

The importance of efficiency and sustainability in water consumption in the context of the Sustainable Development Goals: a proposed regional composite indicator

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Abstract

This paper highlights the importance of accurately quantifying water usage, a valuable and limited resources-, especially in climate change and extreme events such as prolonged droughts. UNESCO warns that climate alterations will affect the availability, quality, and quantity of water needed to meet basic human needs. The study uses current methodologies to quantify the water required in supply chains and assess its sustainability, aligning with United Nations Sustainable Development Goal 6: “Clean and sanitary water for all”. It analyses the role of water in a globalised market, emphasising responsible consumption, waste

recycling and circular practices among different stakeholders. In this context, the water footprint provides information on the volume of water used in production processes, identifying its sources and evaluation mechanisms. The study also proposes a composite indicator to assess the efficiency of sustainable water use in Spain's Autonomous Communities, considering variables such as consumption and pollution from human activities, particularly in the agricultural, industrial and domestic sectors.

Keywords: Water economy, water footprint, SDGs, sustainability, indicators.

1. Introduction¹

Access to water is a fundamental right, recognized by the UN, and is key to sustainable development. However, its availability and quality are increasingly threatened by factors such as population growth, climate change, and the overexploitation of resources, affecting two-thirds of the world's population and compromising economic and social stability [1,2].

In the 21st century, humanity faces a severe water crisis. UNESCO has already warned that “the real tragedy of this crisis is its effect on the daily lives of poor populations, who bear the brunt of water-related diseases, live in degraded and often dangerous environments, struggle to educate their children, earn a living, and meet their basic nutritional needs” [3].

The International Water Resources Association (IWRA) asserts that the crisis is not only due to scarcity but also to unequal and inefficient distribution. Contributing to this are consumerist lifestyles, urbanization, the industrialization of emerging economies, and population growth, alongside climate change, deforestation, and greenhouse gas emissions. UNESCO points out that climate changes will affect the availability, quality, and quantity of water needed to

1 The authors are affiliated with the UNESCO Chair “Water and Peace” at the Spanish universities UNED and URJC (<https://blogs.uned.es/catedraunesco-aguaypaz/>). They wish to pay tribute to the memory of Samuel Crespo Fernández, a graduate in Law and Business Administration and Management from the Autonomous University of Madrid, whose Final Degree Project, directed by Professor Ana M. López, has provided the inspiration for this work.

meet basic human needs. Therefore, the water crisis must be addressed from a broad perspective of problem and conflict resolution.

In a context of extreme phenomena such as storms, droughts, ecosystem loss, or epidemics, it is crucial to properly quantify water use. Recognizing and expressing its value and integrating it into decision-making is essential for equitable and sustainable management [4].

This chapter addresses this need by highlighting tools to quantify the water required in supply chains, assess its sustainability, and understand its role in achieving SDG 6: “Clean water and sanitation for all.” Achieving the SDGs depends on the progressive improvement of healthy freshwater systems. Although renewable, water is a finite and irreplaceable resource that requires efficient management to strengthen the resilience of economic, social, and environmental systems in the face of unpredictable scenarios [5, 6, 7].

Among the highlighted goals are those established in the Post-2015 Water Agenda of UN-Water [8] the inter-agency mechanism for issues related to freshwater and sanitation:

- Achieve universal access to safe drinking water, sanitation, and hygiene.
- Improve the sustainable use and development of water resources in all countries.
- Strengthen equitable, participatory, and accountable water governance.
- Reduce water pollution and improve water quality by reducing untreated domestic and industrial wastewater.
- Reduce mortality and economic losses from water-related natural disasters.

Despite growing social awareness and existing policies, major barriers persist ineffective institutional frameworks, geopolitical inequalities, tense international relations, and resistance from certain industrial sectors to modify their processes. [9, 10]. In addition, inequalities in water access worsen issues such as poor sanitation, decreased agricultural production, and food insecurity. Increasing climate variability exacerbates these challenges.

UNESCO [11] emphasizes that better water management is essential to eradicating poverty. Thus, the water issue is central to the international debate due to its connection with multiple dimensions of inequality. These situations, closely linked to the hydrological cycle, underscore the urgent need for an appropriate valuation of the resource. An economic analysis is needed to prioritize sustainability programs, define trade-offs, design climate budgets aligned with international commitments, apply environmental fees, and provide clear references for policymaking [12,13]. Developing technical and decision-making capacities is a priority to generate knowledge and guide action. Likewise, it is crucial to implement adaptation policies based on effective communication of data. According to the Water Institute, water management involves the planning, development, and distribution of the resource based on efficiency, equity, and sustainability criteria.

Water sustainability must also be financial, implying recovery of the real costs associated with supply and treatment. Given the scarcity and value of the resource, economics must be incorporated into the study of rational decision-making within an integrated water management framework [14].

The urgency of moving toward efficient water management aligns with the principles of SDG 6. Inefficient or commodified management can exacerbate inequalities and jeopardize future sustainability. According to [15], between 2015 and 2018, global water use efficiency increased by 10%, especially in the industrial and service sectors, while agriculture continues to show the lowest efficiency levels. However, many countries lack reliable data and updated methodologies, highlighting the need to strengthen monitoring systems.

In this global scenario, analysing the role of water in an increasingly interdependent economy is particularly relevant. Responsible consumption, recycling, and the circular economy are valued as key strategies. Efficiency and sustainability in water use are central to achieving more equitable and resilient water management. The Water Footprint (WF) is becoming a consolidated tool for measuring the volume of water used in production processes, classifying its sources (green, blue, and grey), and enabling assessments at the level of consumers, companies, or territories, such as river basins. This

facilitates linking these concepts to the targets of SDG 6. Water is a strategic asset, but also an economic and social one. Its efficient and equitable management is essential to ensure the well-being of current and future generations.

Finally, a composite indicator is proposed, based on economic, social, and environmental variables, to analyse water use efficiency in Spain's Autonomous Communities. This tool facilitates territorial comparisons and contributes to the design of more effective policies.

2. Theoretical Framework

2.1. The Role of Water in the 2030 Agenda as a strategic resource

Water is an essential resource not only for life but also for economic growth, social stability, and environmental conservation. It is fundamental to all ecosystems, both aquatic and terrestrial, but is subject to high competition among users. The quantity and quality of water resources determine the type of ecosystem and the services it can provide—provisioning, regulating, supporting, and cultural [16]. Various factors exert pressure on or influence natural ecosystems and affect their productivity. These include population growth, accelerated urbanization and migration; changes in consumption patterns; economic growth; food insecurity and poverty; increased waste; natural disasters and conflicts; as well as the effects of climate change, already evident because of human activity [17]. In addition, there is growing tension over scarce water resources and the impact of policies from other sectors such as energy, industry, economy and finance, trade, and agriculture.

Although the total amount of water on the planet remains relatively stable, its distribution varies. About 97.5% of Earth's water is in oceans and seas, while only 2.5% is freshwater. Of this portion, 69% is stored in polar regions and mountain peaks, 30% in aquifers and soil moisture, and only 1% circulates through rivers and watersheds, accumulating in lakes, lagoons, reservoirs, and other surface water bodies, replenished through the hydrological cycle. This

limitation makes freshwater a highly vulnerable resource at risk of overexploitation.

Regarding the planet's water balance, only 0.007% of freshwater is available for direct human consumption [18]. This tiny portion supports crucial economic and social processes such as domestic consumption, irrigation, energy production, and industrial uses. Although this amount would be sufficient to ensure the survival of all living beings, temporal and geographic availability problems, disruptions to natural water flows, and ecosystem changes challenge humanity's capacity to manage the resource in an orderly, equitable, and sustainable way.

In this context, it can be stated that freshwater resources are increasingly threatened and at risk. [19] identify the main global pressures on water supplies as demographic changes, industrial development, rising living standards, and inadequate land use and water management policies. In fact, both the quantity and quality of surface and groundwater resources are significantly threatened in regions experiencing water stress [20], leading to a reduction in freshwater reserves.

From an economic perspective, water holds strategic value as a critical input in agriculture, industry, and energy production. The interdependencies of international trade have led some countries to rely on imports of goods whose production requires large volumes of water, creating imbalances in global water availability. This is evident in regions where water scarcity affects access to sanitation services, agricultural production, and food security. Trade globalization creates opportunities to enhance productivity and overall water use efficiency. As [9] note: "understanding the virtual water flows entering and leaving a country or river basin can reveal the real water situation of the country or basin in question." In this regard, from a territorial perspective, water pricing policies and volumetric and economic accounting of water resources become important.

The economic impacts of water are widely documented. [21] report that between 1980 and 2020, the likelihood of alternating droughts and torrential rains has increased, affecting agricultural production and economic stability. The World Bank warns of growing pressure on water resources driven by population growth—which

demands more food production—and climate change, which disrupts hydrological cycles. This situation could lead to a 40% gap between water demand and available resources by 2030, especially in poorer countries. Moderate droughts reduce economic growth in developing countries by 0.39 percentage points, while extreme droughts can reduce it by up to 0.85 percentage points [22]. Furthermore, climate-related disruptions compromise financial stability. The NGFS Network for Greening the Financial System estimates that droughts could cause losses of up to €32.7 trillion between 2020 and 2050, increasing the fiscal burden and public debt [23].

In the context of climate change, water security is a growing challenge. As a strategic resource, water must be managed with sustainability, equity, and efficiency criteria, ensuring its responsible use and long-term preservation. Efficient water management is key to balancing economic growth, social equity, and environmental sustainability. Measuring water efficiency is not only an economic concern but also an ethical and social imperative aligned with the SDGs, especially SDG 6, which promotes the availability and sustainable management of water and sanitation for all.

2.2. The Relationship Between Water (SDG 6) and Other SDGs

Access to safe drinking water and sanitation has historically been a global challenge. For centuries, the lack of infrastructure to separate potable and wastewater caused epidemics and diseases that limited the development of societies. It wasn't until the 19th century that sewer and water treatment systems began to be implemented, reducing mortality and improving life expectancy. However, this progress has not been globally equitable [24].














Despite advancements in developed countries, millions of people still lack access to safe drinking water and basic sanitation, which hinders their social and economic development. In 2010, the UN General Assembly recognized access to water and sanitation as a fundamental human right, urging governments and international organizations to adopt more inclusive and sustainable water policies.





Within the framework of the 2030 Agenda, the UN formulated SDG 6: “Ensure availability and sustainable management of water and sanitation for all.” Its goal is to close the gap in access to clean and safe water, improve sanitation infrastructure, and protect freshwater ecosystems. To achieve this, four fundamental principles have been established:

- a) separating drinking water from wastewater, ensuring sanitation infrastructure that reduces disease transmission and improves living conditions.
- b) facilitating access to safe drinking water and treating it adequately, ensuring its availability for human consumption and reducing the time and effort needed to obtain it.
- c) protecting and restoring freshwater ecosystems, preventing pollution and overexploitation of rivers, lakes, and aquifers, which are fundamental for water sustainability.
- d) safeguarding access to water and the right to use it, establishing fair agreements among different sectors (agriculture, industry, local communities, and the environment) to ensure responsible use of the resource.

Implementing the SDGs requires a global partnership involving active participation from governments, civil society, the private sector, and the United Nations system. These goals, with measurable targets and indicators, are indivisible and action oriented. SDG 6 and its link to the 2030 Agenda are closely connected to human rights to water and sanitation. The goal is to monitor and promote more sustainable practices to address water scarcity and ensure its availability (Table 1).

Table 1: Relationship Between Water (SDG 6) and the Sustainable Development Goals.

<p>1 NO POVERTY</p> 	<p>←Water and sanitation reduce vulnerability and improve family income (**)</p>		<p>(**) Water and sanitation are key to the social and economic inclusion of the poorest →</p>	<p>10 REDUCED INEQUALITIES</p> 
<p>2 ZERO HUNGER</p> 	<p>←Water is key for agricultural productivity and food processing (**)</p>		<p>(*) Deaths and economic losses from water-related disasters →</p>	<p>11 SUSTAINABLE CITIES AND COMMUNITIES</p> 
<p>3 GOOD HEALTH AND WELL-BEING</p> 	<p>←Waterborne diseases. Deaths caused by water pollution (*)</p>	<p>6 CLEAN WATER AND SANITATION</p> 	<p>(*) Water pollution from chemicals and waste →</p>	<p>12 RESPONSIBLE CONSUMPTION AND PRODUCTION</p> 
<p>4 QUALITY EDUCATION</p> 	<p>←Water and sanitation improve academic performance (**)</p>	<p>(*) Goals that specifically mention water (***) Relationships with water and sanitation</p>	<p>(**) Water is key to adaptation to climate change and the resilience of people, economic activities, and ecosystems →</p>	<p>13 CLIMATE ACTION</p> 
<p>5 GENDER EQUALITY</p> 	<p>←Water and sanitation rights are violated, especially among women and girls (**)</p>		<p>(**) Reducing marine and coastal pollution requires improvements in water quality →</p>	<p>14 LIFE BELOW WATER</p> 
<p>7 AFFORDABLE AND CLEAN ENERGY</p> 	<p>←Energy production is highly dependent on water (**)</p>		<p>(*) Inland freshwater ecosystems and wetlands: Effects of invasive species on aquatic ecosystems →</p>	<p>15 LIFE ON LAND</p> 

<p>8 DECENT WORK AND ECONOMIC GROWTH</p> 	<p>←Water and sanitation increase labour productivity and economic growth (**)</p>		<p>(**) Importance of collaboration between regions and countries that share water resources to avoid conflicts →</p>	<p>16 PEACE, JUSTICE AND STRONG INSTITUTIONS</p> 
<p>9 INDUSTRY, INNOVATION AND INFRASTRUCTURE</p> 	<p>←Water and sanitation are spaces for innovation and key for industry. The importance of infrastructure (**)</p>		<p>(**) The relationship between water and all the objectives makes it a key area for fostering partnerships and cooperation →</p>	<p>17 PARTNERSHIPS FOR THE GOALS</p> 

Source: own elaboration adapted from [25].

2.3. Efficiency and Sustainability in Water Consumption

Approximately one fifth of the world’s population lives in areas experiencing physical water scarcity. As a limited and irreplaceable resource, water can only be considered renewable if it is well managed. Despite increasing recognition of the need for sustainable water management and multiple international initiatives, significant barriers remain [26, 27]. Among the main obstacles to efficient resource management are:

- Economic and geopolitical factors, which influence investment in water infrastructure and the implementation of efficiency strategies.
- Institutional and legislative frameworks often misaligned with a sustainable management approach.
- Interests of certain productive sectors, which sometimes resist adapting their processes to optimize water use.

In this context, it is key to consider water stress levels across different countries, as these are likely to increase with population growth and the effects of climate change. Physical water stress is defined as the percentage of total freshwater withdrawn annually by major sectors, including environmental uses, in relation to total renewable freshwater resources, expressed as a percentage [11]. More than 2 billion people live in countries with high water stress, with the global average at 11%. A total of 31 countries presents levels between 25% (alert status) and 70%, while 22 countries exceed 70%, indicating severe water stress.

2.4. Definition and Scope of Water Efficiency

In today's context, where efficient water use is essential for sustainability, it is especially important to measure water consumption and its impact across different sectors. This gives rise to the concept of Water Footprint (WF), a metric that quantifies the volume of freshwater (m^3/year) used to produce goods and services. Introduced in 2002 by Arjen Hoekstra, it aims to reflect the impact of freshwater consumption in different regions. Its application is broad: it can be calculated for processes, products, multinational companies, and even entire countries, regions, river basins, or aquifers, allowing identification of areas under the greatest pressure [28,29].

The WF helps identify water dependency in operations or supply chains, assess water security in the context of climate change and scarcity, and support planning decisions. It has become a key tool for governments, individuals, and businesses to improve sustainable water management and use.

Interest in calculating WF has driven the development of tools such as the Water Footprint Network, which promotes fair and smart freshwater use through collaboration among businesses, organizations, and individuals, and the Water Footprint Calculator, which shows how everyday actions affect water consumption. These platforms help reduce individual WFs and foster more sustainable water management.

2.5. The Water Footprint as an Indicator of Water Sustainability

According to the [30], Resolution 64/292 of July, basic access to drinking water and sanitation is a fundamental human right. Water-related needs include a minimum safe supply for drinking, cooking, washing, and food production. However, these needs and equity standards are difficult to quantify. As an economic, common, and public good, it is considered unfair for some users to exceed a reasonable average individual threshold, thereby encouraging equitable use of the resource.

Sustainable development, understood as meeting present needs without compromising future generations, seeks to ensure a balance between economic growth, environmental care, and social well-being. In this regard, water plays a central role: it is essential for reducing diseases, ensuring social well-being, maintaining population productivity, and preserving ecosystems [31]. Additionally, water is at the core of climate change adaptation, serving as a nexus between the climate system, society, and the environment. [32] notes that the interrelationships between water and sustainability go beyond the social, economic, and environmental dimensions, representing crucial challenges in sustaining the services that drive sustainable development.




The study of WF serves multiple public and private purposes. This indicator allows for the evaluation of water sustainability by considering both direct and indirect use across supply chains. It can be expressed in cubic meters per ton of production, per hectare cultivated, per monetary unit, or other functional units. It helps understand how and why freshwater is consumed or polluted, with the greatest impact in water-scarce areas. According to [33], total WF assessment involves four phases:

1. Definition of goals and scope,
2. WF accounting,
3. Sustainability assessment (environmental, social, and economic),

4. Formulation of responses (strategies, policies, or improvement measures).

WF is divided into three components—green, blue, and grey—based on the origin of water (rain, soil moisture, surface or groundwater, and the volume required to manage pollution). This allows for a comprehensive view of water use (see Table 2).

Table 2: Water Footprint (WF) typology.

Green WF: Rainwater stored in the soil and used by vegetation or crops.	
	<p>It is an indicator of human use of water from precipitation, which is not transformed into streams or groundwater, but is stored in the soil or vegetation. This volume of water is used in production without generating wastewater. Green water is especially useful in crops, agricultural plantations, and forests, although not all of it is usable, as a significant portion evaporates.</p> <p>The green WF of the process is calculated as the sum of green water evaporation plus green water incorporation.</p>
Blue WF: Water extracted from surface or underground sources, used in activities such as agricultural irrigation, domestic consumption or industrial production.	
	<p>It is an indicator of the use of fresh surface or groundwater (renewable or fossil) used in the production of goods or services. Blue water from rivers or aquifers is used directly for irrigation, domestic, or industrial purposes, and can evaporate, return to a different catchment area or the sea, or return during a different period than the collection period.</p> <p>To calculate blue water WF, the evaporation of blue water plus the incorporation of blue water and the lost return flow are considered.</p>
Grey WF: Fresh water needed (volume) to dilute contaminants and maintain water quality standards in an ecosystem	
	<p>This indicator is defined as the volume of freshwater needed to assimilate the pollutant load generated in a process (so that these diluted pollutants become harmless). It is based on the concentrations of that pollutant under natural conditions and on the requirements and demands of existing environmental quality standards or legislation.</p> <p>To calculate the grey WF, the pollutant load or concentration is divided by the difference between the concentration required by legislation and the natural concentration present in the receiving water body.</p>

Source: own elaboration based on [33].

WF can be applied at different levels. In the case of a product, it assesses water consumption and pollution generated at all stages of the production chain. It estimates the total volume of freshwater consumed and polluted to produce goods and services used by an individual consumer. It can be analysed in a defined geographic area—a river basin, province, state, nation, or any other administrative or hydrological unit—considering water use and pollution within that space. Finally, in the case of a company, it is calculated based on two main components: the operational or direct component (water consumed or polluted in its activities) and the supply chain or indirect component (freshwater consumed or polluted in the production of all goods and services). Table 3 shows the relationship between the different types of WF considered.

Table 3: Relationship between the different types of WF.

WF of a Product	= Sum of the WF of the production and supply chain necessary to produce the product
WF of a Consumer	= Sum of the WF of all products consumed
WF of a Company	= Sum of the WF of all final products produced by the company
WF of a Delimited Geographical Area	= Sum of the WF of all processes taking place in that area

Source: own elaboration based on [33].

The quantification of the WF represents a step forward toward achieving the SDGs related to water, within a framework of efficient management and consumption. In productive terms, it is a key indicator in strategic sectors such as agriculture and industry, which should incorporate an economic, social, and environmental dimension into their processes. Agriculture accounts for more than 70% of global water withdrawals, while industry and energy account for 20%, and domestic use represents 10%. Given that more than half of the population lives in urban areas, the sustainable development of water resources is closely linked to urban growth, social equity, and environmental sustainability.

The complexity of measuring the WF is crucial to addressing sustainable socioeconomic development. From an economic sustainability perspective, it is necessary to allocate and use/consume water efficiently. Economically speaking, water use is only sustainable

if the benefits outweigh the total costs associated with the WF. To achieve this, it is essential to invest in technologies that improve the collection, utilization, and productivity of water resources, avoiding waste.

5. Indicator of Efficiency in Sustainable Water Consumption in the Spanish Autonomous Communities

3.1. Methodological Approach

Following the previous discussion, the development of an efficiency indicator for sustainable water use in Spain's Autonomous Communities (CC.AA.) is proposed, with the aim of providing a quantitative assessment of the situation based on regional and national statistical data. This analysis will allow for the normalization of indicators and a more precise evaluation of efficiency and sustainability in water management in Spain.

The 2030 Agenda includes 17 goals and 169 targets, accompanied by 231 indicators designed to be measured using statistical data generated by each country. In the Spanish case, the National Statistics Institute (INE) compiles the statistics “2030 Agenda Indicators for Sustainable Development,” publishing indicators related to the SDGs. The indicators are continuously updated and form part of the current annual statistical program, incorporating information from both the INE and other official sources. Regarding SDG 6, monitoring indicators are defined by the Ministry for the Ecological Transition and the Demographic Challenge. In some cases, national-level data is already available, while in others, possible data sources are still being explored (Table 4).

Table 4: Main Monitoring Indicators (INE) of the 2030 Agenda for Sustainable Development in relation to SDG 6.

Indicator 6.1.1 Proportion of the population using safely managed drinking water services. Percentage.
Indicator 6.2.1 Proportion of the population using: a) safely managed sanitation services, and b) hand-washing facilities with soap and water. Percentage.
Indicator 6.3.1 Proportion of domestic and industrial wastewater flows that are safely treated.
Indicator 6.3.2 Proportion of bodies of water with good ambient water quality. Percentage.
Indicator 6.4.1 Change in water-use efficiency over time.
Indicator 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources. Percentage.
Indicator 6.5.1 Degree of integrated water resources management implementation.
Indicator 6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation.
Indicator 6.6.1 Change in the extent of water-related ecosystems over time.
Indicator 6.A.1.1 Amount of official development assistance for water and sanitation that is part of a government-coordinated spending plan. Euros.
Indicator 6.B.1 Proportion of local administrative units with established policies and operational procedures for local community participation in water and sanitation management. Percentage.

Source: Own elaboration based on [34].

Following this logic, the development of an efficiency indicator for the sustainable use of water in the Spanish Autonomous Communities (CC.AA.) is addressed, with the objective of providing a quantitative assessment of the current situation. The information and future updates of the indicators in Table 4 could improve the proposed composite indicator in the following section, provided that regional data is available.

The analysis begins by considering the proportion of water consumed and polluted by human activities, particularly in the agricultural, industrial, and domestic sectors, as reported by the World Water Assessment Programme [7]. Water use is directly related to the productive structures of economies and the amount of water used and degraded by each sector [29].

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According to [35], water demand (QA) is defined as the total volume of actual consumption required for human activity, based on five factors:

$$QA = D (PA, PB, Y, G, N), \text{ where}$$

PA: price of water,

PB: price of other substitute or complementary goods,

Y: income of the resident population,

G: water consumption preferences,

N: resident population.

In a broader reflection, additional factors can be considered to analyse water consumption and demand (Table 5).

Table 5: Main factors affecting water demand.

Factors	Components of the factors
Climate	Temperatures Precipitation Climate type (Atlantic, mountain, etc.) Climatic seasonality (spring, summer, autumn, winter)
Population	Population density Migration movements Population size Urban and rural population
Economic situation	National and personal income Gross domestic product (GDP) Trade balance Water price
Infrastructure	Water supply and impoundment Purification, cleaning and control Pressure in the network, sewerage Water quality
Productive activities	Primary sector: Agriculture, livestock, and fishing Industrial sector Tertiary sector and domestic use
Miscellaneous (related to quality of life)	Green areas Vehicle washing Filling swimming pools or watering golf courses Firefighting

Source: Own elaboration adapted from [35].

In this context, just as the calculation of the WF is an optimal tool for water management, the development of an indicator measuring the proximity or distance to efficiency goals in sustainable water use can also be so. Following the approach of [33], a composite indicator can provide information for decision-making regarding the environmental impacts linked to water consumption, such as strategic planning, priority setting, product and process design, and resource investments.

[36] define a composite indicator as “a simplified representation that seeks to summarize a multidimensional concept into a simple (one-dimensional) index based on an underlying conceptual model.” Thus, it allows the integration of several variables more precisely into a specific characteristic or attribute (Table 6). The construction of the composite indicator requires two basic conditions: 1) A clear definition of the objective or concept to be measured. This is not always an easy task, as the multidimensional nature of the concept complicates its concretization. 2) The existence of basic, clear, reliable, and homogeneous information to carry out the corresponding measurement.

Table 6: Advantages and limitations of a composite indicator.

Advantages	Limitations
Allows reducing the complexity of the information analysed individually or from multiple perspectives.	Perception or confirmation biases when reducing the complexity of a topic into a single value that concentrates and therefore measures everything.
Implementation in phases related to subsystems, sub-indicators, or sub-sections that make up the composite indicator, enabling a more comprehensive view.	Excessive simplification of the analysed problem by summarizing all possible information.
Integrates and summarizes different perspectives on a topic, providing a “contextual overview.”	Confusing and unreliable messages if the indicator is poorly constructed or interpreted.
Facilitates comparability between units of analysis.	Possible redundancy in the selection and inclusion of information that will form part of the composite indicator.
Easy to interpret due to its synthesis capability by reducing the size of the initial list of indicators to consider.	Limited to the information available or measurable.

Source: Own elaboration based on [36].

3.2. Database of the composite indicator

The unit of analysis for the indicator are the 17 Autonomous Communities or regions (NUTS 2 level in the European classification), along with Ceuta and Melilla considered jointly due to statistical availability. Additionally, national-level information is used to normalize all indicators (Spain = 100).

The main limitation is obtaining enough data from the same source with information for all regions. Two groups of indicators are designed to build the composite indicator: 1) related to hydraulic resources and environmental conditions of each region; 2) covering the level of water use/consumption, linked to the productive structure and socioeconomic conditions of the analysed territory.

For the selection of indicators, the integral water cycle is taken as the first reference, which includes the capture and purification of water, the supply (provision and distribution) of drinking water, and the sanitation (sewage and treatment) of wastewater before its return to the natural environment without causing environmental damage.

To facilitate availability, homogenization, and possible replicability of the process, most indicators about available resources are obtained from the Spanish National Institute of Statistics (INE), particularly from the “Statistics on Water Supply and Sanitation.” The information is complemented with the “Water Balance Statistics” from the State Meteorological Agency (AEMET) [37], which includes data on precipitation, evapotranspiration, and soil moisture. For simplicity and utility, annual accumulated precipitation data (litres/m²) and soil moisture expressed as the percentage of water available to plants, considering a total available water reserve equal to the maximum reserve will be used. Similarly, the Climate Surveillance Statistics from AEMET are used, providing key data on climatic conditions such as monthly average temperature, monthly averages of daily maximum and minimum temperatures, and monthly accumulated precipitation. For this analysis, the average temperature of each region is selected.

Regarding available resources, it is fundamental to consider the water available in rivers that cross each Autonomous Community, as well as reservoir water. This information is collected by river basins, which are essential for integrated and sustainable management,

although “water management by basins should not be understood as a ‘panacea’ but as an adaptive co-management practice” [38]. Therefore, the most accurate approach would be to use the information provided by the hydrographic confederations, as shown in Table 7. However, one of the main limitations identified is the lack of homogeneous information about the flow of each river, which should also be distributed by region according to population or area in km². Given this difficulty, it is considered a possible future improvement, and for now, it is omitted from the indicator.

Table 7: Hydrographic Confederations in Spain.

Hydrographic Confederation	Main rivers	Regions (NUTS 2) / provinces (NUTS 3)
Intercommunity		
Geographical demarcation of the Guadalquivir	Genil, Guadaira, Guadalete, Guadalbullón, Guadalquivir	Andalusia, Castile-La Mancha, Murcia, Extremadura
Hydrographic demarcation of the Segura	Segura and its tributaries (Mundo, Taibilla, Guadalentín)	Murcia, Com. Valenciana, Castile-La Mancha, Andalusia
Hydrographic demarcation of the Júcar	Júcar, Cabriel, Turia	Catalonia, Valencian Community, Aragon, Castile-La Mancha, Murcia
Hydrographic demarcation of the Cantabrian Sea	Eo, Portia, Navia, Esva, Narcea, Nalón, Sella, Cares, Nansa, Saja, Besaya, Pas, Miera, Asón and Agüera Nervión, Oria and Urumea and Bidasoa	Asturias, Cantabria, Basque Country, Navarra and Castile and Leon
Intra-community		
Hydrographic Demarcation of Galicia Coast	Verdugo, Ría de Vigo y Ría de Baiona.	A Coruña, Lugo y Pontevedra

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Hydrographic Demarcation of the Internal Basins of the Basque Country		Deba, Urola, Ibaizabal, Butroe y Oka	Álava, Guipúzcoa y Vizcaya
Hydrographic Demarcation of the Internal Basins of Catalonia		Ter y Llobregat.	Barcelona, Tarragona, Gerona y Lérida
Hydrographic demarcation of the Atlantic basins of Andalusia	Guadalete-Barbate Hydrographic District	Guadalete y Barbate	Cádiz
	Tinto-Odiel-Piedras Hydrographic District	Tinto, Odiel, Piedras y Chanza.	Huelva
	Mediterranean Hydrographic District		Cádiz, Granada, Málaga, Almería y Córdoba
Hydrographic Demarcation of the Balearic Islands			Balearic Islands
Hydrographic Demarcation of the Canary Islands			Canary Islands
Shared with other countries			
Miño-Sil River Basin District		Avia, Deva, Limia, Arnoya, Bibei, Miño y Sil.	Galicia, Castile and Leon and Asturias
Duero River Basin District		Duero, Adaja, Águeda, Arlanza, Arlanzón, Bernesga, Carrión, Cega, Eresma, Eria, Esla, Luna, Órbigo, Pisuerga, Tamega, Tera y Tormes	Castile and Leon, Galicia, Cantabria, La Rioja, Castile-La Mancha, Extremadura and Madrid.
Tajo River Basin District		Tajo	Aragon, Castile-La Mancha, Castile and Leon, Madrid and Extremadura

Guadiana River Basin District	Alcudia, Jabalón Azuer, Pinilla, Rus y Córcoles.	Castile-La Mancha, Andalusia and Ex- tremadura
Ebro River Basin District	Ebro y Garona	Castile and Leon, Cantabria, Basque Country, Rioja, Navar- ra, Aragon, Castile-La Mancha, Valencian Community and Cat- alonia.
Ceuta River Basin District		Autonomous City of Ceuta
Melilla River Basin District		Autonomous City of Melilla

Source: Own elaboration. Spanish Agricultural Guarantee Fund (FEGA). List of Hydrographic Confederations. Ministry of Agriculture, Food and Environment.

In the case of reservoirs by hydrographic basin, there are more than 350 reservoirs in Spain with a total capacity of 54,000 hm³ of water, equivalent to 50% of the country's river flow (www.embales.net). The greatest capacity (14,225 hm³) is found in Extremadura, with the La Serena reservoir (Badajoz) located on the Júcar River, followed by Andalusia (11,385 hm³) and Castile and Leon (8,305 hm³), while La Rioja has only 136 hm³ [39]. However, data on stored water cannot be included due to a lack of information for the Balearic Islands, Canary Islands, and Ceuta and Melilla.

Based on the available information for all Autonomous Communities and the relevance of each indicator, Table 8 presents the proposed indicators selected to construct the composite indicator. The table specifies their effect (positive or negative) and their relationship with the aspects developed in the study on water footprint and sustainability. The data correspond to 2018 for water consumption indicators and to 2019 for the rest, totalling 13 indicators used.

Table 8: List of indicators considered for the development of the composite indicator.

Indicator	Effect on the indicator and justification	Relationship with water footprint	Relationship with sustainability typology
Subindicator 1. Water resources and environmental conditions S1			

The importance of efficiency and sustainability in water...

Volume of available potable water litres/inhabitant/day, Source: INE	Positive, water resources	Improving blue WF, increasing the volume of freshwater accessible for consumption	Social Direct, reducing dependence on blue and green water
Percentage of actual losses relative to the volume of water supplied, %, Source: INE	Negative, lost water resources	Worse blue WF, unproductive supply chains	Economic Indirect, technical inefficiency, and waste of water resources
Volume of treated wastewater cubic meters/day/1,000 inhabitants, Source: INE	Positive, water resources	Improving grey WF, recycling and remediation of contaminated water	Environmental Direct reuse of water resources
Volume of sludge generated in wastewater treatment tons of dry matter/year/inhabitants, Source: INE	Positive, generated energy resources	Improving grey WF, recycling and remediation of contaminated water	Environmental, circular economy, sustainable development
Precipitation litres/m ² , Source: AEMET	Positive, generated water resources	Improving green WF, increasing freshwater reserves	Environmental, circular economy, sustainable development
Average temperature degrees °C, Source: AEMET	Affects the water balance	Worse green/blue/grey WF, desertification	Environment, ecosystems, human and animal health, agriculture
% Soil moisture above maximum capacity %, Source: AEMET	Negative, evapotranspiration	Improving green WF, ecosystems and use of blue water	Environmental, ecosystem maintenance and increased rainfall
Greenhouse Gas (GHG) CO ₂ Emissions Kt/1,000 inhabitants, Source: Ministry for the Ecological Transition and the Demographic Challenge	Affects the water balance	Worse green WF, atmospheric carbonization and side effects on other variables (temperature)	Environmental, rising temperatures, deteriorating water and air quality
Subindicator 2. Uses/factors and conditions of water consumption S2			

Sustainability, Innovation and Social Impact

Household water consumption, litre/inhabitant/day, Source: INE	Negative: outdated facilities, inefficient use	Worsening of blue WF, inefficient consumption	Social: waste of water resources due to inefficiency
Population with higher education, %, Source: INE	Positive: increased awareness of efficient use	Improving green/blue/grey WF, contributing to circular economies	Social: understanding and awareness of the importance of a sustainable society
Population density, inhabitants/km ²	Negative: concentration of demand	Worsening of blue WF, overexploitation of water resources	Social: waste generation
Agricultural and industrial activity, %GVA, agriculture and manufacturing industry, as a percentage of total GVA, Source: INE	Negative: intensive operations, wastewater pollution	Worsening of blue/grey WF, crop and pasture needs, CO ₂ emissions, and increased consumption in operational activities	Economic: deterioration of ecosystems
Energy production, GWh per inhabitant, Source: Electric grid	Positive: hydroelectric plants	Improving green/blue/grey WF, energy transition	Economic: renewable energy sources

Source: own elaboration based on [40]. INE Water Indicators, Water Supply and Sanitation Statistics, Regional Accounts, Labor Force Survey, AEMET, Water Balance Statistics and Climate Monitoring Statistics.

6. Results

To construct the index, differentiated weightings are applied to the indicator groups, following the proposal by [40]. Since water resource availability and environmental factors have a more intense and direct impact, Subindicator 1 receives a weight of 60%, distributed equally among its 8 indicators. Subindicator 2, related to use and conditioning factors, is weighted at 40%, assigning equal weight to its 5 variables. This uniform distribution is due to the lack of sufficient historical information to establish differentiated weightings objectively.

Thus, the Composite Indicator of Efficiency in the Sustainability of Water Use in Spanish Regions (IESWUR) is proposed as a weighted sum of the two subindicators:

$$\text{IESWUR} = 0.60 * S1 + 0.40 * S2, \text{ where:}$$

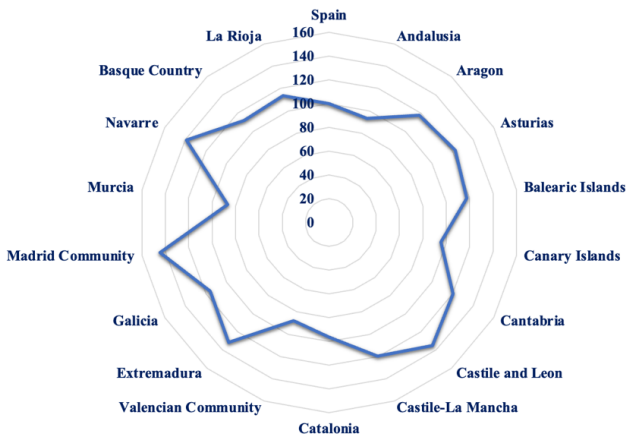
$$S1 = \sum I_i \text{ from } i = 1 \dots 8 \text{ (Table 6)} / n1, \text{ with } n1 = 8$$

$$S2 = \sum I_i \text{ from } i = 9 \dots 13 \text{ (Table 6)} / n2, \text{ with } n2 = 5$$

These are calculated based on data referenced to the value obtained for Spain, set to 100, so that all Autonomous Communities are comparable. Each indicator I_i (with $i = 1 \dots 13$) is previously adjusted either according to the number of inhabitants or expressed as a share of a regional total or as a percentage, as specified in Table 6.

The results show a relatively better positioning for the Community of Madrid, Navarre, Castile and Leon, Extremadura, and Asturias, which, along with seven other regions, exceed the national average (Spain = 100). In contrast, five regions—along the Mediterranean arc, the south, and the Canary Islands—show values below the national reference. Figure 1 offers a clearer visualization of these divergences, which are mainly based on differences in demographic and economic variables, especially in the productive structure.

Figure 1: Indicator of Efficiency in the Sustainability of Water Use in the Spanish Autonomous Communities (IESWUR).



Source: Own elaboration.

7. Conclusions and Recommendations

This work presents a proposed quantitative analysis tool based on an indicator of sustainability and efficiency in water use, which reflects how analytical approaches change when certain variables are incorporated. The composite indicator, made up of thirteen variables, offers a simplified summary of the behaviour of environmental conditions, consumption, and the use of water resources. The variables are grouped into two dimensions: water resources and environmental conditions; and water consumption uses/factors and constraints. The resulting composite indicator, IESWUR, highlights how climatic, demographic, social, political, and economic differences among the Spanish Autonomous Communities affect the efficiency of sustainable water use.

Regional differences shown by the composite indicator can be explained by uneven population growth, migratory movements, changes in consumption patterns, climatic and environmental conditions, improvements in water supply, and the impact of tourism in certain regions. In terms of consumption, there has been an intensive increase in goods and services linked to improved household income during Spain's periods of economic growth, which has progressively increased the water footprint. Regarding population growth, the explanatory factor is the arrival of both national and foreign immigrants, which raises demand for water resources.

In the study by [35] on the total supply of water footprint in Spain and its regions, useful insights are offered to interpret the results of the proposed composite indicator. At the national level, an upward trend in water supply is observed, driven by increasing demand from the population and productive sectors. At the regional level, this demand follows different patterns depending on the climatic, demographic, social, political (management), and economic conditions of each region.

In this regard, measuring efficiency requires improving primary data collection and strengthening water governance. Prolonged droughts, desertification, and population growth demand more efficient and resilient management models, as highlighted by [41]. This entails not only modernizing infrastructure and water-saving

technologies but also strengthening international cooperation and developing composite indicators that allow for assessing performance in water resource management.

Water scarcity can be physical—a lack of available water—or economic—a lack of infrastructure and financial resources to guarantee its access and distribution—. Both limit sustainable development and can cause conflicts between sectors and territories. Therefore, integrated water management is essential to improve efficiency, requiring greater coordination between sectors and governments to prioritize investments in water. Ensuring its future availability demands a comprehensive approach that combines technological innovation, effective public policies, and a global commitment to its conservation.

In this context of increasing global water scarcity, it is crucial to move toward a circular economy approach linked to water reuse. As noted by [42], it is essential to promote social acceptance of reclaimed water use, as even technically and economically viable water reuse projects can fail due to social rejection. This perception depends on trust in the technology, the regulatory framework, project management, and the quality of the reclaimed water.

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