WATER PRODUCTIVITY IN AGRICULTURE: CHALLENGES IN CONCEPTS, INDICES, AND THE VALUES

PRODUCTIVITE DE L'EAU EN AGRICULTURE : DEFIS DANS LES CONCEPTS, LES INDICES ET LES VALEURS

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ABSTRACT

During the past decades emphasis on improved agricultural water management has been focusing on increasing irrigation water use efficiency, but more recently emphasis is also being given to producing more crops with relatively less water (increasing water productivity). There are confusions in the literature on the interpretation of the terms irrigation efficiency (E), water use efficiency (WUE) and water productivity (WP). Unlike to the WUE, the area is not a concern in WP, but the summation of all the crops values and total water used are important here. Thus, WUE addresses individual crops, one at a time and WP addresses a group of crops. However, the confusion arises when these two terms are used interchangeably. Most of the WUE values presented in the literature are under experimental conditions. Little data are available on the crops WUEs, especially in the field scale, which are measured under farmer's management conditions. Studies normally assume no linkage between numerator and denominator in the WP ratio, and hence most of attempts were made on increase of crop (kg, the numerator) and reduce of water use (m^3, the denominator) in different studies individually. This has lead most of the attempts in reducing the water used to be not much significant in improvement of WP. This challenge is very important in identification of the sources of inefficiencies and to provide the effective and relevant solutions. Overall, this paper attempts to provide a vision on the concepts of WP and its related indices e.g., WUE, and E, and to elaborate the challenges on definitions, measurements, values, and the use of these indices for the better planning and efficient use of water in the agricultural sector.

Key words: *Water productivity, Water Use Efficiency, Irrigation efficiency, Challenge, Index, Agriculture.*

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RESUME ET CONCLUSIONS

L'utilisation efficace des ressources en eau dans le secteur agricole est une grande préoccupation de la gestion de l'eau dans le monde, en particulier dans les régions arides. Par conséquent différents indices ont également été développés pour indiquer comment l'eau est utilisée efficacement. Parmi les indices les plus courants et principalement utilisés dans la dernière décennie sont l'indice de «l'efficience d'irrigation (E) ». Toutefois, au cours des dix dernières années, l'indice de l'efficience d'irrigation a été progressivement transformé, à la fois dans la littérature et la pratique, avec l'introduction des indices de l'efficience d'utilisation d'eau des cultures (WUE) et de la productivité de l'eau agricole (WP).

L'indice WUE indique comment l'eau est utilisée de manière efficace dans la production agricole. Le numérateur est le rendement des cultures dans différentes formes (le rendement biologique (sec ou humide), le rendement de la photosynthèse, la protéine produite, la calorie produite, le rendement économique, etc par hectare) et le dénominateur est l'eau appliquée (sous forme de la transpiration, de l'évapotranspiration, et le volume net ou brut de l'eau utilisée par hectare). C'est pourquoi cet indice peut avoir des unités différentes, par exemple, kg/m3, selon les unités du numérateur et du dénominateur. Alors, l'efficience de l'irrigation est sans dimension (eau / eau), valable seulement pour le domaine/l'échelle de l'exploitation (ha), et souvent exprimée en pourcentage.

Suite à l'introduction de l'indice de WUE, le terme WP devenait populaire dans la littérature de la gestion d'eau. Ce terme a été introduit pour évaluer et analyser l'eau utilisée à différentes échelles, à savoir le terrain / l'exploitation, le système de distribution de l'eau, et à l'échelle des bassins. Le groupe de travail est la production agricole (pas le rendement des cultures) ou la valeur de la culture économique (bénéfice ou brut) pour le volume ou la valeur de l'eau utilisée ou dérivée du système, respectivement.

La superficie (ha) ne pose pas aucun problème dans la définition de WP, mais la somme de toutes les cultures (non agricole), les valeurs et l'eau totale utilisée sont importants. Par conséquent, l'échelle (pas de zone) n'est pas un sujet de préoccupation dans le calcul de WUE. Cependant, lorsqu'on calcule le WP, l'échelle est importante.

Sur la base des discussions, un défi se pose dans la littérature, lorsqu'on utilise les termes de WUE et de GT. Non seulement on utilise ces deux termes de façon interchangeable, mais aussi la WUE des cultures uniques est estimée dans les grandes régions.

Un autre défi qui se pose à l'indice de WP concernant la planification et la prise de décision pour son amélioration, est sa valeur réelle. Le défi comprend les valeurs du numérateur et du dénominateur. Les valeurs de WP pourraient être affectées par les différentes définitions et les circonstances. Les informations disponibles dans les publications hydrologiques sur les essais agronomiques et les interventions d'irrigation sont souvent trop limitées pour comparer les valeurs de la productivité de l'eau (WP), c'est à dire le rapport entre la biomasse végétale produite et la quantité d'eau utilisée de manière significative dans la production dans différentes années, régions etc.

Compte tenu de ces discussions, le numérateur est la somme du rendement de toutes les cultures, ou un réseau d'irrigation, et / ou le bassin. Les rendements des cultures ne

sont pas du même genre. Certains sont produits dans les conditions humides, certains en conditions sèches, certains peuvent être considérés dans les deux types (sèches ou humides, comme la luzerne et le maïs), et pour d'autres cultures le produit final est plus important (par exemple, la canne à sucre, le riz , etc.). Le même genre de problème s'applique également au dénominateur.

Le dernier défi qui se pose à l'indice WP est de choisir entre l'économie d'eau potable ou l'utilisation efficiente de l'eau. Il est très important d'identifier les sources inefficaces et de fournir les solutions efficaces et pertinentes. Ce document affirment que le numérateur et le dénominateur sont indépendants, mais aussi interdépendants. Si les sources d'inefficience peuvent être identifiées, la WUE pourrait être améliorée.

Il est conclu que l'utilisation de l'indice de WP pose un défi dans l'utilisation pratique de l'eau. Il est plutôt l'indice conceptuel scientifique qu'un index pratique. Par conséquent, d'autres indices pertinents devraient être déterminés et liés à cet indice. Dans l'ensemble, ce document tente de fournir une vision sur les concepts de WP et de ses indices, et d'élaborer les défis que posent les définitions, les mesures, les valeurs et l'utilisation de ces indices pour améliorer la planification et l'utilisation efficace de l'eau dans le secteur agricole.

Mots clés : *Productivité de l'eau, efficience d'utilisation de l'eau, efficience d'Irrigation, défi, indice, agriculture.*

1. INTRODUCTION

Efficient use of water resources in agricultural sector has been a great concern of water management in the world, especially in the arid regions.

The irrigation efficiency, in all its kind associated with the different parts of the water delivery system, i.e., from the source of water to the soil profile, is the ratio of water used to the total water applied. Israelsen (1950) has said: "With a given quantity of water diverted from a river, the larger the proportion that is stored in the root-zone soil of the irrigated farms and held there until absorbed by plants and transpired by them, the larger will be the total crop yield." He then defined irrigation efficiency as the ratio of the irrigation water consumed by the crops of an irrigated area to the water diverted from the water source into the irrigated area.

Probably the first use of the term "water use efficiency," to mean the ratio of crop production to evapotranspiration, was by Viets (1966). The term has since become widely used to describe the yield (photosynthesis, biological, or economic) per unit of water (transpiration, evapotranspiration, or applied water). This agronomic view differs from the engineering definition given by Israelsen (1950).

Productivity, in general, is a ratio of output per unit of input. Economists refer to total factor productivity as the value of output divided by the value of all inputs. But the concept of partial productivity is widely used by economists and non-economists alike. Depending on how the terms in the numerator and denominator are expressed, water productivity (WP) can be expressed in general physical or economic terms (Kijne et al., 2005).

Molden (1997) introduced the broader term WP, for analysis of water use at different aggregation levels. The concept of WP was intended to be supportive for "reporting results of water-related agronomic trials and irrigation interventions" and "to identify opportunities for water savings and increasing WP and for supporting the decision process for water allocation" (Bessembinder et al., 2005).

Considering the concepts of efficiency and productivity of water, different indices also have been developed to indicate and quantify how the water is used efficiently. Among the most commonly used indices is the "Irrigation efficiency" (E) index. However, in the recent decade the irrigation efficiency concept and index was gradually replaced, both in literature and practice, with the introduction of crop water use efficiency (WUE) and agricultural water productivity (WP) indices.

Overall, this paper attempts o provide a vision on the concepts of WP and its related indices e.g., WUE, and E, and to elaborate the challenges on definitions, measurements, values, and the use of these indices for the better planning and efficient use of water in the agricultural sector.

2. BACKGROUND

During the past decades emphasis on improved agricultural water management focused on increasing irrigation water use efficiency, but more recently emphasis is also being given to producing more with relatively less water (increasing WP).

Traditionally defined irrigation efficiency has been prevalent for nearly a century in assisting engineers to design better irrigation systems and assisting specialists to develop improved irrigation management practices. But there are situations when traditional 'irrigation efficiency' may be misleading and where newer irrigation-related terminology can better describe the performance and productivity of irrigated agriculture (Kassam et al., 2007). On a river-basin level, improved terminology is needed to adequately describe how well water resources are used within the basin.

Efficient management of water for irrigation requires a full understanding of water balance for the field, irrigation project, or river basin. Developments are also made on the classic term of irrigation efficiency with recent modifications such as effective irrigation efficiency which reflects the efficiency of the system in terms of the amount of water effectively consumed by the system, taking into account outflows water as not wholly "wasted" or "lost" from river basins and that can be recovered and made available for use in the context of the water balance of the river basin.

Much attention has been paid recently for improving the efficiency of water use in agriculture. Nonetheless, progress has been slow due to a number of problems. One problem is the lack of a definitive means to relate the efficiency of the various parts of the WP system to the overall efficiency of the whole, especially when going from scales of farm/fields to watersheds and regions (Hsiao et al., 2007). Complicating this scaling up process is the fact that apart from the water used consumptively, the same water may be used several times within the same watershed or river basin through the recycling of drainage or runoff water, or even the use of polluted wastewater. Thus, the definition of WP is scale and user dependent. Molden et al. (2003) refers to this problem as “which crop and which drop”.

The key strategy now being advocated for addressing water-scarcity problems is to enhance the productivity of water in agriculture by producing more output with the same amount of water. In its broadest sense, agricultural WP means increasing the value of water across agricultural uses (for crops, orchards/trees, forestry, fisheries and livestock), and uses affected by agriculture (Hussain et al., 2007). However, as Molden et al. (2001a, b) argue, the means for improving the productivity of water are not always apparent because of interactions between different uses and complex flow paths of water. Also, Barbier et al. (1997) suggest that due to the multi-functionality of many natural resources, it is not always obvious how the myriad goods and services provided by these resources affect human welfare. The development of effective tools for measuring WP and value of water is therefore important for exploring ways and means of enhancing the productivity and benefits of water resources.

The benefits of agricultural water are often seen and evaluated in terms of direct, crop-productivity related benefits generated at the local level (Molden et al., 1998) or aggregate, production-related benefits at the national level. However, actual total benefits from agricultural water are often many times more than just the productivity-related benefits if other benefits from livestock, horticulture and aquaculture, and from related enterprises are also accounted for. There is emerging evidence from recent studies that the total benefits could be much larger when indirect benefits generated through water-induced expansion in farm and non-farm activities (such as expansion in investments, production, consumption, employment and wages, and expansion in overall mobility of goods and services) at the micro/local, meso/regional and macro/national levels are also accounted for (Hussain, 2005). Further, economy-wide farm to non-farm income multipliers are large and vary considerably across settings.

3. THE CHALLENGES IN THE WATER PRODUCTIVITY CONCEPT AND INDEX

3.1. Challenges in definitions and the presented values

Engineers and scientists need to carefully define the efficiency terms that they use in the context of irrigation to avoid misinterpretation by readers. More important, they need to consider using terminology based on the physics of the water resource system and conservation of mass to avoid misunderstandings by the general public. Authors also need to avoid making claims that are not valid or can be misleading (Jensen, 2007).

WUE is a concept that has historically caused much confusion for scientists, water suppliers and end users alike. Much of this confusion has stemmed from the range of terms available to describe WUE and a lack of understanding of what WUE represents. The indicators used vary according to the intended measurement and have varying inputs, outputs and boundary conditions. Both spatial (area) and temporal (time) boundaries need to be specified. Area boundaries might include a field, farm or region, whilst time boundaries could be a single irrigation event, a month, the growing season or a year. It is important to understand the inputs and dimensions of indices and efficiency terms as well as the scale at which they are applied (Wigginton et al., 2004).

The concept of WP as introduced by Molden (1997) was intended to be supportive for reporting results of water-related studies and to help identify opportunities for water saving. For identifying these opportunities, comparison of WP-data based on a clear definition and circumstances is needed. Currently, this comparison is severely complicated by a lack of information on the reported WP-values (Bessembinder et al., 2005).

In the WP index, total dry or fresh biomass or harvested product can be used in the numerator, expressed in physical or economic terms. In the denominator the transpiration (T), evapotranspiration (ET), amount of irrigation water, water input, etc. can be used. These parameters variously used in calculating WP index are often not stated explicitly. It is also not stated clearly as to over which period the denominator is calculated, e.g. sowing to harvest or also including the land preparation period, salt leaching requirements, effective rainfall, etc. To be able to compare WP-values and to explore the limitations and opportunities to save water, as was the objective of Molden (1997), more information on WP is needed than is commonly provided (Bessembinder et al., 2005).

The use of different experimental methods or simulation models to determine the biomass or ET will affect the WP-values, since all methods will include some error. WP-values are also affected by variation between years and regions in evaporative demand and growing season. Several authors report an increase in the WP of irrigation water with increased fertilization. Also better control of weeds, pests, and diseases can increase WP. Opportunities are often explored by looking at the highest WP found in literature for a certain crop. However, without knowledge about the exact WP-definition, the methods used, and the circumstances under which the WP-values were obtained, fair comparison of all these WP-values cannot be made. Consequently, the opportunities to increase WP cannot be explored completely (Bessembinder et al., 2005).

The comparison of WP-values is fundamental for exploring the limitations and opportunities for improvement of WP, and thus for a more efficient use of the fresh water resources. Currently, this comparison is severely complicated by a lack of comprehensive information on the reported WP-values (Bessembinder et al., 2005).

The definitions of WP used in any study depend on the aim, stakeholders and scale, besides an understanding of which ‘drop’ of water we are talking about. However, using T as the denominator is valid at all scales, and it also gives insight in the real crop water needs. Therefore, the use of this transpiration water productivity (WPT), beside other definitions, should be the standard adopted in any experiment on WP. To make comparison of WP-values easier, normalization is needed. This requires more standardized reporting on experiments concerning crop water use. The following minimum dataset is required in all cases (Bessembinder et al., 2005):

- Harvestable product and total (aboveground) biomass. Dry matter content of the harvestable product and total biomass is also needed
- Method or model used for biomass estimates and date of biomass determination
- Dates of crop stages: dates of emergence and physiological maturity should be given, and preferably also the dates of sowing and harvest
- Location, year and/or weather conditions for which the WP is determined/simulated

- Total (E)T, period considered for (E)T, and method used to determine or estimate (E)T
- Management practices/level: level of fertilization, presence of weeds, pests and or diseases, timing and level of water stress; and
- Cultivar

Most of the above data are known. The information provided in publications on water-related agronomic trials and irrigation interventions is often too limited to compare values of WP from different years, regions, etc. in a meaningful way. In other aspects, most of the WP values presented in the literature are also under experimental conditions. Little data are available on WPs in the field scale, under farmer's management conditions. This is mainly because non-precise information on the volume of water applied by the farmers in each irrigation event. However, the severity of this deficiency is less for the values reported on irrigation efficiency.

Other challenge in these aspects is the concept and definition of WP, vis-à-vis, that of WUE. In the case of WP, the scale is important whereas, for WUE a single crop is the platform of information.

Based on the above discussions, we may say that there exists confusion in the literature in the use of the terms of WUE and WP. The common mistakes are interchangeable use of the two terms and referring to the single crop-based estimate of WUE over large areas as WP and sometimes as Basin Scale WP.

Direct use of WP index and its real value for planning and decision makings is another challenge due to the uncertainties associated with the numerator of the WP expression. The numerator is sum of the yield of all the crops over the land under consideration. The crops yields are, however expressed differently; some on wet basis, some on dry basis and some on both (alfalfa and corn), and for some other crops the final product is more important (Sugar cane, sugar beet, paddy, etc.). The same kind of problem also applies for the denominator of the WP expression, particularly when the scale of water domain crosses from lower to higher (basin and national) level. In the higher order scales, it is difficult to really determine how much water actually is used for crops production. It will be very difficult to determine WP at the national level, though different literature and reports quote some figures as the average value of WP at the country level, which is, to say the least, misleading. This problem will be very complicated for the economical WP, as determination of the economical value of water or its opportunity costs in the denominator of the WP index, is very difficult or impossible. This challenge is pointed out by Hussain et al. (2007) and is further elaborated in section 3.3.

3.2 Water related productivity

Improvement of agricultural WP will help to produce more food with less water (or "more crops per drop"). It will cause reduction of water consumption in the agricultural sector and will allow releasing more water for other sectors. However, for improving agricultural WP, firstly the sources of inefficiencies and main factors and parameters leading to the low values of WP should be identified.

In the recent decade, land and water issues have become increasingly complex. Therefore, for decision making and planning on land and water issues and enhancing their productivity further, more precise, and more comprehensive information are required. WP is a broad concept and the problems and associated measures for its improvement at every scale could be numerous (Heydari et al. 2009).

Based on Kassam et al. (2007), all the yield improvement research (including genetic enhancement and crop and natural resource management) has made an important contribution to global increases in agricultural WP experienced over the last five decades or so. In contrast, little progress has been made in reducing evapotranspiration, the denominator in the WP ratio.

The challenge here is studies normally assume no linkage between numerator and denominator in the WP ratio, and hence most of researches were for increasing crop Kg (numerator) and reducing water use (m^3) (denominator). But to improve WP, we should improve both denominator and the water related factors of the numerator simultaneously. This is what is so called here as Water Related Productivity or Water Use Related Efficiency (WURE). For example from WUE aspect, releasing cold resistance crop varieties could improve crop yield and hence crop WUE, because of yield increase (increase of the numerator) without any linkage with the denominator. But based on WURE concept, there is no direct concern of crop cold stress and WP. But on the other hand, release of heat or drought resistance crop varieties are important here, because these varieties could save water (denominator) and also could produce higher or reasonable yield (numerator) with less amount of water under aridity and water stress conditions. In this case, there is linkage between numerator and denominator in the WP ratio.

This challenge is very important in identification of the sources of inefficiencies and to provide the effective and relevant solutions. Based on the above discussions, the ultimate value of WUE index (kg/m^3) depends on crop yield (kg) in the numerator and water consumed (m^3) in the denominator. There is common perception that the numerator and denominator are independent and any factor leading to any changes in the value of numerator and denominator can directly affect the value of the WUE index. While this paper argues that, the numerator and denominator are independent but on the other hand for the efficient improvement of WP in the field of improvement (reduce) of denominator, efforts should be focused on interrelated factors. If the interrelated sources of inefficiencies are identified, the WUE could be improved much higher and more efficiently.

3.3 Use of the inter-linked and supplementary indices

The concept of WP is linked with the value of water. In the past studies on the productivity and value of water, a variety of indicators and measures of water value have been developed and used. These may be classified into two broad categories: (a) indicators based on land productivity, and (b) indicators based on WP, as given in Table 1 (Hussain et al., 2007). Except for 1 and 9, which are physical indicators, all the others are monetary indicators of value of water. Indicators based on physical productivity are simple but useful only for single product cases, whereas monetary indicators are useful where several products or enterprises or multiple uses of water are to be analyzed.

Table 1. Indicators of productivity and value of water (Hussain et al., 2007) (Indicateurs de productivité et de valeur de l'eau)

Indicators	
(a) Land productivity-based indicators	(1) Average product per unit of land (2) Average gross value of product per unit of land (3) Average gross margins per unit of land (4) Average net value of product per unit of land (5) Average net product per unit of cultivated/irrigated land (6) Average differential value of product per unit of land (7) Marginal productivity of land (8) Value of marginal productivity of land
(b) Water productivity-based indicators*	(9) Average product per unit of water (10) Average gross value of product per unit of water (11) Average gross margins per unit of water (12) Average gross net value of product per unit of water (13) Value of marginal productivity of water

*: Commonly used denominators for calculating WP based indicators are amount of water diverted/supplied, water applied, gross inflow of water (rainfall plus irrigation), and crop evapotranspiration (ET)

Studies of Hussain et al. (2007) concludes that the popular productivity indicators based on crop output do not capture the full range of benefits and costs associated with agricultural water use. Efforts should be directed not only at increasing the productivity of water in terms of mass of output per unit of water, but also the overall benefits or value of water at various levels for larger growth and poverty alleviation impacts, considering the sustainability of the systems.

Based on the above discussion and considering the limitations of existing indicators for estimating the value of agricultural water at various scales, Hussain et al. (2007) propose a set of new indicators that can account for both direct and indirect net benefits and can be applied to derive both average and marginal values of agricultural water from farm to basin/macro scales. These are presented in Table 2.

Studies of Hussain et al. (2007) also concludes that, there is no single value of water and it differs temporally and spatially; and that it is important to consider four key dimensions in estimating water value including: time, space, use, and impacts. They raise four main points: 1) The popular productivity indicators based on crop output do not capture the full range of benefits and costs associated with agricultural water use, 2) The value of agricultural water may not be as low as it is generally perceived or estimated when all major uses and direct and indirect benefits of water are properly accounted for, 3) The value of water varies across time and space, and the value to stakeholders at various scales (farmer, system manager, basin planner and national policy maker) could be quite different. For example, the estimate of agricultural water value in the upper Indus basin in Pakistan varies from US$0.04/m^3 at the farm scale to US$0.22/m^3 at the national scale. The farm scale value is more relevant for agricultural water pricing policies, but for water sector investments and allocation, the national scale value is important. The decision-making processes related to water sector investments, allocations, management, and charging/cost recovery schemes could be potentially misguided if key dimensions of water value that are related to water availability and use, benefits/costs, temporal and spatial aspects are not properly accounted for invalidation, and 4) Efforts should be directed not only to increasing the productivity of water in terms of mass of output per unit of water, but also the overall benefits or value of water at various levels for larger growth and poverty alleviation impacts, considering the sustainability of the systems.

Heydari et al. (2011) also provides some other relevant supportive indices related to the productivity of water (Table 3).

Table 2. Indicators for valuing agricultural water (adopted from Hussain et al., 2007) (Indicateurs pour l'évaluation de l'eau agricole)

Value indicator	Description of numerator	Denominator	Scale
Crop or Farm value ($/m^3)	Useful where there are several outputs/ crops. Specific measures may include gross or net value of product or gross margins or net benefit of water derived by comparing situations with and without irrigation (to be converted to standardized units for cross-country comparison). However, it accounts for only the benefits of water use in the crop sector, and not for benefits of water use for other activities in farming/agricultural systems. Indirect benefits related to crop productivity can be accounted for by using an estimate of the relevant multiplier.	Volume of water depleted by agricultural use (Et), flows into sinks and pollution) or volume of water supplied [rain (R) plus irrigation water (I)]	Farm
Agricultural value ($/m^3)	The above indicator provides the basis for estimating this indicator, which can be useful in situations where agricultural water is also used for non-crop sectors such as for raising livestock, for fish and poultry farming, and for orchards and trees on farms. While this indicator can account for water-related benefits both from crop and non-crop sectors, it does not account for water-related benefits generated in non-farm/nonagricultural sectors. For this indicator, part of indirect benefits related to crop productivity and non-crop sectors can be accounted for by using estimates of the relevant multipliers.	Available water to agriculture = R + I—committed flows—depletion by non-ag uses	System

Value indicator	Description of numerator	Denominator	Scale
Rural economic value ($/m^3)	The above indicator provides the basis for estimating this indicator. This indicator can account for water- related benefits generated in both farm and non-farm sectors (at rural-regional level). Non-farm sectors include such sectors as local value adding enterprises that depend on the farm sector through backward linkages (input supply) and forward linkages (output marketing and processing), and use water from the agricultural sector. While this indicator accounts for part of indirect benefits at the rural-regional level, it does not account for water related indirect benefits at the broader economy level.	Available water for agriculture	System/ Basin
Total socio-economic value ($/m^3)	The above indicator provides the basis for estimating this indicator, which can account for all economic and social benefits and costs related to water. It is composed of two sub-indicators as given below.	Available water for agriculture	Macro
Macro economic value ($/m^3)	This indicator can account for all direct and indirect economic benefits and costs for all uses of water at the broader economy level, using estimates of economy-wide multiplier impacts (both positive and negative).	Available water for agriculture	Macro
Social value ($/m^3)	This indicator may include benefits or (disbenefits) in terms of: Job generation, Food security, Food self-sufficiency, Resource distribution/equity, Poverty alleviation, Other social benefits (or disbenefits). These social impacts may be accounted for by using weights assigned to these parameters or by estimating the impacts.		Macro

Table 3. Supportive planning indices related to the improvement of water productivity in Iran (Heydari et al., 2011)(la planification de soutien des indices liés à l'amélioration de la productivité de l'eau)

Index	Numerator	Denominator	Description	Value*
Land Drainage	The area with drainage systems (ha)	The total waterlogged and saline area (ha)	It indicates the extent of drainage networks construction along with irrigation networks development.	0.15
Irrigated lands ratio	Irrigated lands with irrigation networks in place (ha)	Total irrigated lands by surface water (ha)	It is indicator of the extent of development of irrigation networks as compared to that of surface water resources.	0.21
Fully equipped irrigation networks	The irrigation networks equipped with the tertiary and fortieth canals (ha)	The total lands under irrigation networks (ha)	Indicator of the extent of development works in lower order water distribution systems as compared to that of irrigation networks under surface water resources.	0.09
Moderni-zation	Irrigated lands with the modern irrigation systems (ha)	The total irrigated lands (ha)	Indicates the investment, progress, and infrastructure works in sustainable development of pressurized irrigation systems.	0.11
The percent of losses of agri-cultural products	The amount of losses of agricultural products in all processes (kg/year)	The total agricultural production (kg/year)	Indicates the extent of investments, progress, and infrastructure in reducing losses of agricultural products from field to consumption.	25%
Water utilization	Water left in the reservoir at the end of cropping season (BCM)	Water stored in the dams at the start of cropping season (BCM)	Indicates how we use water efficiently and consider the risk of probable drought in the next year.	0.25

*: Estimated values for the Iran country in the current conditions

4. CONCLUSIONS

Improvement of WP will be a big challenge for water scarce and high population-growing regions of the world, especially in the regions with poor economy, e.g., developing countries.

There are ambiguities in WP concepts, definitions, use, and their measured values, especially when these values are to be used for the planning and decisions makings at the macro level.

Productivity indicators based on crop output do not capture the full range of benefits and costs associated with agricultural water use. WP index alone is inadequate to respond to all the issues related to the efficient use of water and its productivity. Together with WP index, other past and newly suggested inter-linked indices are also needed for the full understanding of water efficiency, water value, and great improvement in efficient and sustainable use of water in agriculture.

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