{total}}) \cdot (\bar{X}_{irr} \cdot \bar{X}_{p,cons})]+[(\frac{WF_{blue}}{WF_{total}}) \cdot (\bar{X}_{irr} \cdot \bar{X}_{p,cons})]+[(\frac{WF_{grey}}{WF_{total}}) \cdot (\bar{X}_{irr} \cdot \bar{X}_{p,cons})] \quad (24)$$

where:

AWV_{Hun} = Adjusted value of WAC on Hungary (HUF/ha).
WF_{green}, WF_{blue}, WF_{grey} = Green, blue and grey water footprint of Hungary (m^3/t).
WF_{total} = Water footprint of Hungarian wheat production (m^3/t).
$\bar{X}_{irr}$ = Average volume of irrigation (m^3/ha).
$\bar{X}_{p,cons}$ = Average price of consumer water fee (HUF/m^3).

According to HCSO (2013/c) data the cultivable territory of Hungary is 5 338 000 hectare. Completing the national, aggregated AWV with this the following estimation can be calculated (Equation 25. and Table 7):

$$AWV_{agg} = AWV \cdot T_{agr} \quad (25)$$

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).

Table 7: Aggregate value of water used for agricultural production, which is based on average price of water consumption, Hungary

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) (AWVagg).
AWV*green*	0,47	170 920	912 369 518 740
AWV*blue*	0,32	116 371	621 187 757 440
AWV*grey*	0,21	76 368	407 654 465 820
AWV*total*	**1**	**363 659**	**1 941 211 742 000**

Source: own calculation according to HCSO (2013/c) and Table 6.

From the results of Table 7. the corrected total water values of Hungary, on the basis of agricultural water use, by on water footprint calculations based adjusted values of Water Allowance Coefficient can be seen. According to these value of rain water (green water) it is close to 912,5 billion forints. The value of irrigation water (blue water) is more than 621,18 billion forints and the volume of dilute water need (grey water) is over 407,65 billion forints. According to this estimation, the national aggregate water value is more than 1 941,211 billion forints.

Water Allowance Coefficient is able to demonstrate the total value of water and its types. For example as a correction co-factor of land valuation, at the right place, it may change land prices regarding to the green, blue and grey components. Using AWV may also cause interesting, unexpected results in the industry and the tertiary sector. However, urbanisation effect calculations must be considered, which can be reflected, for example, by population density data involvement as a limitation factor. These opportunities are challenging and are expected to meet them as results of further researches.

4.7. Results

1. During the review of references of general methodology related to natural resources it has been proved that the widespread assessment processes are not able to evaluate water as a natural resource.

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

3. The lower the WAC in a region, which is the closer to zero is, the more unfavorable 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.

4. Wheat water footprint change based WAC, compared to the national average, has favorable values at the regions of Southern Transdanubia, Western Transdanubia, Central Transdanubia and Northern Hungary. In these regions WAC reduces value of water resource. Compared to the national average, unfavorable values can be seen in the regions of Southern Great Plain and Central Hungary. In these regions WAC increases values.

5. Different types of WAC can be distinguished. Accordingly, use of rain water stored in soil, soil moisture is WAC*green*. Irrigation water is WAC*blue*, and water need of dilution of polluted water is WAC*grey*. These types are not sync whit the total WAC, thus do not change the same volume or the same direction of water value.

6. The monetary valuation of water as a natural resource is connected to the consumer price of water. The determined base, consumer price from values of domestic consumers is 331 HUF/m^3, which is in connection with the average irrigation volume on a hectare by regions, which is corrected by WAC.

7. The value of rain water in Southern Transdanubia is the lowest, and is the highest in the Southern Great Plain. In Central Hungary, the irrigation value of water is the most favourable compared to the other regions, 218 195 HUF/ha. This value is the highest in Western Transdanubia and Southern Great Plain (370 168 and 371 778 HUF/ha). Value of water need for dilute polluted water is the lowest in Northern Hungary and the highest in Southern Great Plain.

8. The value of water used for agricultural production on a hectare is 363 659 HUF in Hungary. Rainwater has the highest value from it, 170 920 HUF, which is almost half

of the total Adjusted Water Value (AWV). The next is irrigation water, which is almost one third of the total value. Tthe water need for dilute polluted water has the lowest value with 21%.

9. WAC based aggregated AWV in Hungary is over 1 941,211 billion forints. Value of rainwater (green water) is close to 912,5 billion forints. Value of irrigation water (blue water) is over 621,18 billion forints, the value of water need for dilute polluted water (grey water) is more than 407,65 billion forints.

10 WAC is able to demonstrate the total value of water and its types. For example as a correction co-factor of land valuation, at the right place, it may change land prices regarding to the green, blue and grey components. In case of other calculations, integration of a population density factor would be necessary.

Summary

In our study, we tried to determine value of water from natural resources. After reviewing existing methods with formatting a specific system, we tried to model a value added framework in which so-called *sustainability* values, values of *natural* conditions of water resource and values of *social* utilization appear with different weight. In the model, these factors by adapting economic, social and environmental changes and with taking those into consideration can be upgraded as well. During the research it became clear 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 uniform system by the utilization of 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 with also considering both the direct and indirect usage of water. It covers the absolute volume of our freshwater needs, which also can be determined as the availability potential of freshwater resources.

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).

Methodological statement: because the change of AWVs among regions vary, the distances of regional values would disappear by ranking. To eliminate this, the WAC values were directly used.

According to our main results, the value of agricultural water use on a hectare is 363 659 HUF in Hungary. Of this, rainwater has the highest value, 170 920 HUF, which is almost half of the total AWV. The next is irrigation water, which is almost one third of the total value. The water need for dilute polluted water has the lowest value with 21%, 76 368 forints. WAC based aggregated AWV in Hungary is over 1 941,211 billion forints. The value of rainwater (green water) is close to 912,5 billion forints. The value of irrigation water (blue water) is over 621,18 billion forints, the value of water need for dilute polluted water (grey water) is more than 407,65 billion forints.

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 regarding to the green, blue and grey components. Using AWV may also give interesting, unexpected results at industry and the tertiary sector. However, urbanisation effect calculations must be considered, which can be reflected, for example, by population density data involvement as a limitation factor.

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