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The Evaluation of Water-Resouces: a socio-economic perspective

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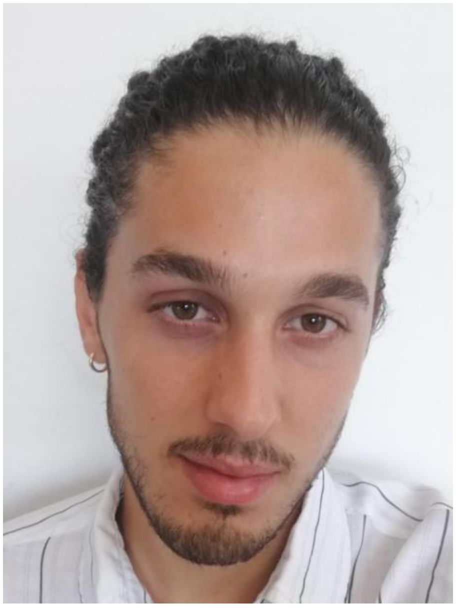

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INTRODUCTION

Water is an essential element for the existence and persistence of life on Earth. It is fundamental for human lives, ecosystems, and industry; hence it is necessary for the provision (clearly connected to the quality and quantity of the available resource) of services, such as hydroelectricity generation and goods like drinking and irrigation water [1]. However, water resources are scarce and bulky; indeed, it is estimated that the Earth contains nearly 1400 million km3 of water of which only 35 million km3 of freshwater. The big amount of water contained in ice caps, glaciers and the depths of the Earth is not available, hence suitable freshwater comes from rainfall generated from the hydrological circle. The rainfall annual average amounts to 119 000 km3 of which 74 000 km3 returns to the atmosphere due to evaporation. It is also estimated that the available quantity at affordable costs goes from 9 000 km3 to a maximum of 14 000 km3 of the remaining 45 000 km3; like a teaspoon compared to a bathtub [2]. Furthermore, with regards to the bulky aspect; it stands out how water resources value per unit of weight is usually low, hence it is not, in terms of volume, cost-effective the conveyance of the resources except when their marginal volume is relatively high [3]. This article claims to start the assessment of water resources from a general perspective to a particular one. Starting from an analysis of environmental valuation issues, hence the concept of functional value diversity, whose aim is overcoming the valuations based only on the intrinsic value of water resources, rather focusing on the flow of goods and services connected to water resources, and all their flow across environmental sectors. Furthermore, observing the estimation of a population of about 9.7 billion people in 2050; a global water demand whose increase is expected to 20 to 30% above the current level of actual use, (mainly due to rising demand in the industrial and domestic sector) and the evidence that population and water resources are distributed in a non-uniform way on the planet, the actual situation is described [4,5] and this is why the Total Economic Value of water resources must be assessed and considered. For this very reason; and also due to the fact that environmental stresses must be accounted in market-prices, the aim of the article is drawing up different approaches to the valuation of water resources to then illustrate some new approaches should be introduced and new perspectives based on some present population and development trends.

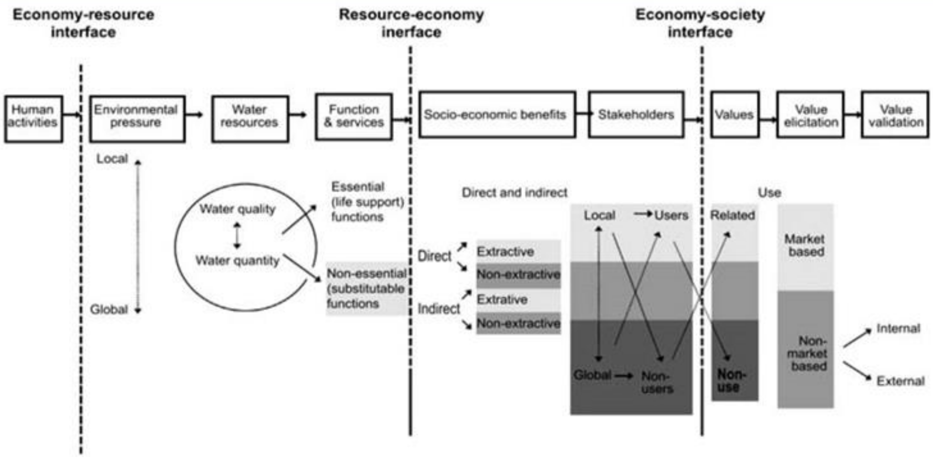
ISSUES RELATED TO THE ECONOMIC VALUATION OF WATER RESOURCES

Water resources provide a big amount of goods and services (not only physical ones but also moral, intrinsic and aesthetic) that are often not considered. A big problem is that this flow of G&S does not have a market value, detaching from the economic value; that’s the reason why water prices just consider direct use value without considering the indirect use-value i.e. the ecosystem functions e.g. hydrological and biogeochemical ones [6]. To fully understand the value of water. It is now clear so, that what we should take into account is not the commodity of water itself or the water ecosystem in toto, since the individual valuation of the G&S provided by water resources and, thanks to the specialized knowledge of experts, the deep interrelations existing between them. Environmental valuation issues are such difficult ones, also due to the presence of joint products i.e. products originated from the transformation of a common output. Furthermore, human activities exercise, as locally as globally, environmental pressure, impacting water resources quantity and quality hence the flow of G&S provided by the resources. This final amount of G&S influences stakeholders consequently impacting on the socio-economic benefits of the individuals [7].

Gibbons in 1986 assessed water use in different sectors e.g. the agricultural, municipal, hydropower, recreational, aesthetic and industrial one with different methods per each sector. The results were inexact, and it was not even possible to compare the results due to the use of different techniques; another missing aspect was the lack of consideration of physical and economic aspects of water resources use, and also of the external impacts [8]. These latter elements were integrated in the later framework by Bergstrom and National Research Council; in a work that aims to connect «groundwater quality and quantity to changes in the services provided and, thereby, to the value placed by society on resultant changes in groundwater use» [9]. In this framework the value of the flow of G&S provided by groundwater is presented as dependent on three couples of interrelations; between human activity and groundwater quantity and quality, and respectively between this latter element and the flow of G&S provided by the resources, and lastly between the connection of this flow to its economic value. Although the framework is an interdisciplinary one, based on different disciplines hence based on cooperation, the missing piece is the full consideration of surface water, being the study related just to groundwater characteristics [10].

In the way to a holistic approach to water resources; as presented in the FAO document *Economic valuation of water resources in agriculture; from the sectoral to a functional perspective of natural resource management*; "Functional value diversity" is presented as an ideal path to sustainable development of water resources. Characterized by a management whose first objective is maintaining the interactions and elements that characterize the water ecosystem, and that considers integrity as a *trait d'union* between what is "on the surface" and what is underneath the surface and usually not accounted. Among all the functions provides by water resources the ones that provide the biggest amount of socio-economic benefits are the hydrological, biogeochemical and ecological ones. The Hydrological function ensures floodwater retention, thanks to natural flood protection hence the capacity of storage of natural water bodies; hence the value is the one of the G&S present in the area of risk. Moreover, this function provides groundwater recharge, with his direct, indirect and on-use values. Furthermore, it is essential for water supply; and sediment retention which improves water quality and soil fertility. However, there are also some threats to this function e.g. removal of vegetation, channelization, and reduction in recharge rates. Biogeochemical function is necessary for nutrient retention and nutrient export ensuring better water quality; but it must face some threats too, like the removal of vegetation and flow barriers. Finally, the Ecological function, that provides a habitat for species, having a strong socio-economic impact being connected to fishing, tourism, and hunting; and not least to food web support as an essential element for agriculture. In more, this function shows all its potential only when considered together with the biological organisms. The big threats presented are overexploitation, overcrowding, inadequate management and pollution [11] (the actual situation in the Amazon rainforest is peculiar with an exponential increase in the number of wildfires, from 1,809 in 2013 to 7,625 in 2019) [12]. What stands out from this paper is the need for a multidisciplinary approach that moves from a sectoral approach to a holistic one, considering also, that both, the allocation of the resources and the actions of the individuals are not just based on economic expectations but also peer expectations, then social and cultural aspects are crucial and economic and non-economic aspects must be considered. In this regard Integrated Environmental Assessment (IEA)is presented as a methodology based on real-world problems and a team-based analysis with a bottom-up approach that plays a crucial role in eliciting public perception. Moreover, the assessment is about a continuous process of feedback analysis and based on efficient communication [13].

Figure 1; general framework for monetary valuation of water resources.



[Source: (http://www.fao.org/3/y5582e/y5582e00.htm) chapter2, page 3]

ECONOMIC VALUATION OF WATER RESOURCES:

The Na Lei approach presented in 2018 to valuation of water resources starts from a philosophical point of view. Analyzing the words of an ancient Chinese philosophy classic *The Tao Te Ching; The Book of the Way and its Virtues***,** indeed denotes that even a thought from such a different era and culture points out some crucial elements that still need to be solved nowadays; concerning such an important good for the existence of life on Earth, that is water. Reporting the words of the passage number 8; «The supreme goodness is like water. It benefits all thing without contention. In dwelling it stays grounded. In being it flows to death. In expression it is honest […]. In governance it does not control. In action it aligns to timing. It is content with its nature, and therefore cannot be faulted. » [14]; stands out how the presence of some water related issues have ancient roots**.** Therefore, for this approach is crucial the focus on interrelations between water resources (and the flow of G&S they provide) and Life on Earth in all its forms. Following the Na Lei paper *Discussion on evaluation model of water resource value*, the first feature of water resources' value is the consumption aspect; strictly connected to the utility of individuals, but also the utility derived from the consumption and usage of some natural resources essential for consumers' life. The second element presented by Na Lei is the production of water resources; hence refers to the hours of work that need to be paid at a social level to produce and reproduce water resources. Finally, the last feature is connected to the assumption that in market-based economies, are producers and consumers that along establish the value of water resources; following the changes in utility and paid labour hours. In least the paper, after focusing on utility and labour, focuses on the importance of economic and technological development for a deeper comprehension of water resources value indeed when the consumers' demand increases equally to the social work needed, the value of water resources keeps increasing [15]

The assessment of water resources should be based on an analysis focused on the interrelations between the structures and processes of the resources and the flow of G&S they provide. De Groot in 1992, used a framework based on the nature of contribution of water resources on human welfare. He identified three main directives; the «ecological value», that incorporates conservation and existence value, and that is usually accounted qualitatively but that can instead be considered using a quantitative perspective e.g. taking into account the number of species. He then proceeded talking about «social value», that comprises health and option values, a directive that can establish availability basing on minimum standards; and finally, «economic values», that encompasses consumptive and productive uses, and employment value. The directive is set out using quintiles e.g. volumetrically indicating the resources, but monetary units are used too, i.e. in terms of the value of the resources; and least, considering the amount of people engaged in a function [16]

Turner and Postle in 1994, divided the use of water resources hence their value in four categories. The first one is «abstraction of water», for all the sectors i.e. for irrigation when talking about agriculture but also for the domestic and industrial use. The second category is «fisheries» in different aspects: commercial, non-commercial and recreational ones. Considering «recreation» the authors refer both to in-stream recreation e.g. swimming in a river, canoeing or sailing, and also out-of-stream recreation for example walking near to a basin or a river, but also activities like bird watching or just like picnicking. Furthermore, the last category considered is «biodiversity» in terms of landscape and animal species conservation [17].

Another approach on economic valuation of water resources is the one carried out by Young in 1996. He divides water resources economic value in three categories; the first one is «Commodity benefits» the benefits linked to personal drinking, but also to the water resources used for sanitation or cooking and lastly to economic activities as connected to agriculture *e.g.* the water used for irrigation, as for the industrial one. The second class is «Public and private aesthetic and recreational values» always more important with the increase in time dedicated to the "care of himself". His approach then leads to «Waste assimilation benefits» related to the sink function of water resources, necessary to eliminate residuals of human activity. The last two classes are «Dis-benefits or damages» and «non-use values» hence the ones connected to the indirect experience of the resources. Therefore, the framework foresees the possibility of intrinsic values, eco-system preservation and socio-economic [18].

One more orientation is given by Rogers, Bathia and Huber 1997, and aims to assess water resources value comprising economic and intrinsic value. Economic value is made up of four directives; «Value to water users» hence the value in the agricultural and industrial sector and the willingness to pay in the domestic one, «Net benefits of return flows» that points out the importance of return flows for hydrological sectors, «Net benefits from indirect use» and «Adjustments for social objectives». However, intrinsic value comprises bequest, pure-existence values and stewardship [19].

The approach to valuation presented in the FAO document *Economic valuation of water resources in agriculture; from the sectoral to a functional perspective of natural resource management,* is based on the framework on Total Economic Volume by Pearce and Turner of 1990. Thereby, it claims to identify various types of welfare derived from a natural resource or an environment in general; the welfare is composed of use- and non-use values and by two other values usually categorized neither as use nor as non-use value. The use-value category is made up of: direct use values that can be consumptive therefore water-based hence connected to the amount of water resources used for irrigation or necessary for fishing; or water-dependent *i.e.* linked to materials but also products used for production or consumption, *e.g.* provision of groundwater for agriculture and industry provided by groundwater recharge; but they also can be non-consumptive therefore aesthetic, hence what the observation inspires in a subject; recreational *e.g.* swimming activities, and distant use value that can be related to the media (hence it not clear how it belongs to this category). Furthermore, the other category is Indirect use values: hence services provided by water resources but not directly *e.g.* the maintenance of water table, granted by groundwater recharge, the improvements in water quality provided by the nutrient export function, but also the natural flood protection necessary to reduce the potential damages to environment, industries and crops ensured by floodwater retention. The non-use category instead, is connected to the aware that a resource is maintained, hence it is connected to ethic and altruism, and the features are: the existence value *i.e.* the consciousness that a resource keeps existing, the bequest value hence the awareness that future generations will have the opportunity to use the resource and least, philanthropic value *i.e.* the gratification that derives from knowing that contemporaries and future generation can use the resource. Furthermore, there are other two categories of values earlier present, as neither part of the use value nor as the non-use value category, that are option and quasi-option values. These two elements are linked to the concept of sustainability indeed; the option value is the satisfaction derived from the certainty that a scarce resource is available for future generations while the quasi-option value is based on the concept of a better information that can ensure better management and awareness of the resources. The paper redacted by Turner, Georgiou, Clark, Brouwer and Burke in 2004 then points out that the «Use of TEV in the analysis of alternative allocations ensures that the full social benefit of goods and services provided by water is taken into account. This is necessary to indicate to decision-makers the welfare improvement that is offered by alternative allocations» [20]. However, not being enough inclusive concerning natural systems interrelations, a whole of additional values by different authors is considered, the same values that are essential to fully understand intrinsic characteristics of natural systems. The first one is «inherent value», presented by Farnworth in 1981, that comprises the value of the services necessary for the existence of the flow of G&S provided by natural systems. The following one is «contributory value», by Norton 1986, a concept based on the importance of differences; notably the importance at a social and economic point of view of biodiversity. Therefore, another value is «indirect use value», by Barbier 1994, which focuses on the importance of regulatory natural systems' flows for the economic sector. Finally, the last two features are «primary value», by Turner and Pearce 1993, and «infrastructure value», by Costanza 1997, which is centred on the concept of green infrastructure (hence climate mitigation, biodiversity conservation, climate adaption and other ecosystems services) as crucial ones for the TEV. The elements only just presented are core ones to three essential aspects of natural systems; that are: «complementary relationships» an element that needs a specialistic approach to be taken into account being marked by the thick and multiple interrelations that characterize natural systems. Another element is «keystone species», an element focused on the importance of some particular species that are essential for biotic and physical processes; *e.g.* the importance of bees for the presence of life on Earth. And lastly, «Goods and services provided by a natural system are dependent on the structure and functioning of the systems», a concept that can be analysed in terms of «primary value» hence the description of the ecosystem characteristics that have the role of "maintaining everything together" hence the «glue value»; and the «secondary value», that refers to the continue regeneration of the system. What the paper wants to focus on, is therefore the fact that TEV does not consider this range of values and characteristics, and that water has infinite values that need to be considered and accounted since we cannot avoid the consideration of a sustainable management of water for resources [21].

LOOKING FORWARD:

After having taken into account the main characteristics of water resources, the core concepts of functional value diversity, IEA and the economic valuation of water resources; a new and sustainable approach to pricing must be considered, and thus allocation of water resources has to be examined. Following the FAO approach is observable how the costs of inefficiencies, such as the use of water resources for low value uses, are increasing, hence some chances to reach development have been lost. This relates to the concept of opportunity-cost so the value of the opportunity lost, in fact, decision-makers must balance water demand among sectors considering the benefits they could have obtained allocating water in other uses. Therefore, the tool that can be used is cost-benefit analysis, which aim is analysing the efficiency of different alternatives; comparing costs and benefits (measured in different units) thanks to the use of a common unit that is money; and considering efficient, an alternative with a positive NPV (net present value) so the difference between costs and benefits. Economically efficient allocation corresponds to the "Pareto optimal" an allocation impossible to modify to improve the benefit of a subject without reducing someone else's. Efficiency in allocation is necessary to maximize the benefits derived from water resources and the value of the resources among the various sectors, also understanding the high value uses for the specific society and consequently allocating water resources into those ones. However, the main reasons for inefficiencies in water use are connected to the non-marketed aspects of water resources for which market failures arise. In presence of externalities water prices and tariffs do not encompass the positive or negative influence derived by the action of a subject or industry to another. This is something that the EU is trying to avoid with the article 9 of the *European Water Framework directive* and its "polluter pays principle" [22]. Furthermore, water resources have some public good characteristics that make the risk of *the tragedy of commons* high. In situations of open access indeed, the tragedy between individual and collective interest can lead to the depletion of the resources and opportunistic behaviours [23]. Therefore, another case of market failure is the natural monopoly, a situation that in presence of "net services" involves only one big subject on the side of the supply, to face the big initial sunk costs necessary for the supply. Together with market failures, policy and institutional failures can occur; these refer to the creation of market price distortions by unsuccessful policies but also because of the lack of attention for impacts on other sectors. An example of policy failure in agriculture is subsidized irrigation, indeed, in supplying water at a lower price it encourages free-riding behaviours, with a consume that exceeds the social optimum. It is through pricing that it could be possible to face and avoid inefficiencies and improving allocation issues. Incorporate the opportunity-cost on the price and let the users cover the whole cost of the supply is part of the conventional economic thought even though it is a difficult aim to reach in terms of acceptability both political and individual. It would be a radical change from the use of volumetric price, flat rates or fixed charges to a complete and sustainable approach to pricing that could lead to efficient allocation.

Marginal Opportunity Cost considers the physical aspect of the resources, considering the potential depletion.

$$MOC = MDC + MEC + MUC$$

MOC consists of direct economic cost *e.g.* costs of labour and abstraction; external cost *i.e.* costs imposed on a third party not engaged in the water use; and user cost *i.e*. a scarcity premium encompassing the stock of the resource, the rate of exploitation, the strength of future demand and availability in the future. MOC is a tool to allocate water to high value uses and to pay attention to the externalities related to water use [24].

CONCLUSIONS:

The evolution towards a holistic approach to water resources valuation hence IEA, and a whole new and sustainable approach to pricing obtainable with the introduction of MOC; are two drivers of the evolution of the water resources' field. There is thus, the necessity to pay attention on transformation and innovation. First of all, the innovation of some new forms of management *e.g.* the IWRM; and to alternative forms of transformation of the "value" of the resources into monetary units, hence pricing. Furthermore, there is the need to pay attention to some core concepts like virtual water and the water footprint. Concerning the first feature it is possible to use the concept of virtual water, firstly carried out by Allan in the ‘90s, also as a central one to understand that , it is more convenient for water-scarce countries to trade virtual water instead of the “pure” resource. Moreover, that is possible to estimate the water embedded by different kinds of products *e.g.* primary products, transformed and processed ones but also for multiple-, non-water and by-products; furthermore, the water needed to grow live animals and to produce livestock [25]. In addition, at a global level, it is possible to compare virtual water balance of the global regions, hence what the analysis of the data shows is that some regions like Oceania, South America, and North and Central America are net exporters with virtual water balance/ water for food equal to -154%, -28%, and -22% while continents like Asia and Africa are net importers with percentages like 15% and 32%. Regarding cereals as fundamental products for food security, feed use and production of biofuels, and given that cereal production is expected to increase by 367 Mt in 2028 (maize is the crop that will have the biggest growth, +181 Mt, followed by wheat with +86 Mt) and that global cereal use is growing by 382 Mt in 2028 (a relevant but subdued growth due to the slowdown in cereals demand for feed use by the People’s Republic of China), decision- and policy-makers have to pay more attention on the concept of virtual water [26]. Furthermore, 60% of the virtual water traded is from vegetal products and since global liberalization of trade is increasing and always a bigger amount of water in countries is used to produce what will be then exported to other countries; here’s an evidence of why the concept of virtual water should play a crucial role in water-management decisions at a local, national and international level. Virtual water Is also strictly connected to water footprint of nations and of single products as another potential core directive to an innovative, sustainable and holistic approach to water resources assessment and pricing [27].

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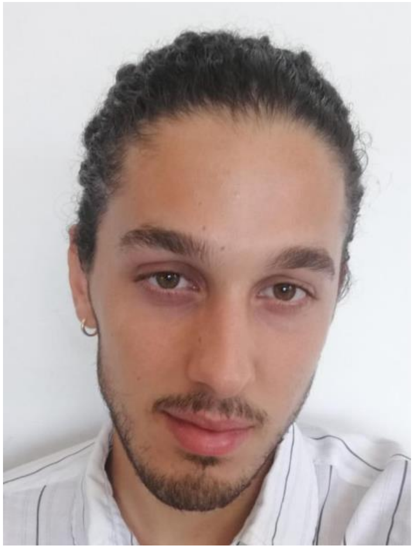

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