


Sustainability Water Index (SWI) for Peruvian River Basins¹ *Índice de Sostenibilidad del Agua (ISA) en cuencas del Perú*

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Abstract: The article presents a methodological proposal for assessing water sustainability in river basins using the Water Sustainability Index (WSI) and its application in the river basins of Chili, Caplina, Chancay-Lambayeque, and Urubamba, as well as at the national level in Peru, for the period 2012-2021. The WSI consists of three sub-indices based on the components of sustainable development: economic (SiE), social (SiS), and environmental (SiA). The WSI rating scale ranges from 0 (lowest) to 100 (highest). Intrinsic and extrinsic indicators, both economic, social, and environmental, were selected. The results show that, both at the basin level and nationally, the social component performs best. However, significant challenges remain in the environmental component (Caplina and Chili River basins) and the economic component (Chancay-Lambayeque, Chili, Urubamba River basins, and national level). Additionally, the risk of water unsustainability is linked to both physical factors (water scarcity in the Caplina basin) and management issues (in the Chancay-Lambayeque basin).



Keywords: Water Sustainability. Water Security. Sustainable Development. Sustainable Development Goals. Peru

¹ The article is based on the thesis "Water sustainability indicators in basins of Peru", prepared by the main author of the article, advised by the second author, to obtain the degree of Doctor in Water Resources at the National Agrarian University La Molina, Peru.

Resumen: El artículo presenta una propuesta metodológica para la evaluación de la sostenibilidad del agua en cuencas hidrográficas mediante el Índice de Sostenibilidad del Agua (ISA) y su aplicación en las cuencas hidrográficas de los ríos Chili, Caplina, Chancay-Lambayeque, Urubamba, y en el ámbito nacional del Perú, en el periodo 2012-2021. El ISA está conformado por tres subíndices basados en los componentes del desarrollo sostenible: económico (SiE), social (SiS) y ambiental (SiA). La escala de valoración del ISA va de 0 (más bajo) a 100 (más alto). Se han seleccionado indicadores intrínsecos y extrínsecos, económicos, sociales y ambientales. Los resultados demuestran, en el ámbito de las cuencas analizadas, así como en el ámbito nacional, un mejor desempeño en el componente social; asimismo, existen importantes retos en el componente ambiental (cuencas de los ríos Caplina y Chili) e importantes retos en el componente económico (cuencas de los ríos Chancay-Lambayeque, Chili, Urubamba, y ámbito nacional). Por otro lado, el riesgo de insostenibilidad del agua está relacionado tanto a los aspectos físicos (escasez de agua en la cuenca Caplina) como a los aspectos de gestión (en la cuenca Chancay-Lambayeque).

Palabras clave: Sostenibilidad del agua. Seguridad del agua. Desarrollo sostenible. Objetivos de desarrollo sostenible. Perú.

1. Introduction

Water is fundamental to all human activities, the maintenance of ecosystems (Bertule et al., 2018), and achieving sustainable development, which aims for the balanced and integrated development of economic, social, and environmental components (UN, 2015). The 2030 Agenda for Sustainable Development (2015) established 17 Sustainable Development Goals (SDGs). SDG 6, which seeks to "Ensure availability and sustainable management of water and sanitation for all," articulates the aspects of water sustainability necessary for national and global policies and impacts other SDGs due to existing interdependencies (UN-Water, 2016; Cai et al., 2021; Taka et al., 2021; Bertule et al., 2018).

Sustainability assessment has been of interest to the scientific community since the establishment of the concept of "sustainable development", with a parallel interest in assessing water sustainability (Juwana et al., 2012; Vollmer et al., 2016; Di Vaio et al., 2021).

Water sustainability assessments have been conducted using an indicator-based approach (Juwana et al., 2012; Vollmer et al., 2016). Bertule et al. (2018) reviewed the approach for monitoring indicator 6.5.1: "degree of implementation of integrated water resources management (IWRM)," comparing it with other indicators, such as the OECD's principles of water governance. Cai et al. (2021) analyzed, at the national level, how water security or sustainability, in accordance with SDG 6 targets, has become a strategy for

addressing water risk in 232 countries and territories. They also proposed the SDG 6 Index (SDG6I), which has allowed for the determination of a baseline for SDG 6 indicators through numerical scores ranging from 0 (lowest score) to 100 (highest score).

Breuer and Spring (2020) conducted research on the implementation of the 2030 Agenda in the Cuautla River basin in Morelos, Mexico. Tinoco et al. (2021), based on Bertule et al. (2018), developed a comparative analysis of water governance in Mexico, Chile, and Brazil based on SDG indicator 6.5.1. Bezerra et al. (2022) published the results of the operationalization of integrated water resources management in basins in Brazil, Colombia, and Peru; likewise, the OECD has published on water governance in Peru (OECD, 2021).

In Peru, with the approval of Law 29338, the Water Resources Law, in 2009, as well as the creation of the National Water Authority (ANA) in 2008, a new stage of water management began, guided by the "degree of implementation of integrated water resources management" or IWRM (ANA, 2019a). In turn, the evaluation of IWRM was carried out using SDG indicator 6.5.1 (ANA, 2017, 2019b, 2023) and by developing a pilot test for the application of the indicators of the OECD Principles of Water Governance (ANA, 2019a).

The objective of this work is to present the proposed Water Sustainability Index (WSI), a methodology for quantitatively determining the state of water sustainability in a basin or country on an annual and comparative timescale, based on the components of sustainable development: economic development, social equity, and environmental sustainability. The proposal incorporates the scale for quantifying and using SDG 6 indicators from Cai et al. (2021). Furthermore, it differs from the indices proposed by Juwana et al. (2012), Vollmer et al. (2016), and Cai et al. (2021) by proposing a balanced quantification of the contributions of the components of sustainable development (economic, social, and environmental), as well as by incorporating both intrinsic (inherent to water) and extrinsic (external but influencing the water situation) indicators. To demonstrate the applicability of the index, the application has been developed in four hydrographic basins of Peru (Chili, Caplina, Chancay-Lambayeque and Urubamba) and at the national level; it should be noted that some limitations were faced in the research ².

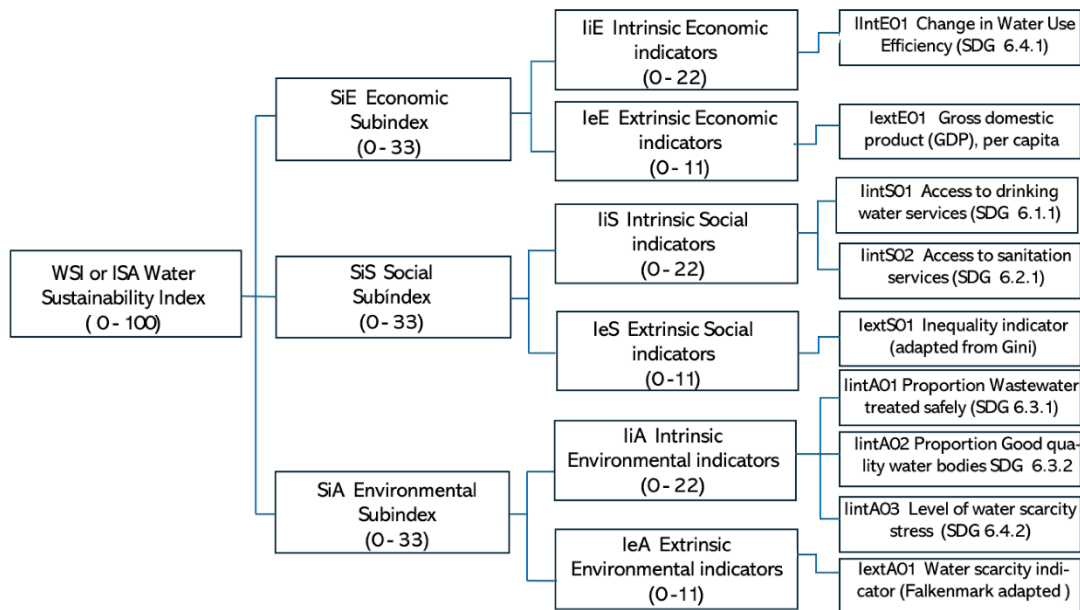
2. Methodology

To establish an index that allows for the quantitative assessment of water sustainability, the methodology for determining the ISA is based on three sub-indices, each representing a component of sustainable development (economic, social, and environmental), with equal weighting (1/3 for each). The sub-indices, in turn, are composed of intrinsic

² The limitations in the research were: the discontinuity in the evaluation of the Gini indicator (inequality indicator) at the departmental level, by the INEI; and the evaluation of the SDG indicator 6.3.2. (percentage of water bodies of good environmental quality) in periods longer than annual, since it has been identified that in the period 2015-2021 the evaluation was done only once, as well as not considering any basin in the Titicaca slope.

indicators, or indicators specific to water itself, and extrinsic indicators, which are external factors that influence the water situation. The weighting is 2/3 for intrinsic indicators and 1/3 for extrinsic indicators. The number of intrinsic or extrinsic indicators in each sub-index is determined by their relevance to the component (economic, social, or environmental), as well as the availability of information for the indicator in official sources (Aguirre-Núñez, 2023). The number of indicators (which varies for each sub-index) is moderated by the similar weight assigned to each sub-index (1/3). Figure 1 shows the ISA schematic.

Figure 1. Structure of the Water Sustainability Index WSI (ISA)



Source: own elaboration.

2.1 Criteria for defining the ISA, the sub-indices, and the indicators

The Water Sustainability Index WSI (ISA) is considered to assess water sustainability (not management, which is assessed by SDG 6.5.1), with the WSI itself being an outcome indicator rather than a process indicator (Cai et al., 2021), and the processes for weighting the indicators should be simple and robust (Munda & Nardo, 2005). Similar to the scale used in other indices (Cai et al., 2021), a rating range of 0 to 100 has been adopted for the WSI to assess water sustainability. The WSI (ISA) score is determined by summing the economic, social, and environmental sub-indices, each with a similar weighting (1/3). The range of the sub-indices is from 0 to 33.33. Each sub-index, in turn, is determined from the results of the intrinsic and extrinsic indicators. The selection of indicators was based on the availability of information from official sources. The WSI (ISA) will allow for the development of a comparative spatial and temporal analysis of water sustainability.

2.2 Structure, formula and range of values of the WSI (ISA)

The structure of the WSI (ISA) is shown in Figure 1 and the formula for the calculation is presented in formula (1):

$$ISA = SiE + SiS + SiA \dots\dots\dots (1)$$

Where:

WSI (ISA) = Water Sustainability Index

SiE = Economic Development Sub-index

SiS = Social Equity Sub-index

SiA = Environmental Sustainability Sub-index

In this sense, the ISA is a composite index, since it requires a series of variables (sub-indices or indicators) for its determination or evaluation (Munda & Nardo, 2005).

To determine a composite index, such as the WSI (ISA), the constituent components (sub-indices) must be aggregated with their respective weights (Cai et al., 2021; Sachs et al., 2018). This ensures that policymakers, implementers, and decision-makers consider each component of sustainable development (economic, social, and environmental) with equal importance and in an integrated or indivisible manner. Similar weights are assigned to each of the sub-indices: economic (SiE), social (SiS), and environmental (SiA). Specifically, the weight of each sub-index is 1/3, considering each sub-index to be equally important (Sachs et al., 2018). The formula for determining the ISA is described in Formula 2:

$$ISA = \left(\frac{1}{3}\right) SiE + \left(\frac{1}{3}\right) SiS + \left(\frac{1}{3}\right) SiA \dots\dots\dots (2)$$

The WSI (ISA) ranges on a scale from 0 to 100 and the sub-indices SiE, SiS and SiA range from 0 to 100 on a relative scale and from 0 to 33.33 on an absolute scale, when multiplied by their respective weighted values.

The SiE, SiS, and SiA sub-indices are composed of intrinsic (Iint) indicators, which are essential or internal to water, and extrinsic (Iext) indicators, which are external and influence the performance of the component represented by the sub-index. The selected intrinsic indicators correspond to the SDG 6 indicators, which have been classified according to the component with which they are most closely related (economic, social, or environmental). For the extrinsic indicators, those representing the respective sub-index component (economic, social, or environmental) and impacting the water situation in the basins have been selected. The number (n) of indicators, whether intrinsic or extrinsic, does not necessarily have to be a fixed number, as this number is determined based on the number of SDG 6 indicators relevant to each component (economic, social,

or environmental). This characteristic gives the methodology a high degree of flexibility. The weighting adopted in relative terms for the set of intrinsic indicators is 2/3 or 0.667, and for the set of extrinsic indicators it is 1/3 or 0.333, which, expressed in percentage terms and in terms of the methodology's rating scale, would correspond to 22.22% for the intrinsic indicators and 11.11% for the extrinsic indicators.

The proposed structure of the ISA provides flexibility that would allow the incorporation of more indicators (for example, those that may be very specific to a basin) without altering the weighting of the economic, social, and environmental components.

2.3 Structure and formula of the economic development sub-index (SiE)

The SiE is made up of intrinsic (IintE) and extrinsic (IextE) indicators, whose structure is shown in Figure 1 and as described in formula 3:

$$SiE = \left(\frac{2}{3}\right) * \frac{IintE1 + IintE2 + \dots + IintEn}{niE} + \left(\frac{1}{3}\right) * \frac{IextE1 + IextE2 + \dots + IextEn}{neE} \dots\dots\dots (3)$$

Where

niE = number of intrinsic economic indicators

neE = number of extrinsic economic indicators

2.4 Structure and formula of the social equity sub-index (SiS)

The SiS is made up of intrinsic indicators (IintS) and extrinsic indicators (IextS) whose structure is shown in Figure 1 and as described in formula (4):

$$SiS = \left(\frac{2}{3}\right) * \frac{IintS1 + IintS2 + \dots + IintSn}{niS} + \left(\frac{1}{3}\right) * \frac{IextS1 + IextS2 + \dots + IextSn}{neS} \dots\dots\dots (4)$$

Where

niS = number of intrinsic social indicators

neS = number of extrinsic social indicators

2.5 Structure and formula of the environmental sustainability sub-index (SiA)

The SiA is made up of intrinsic (*lintA*) and extrinsic (*lextA*) indicators according to the structure shown in Figure 1 and according to formula (5):

$$SiA = \left(\frac{2}{3}\right) * \frac{lintA1 + lintA2 + \dots + lintAn}{niA} + \left(\frac{1}{3}\right) * \frac{lextA1 + lextA2 + \dots + lextAn}{neA} \dots\dots\dots (5)$$

Where:

niA = number of intrinsic environmental indicators

neA = number of extrinsic environmental indicators

2.6 Indicators of the economic (SiE), social (SiS) and environmental (SiA) sub-indices

Tables 1, 2, and 3 present the indicators for the SiE, SiS, and SiA, with their respective classifications (intrinsic and extrinsic) and sources of information. The sub-indices are calculated using formula (1), formula (2), and formula (3), respectively.

Table 1. Indicators of the Economic Subindex

Indicator	Indicator Description	Unit	Source
Intrinsic Economic Indicator 1 (<i>lintE1</i>)	Change in Water-Use Efficiency Over Time (SDG Indicator 6.4.1)	Normalized to a 0–1 scale, as described in Section 2.8	National Institute of Statistics and Informatics (INEI) and National Water Authority (ANA)
Extrinsic Economic Indicator 1 (<i>lextE1</i>)	Gross domestic product (GDP), per capita	Normalized to a 0–1 scale, as described in Section 2.8	INEI

Source: Own elaboration.

Table 2. SiS indicators

Indicator	Indicator Description	Unit	Source
Intrinsic Social Indicator 1 (lintS1)	Proportion of the population with access to safely managed drinking water services. SDG Indicator 6.1.1.	Percentage (%) normalized to the scale 0 to 1, as described in section 2.9.	Superintendency of Sanitation Services (SUNASS), INEI
Intrinsic Social Indicator 2 (lintS2)	Proportion of the population using safely managed sanitation services, including a handwashing facility with soap and water. SDG Indicator 6.2.1.	Percentage (%) normalized to the scale 0 to 1, as described in section 2.9.	SUNASS, INEI
Extrinsic Social Indicator 1 (IextS1)	Inequality indicator (adapted from the Gini coefficient, Atkinson (1970))	Inequality indicator (adapted from the Gini coefficient, Atkinson (1970))	INEI (2015); Central Reserve Bank of Peru BCRP (2020); World Bank website (period 2015-2021) https://datos.bancomundial.org/indicador/SI.POV.GINI?locations=PE

Source: own elaboration.

Table 3. SiE Indicators (*)

Indicator	Indicator Description	Unit	Source
Intrinsic Environmental Indicator 1 (lintA1)	Proportion of wastewater treated safely (SDG indicator 6.3.1.)	Percentage (%) normalized to the scale 0 to 1, as described in section 2.10.	SUNASS, INEI
Intrinsic Environmental Indicator 2 (lintA2)	Proportion of good quality water bodies (SDG indicator 6.3.2.)	Percentage (%) normalized to the scale 0 to 1, as described in section 2.10.	ANA, INEI
Intrinsic Environmental Indicator 3 (lintA3)	Level of water scarcity stress: water withdrawal as a proportion of available water resources (SDG 6.4.2.) *	Percentage (%) normalized to the scale 0 to 1, as described in section 2.10.	ANA, INEI
Extrinsic Environmental Indicator 1 (IExtA1)	Water scarcity indicator (Falkenmark indicator, Falkenmark (1989))**	Standardized to the 0 to 1 scale, as described in section 2.10	Prepared with information from ANA and INEI

Note (*). Water withdrawal from the natural source is more closely linked to the environmental dimension of water sustainability

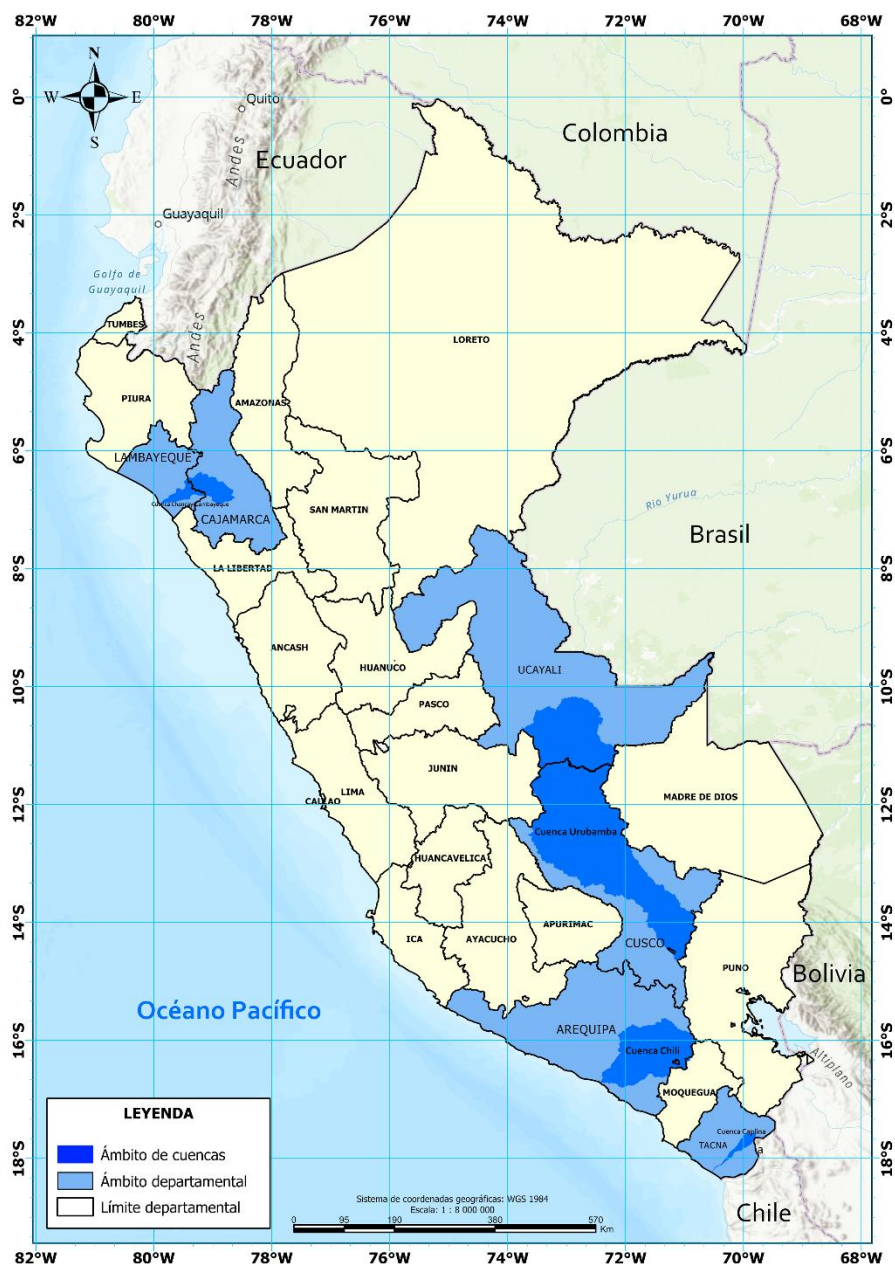
Note (**). Although the indicator is estimated based on water availability per person, it assesses the pressure exerted on water in the basin, and the impact is related to the environmental dimension.

Source: own elaboration

2.7 Scope of application of the WSI (ISA)

The WSI (ISA) has been applied to the Chili, Caplina, Chancay-Lambayeque, and Urubamba River basins, as well as at the national level. The basins were selected to represent the country's different hydrographic slopes (Pacific and Amazon), their geographical location (north and south), and the availability of basin-scale data. The Titicaca basin and the lowland rainforest were not included, as both present greater challenges in reconciling basin-scale and departmental-scale indicators. The basin areas are represented in Figure 2.

Figure 2. Territorial Scope of the Research: National and Basin Levels



Source: own elaboration

2.8 Standardization of the indicator scale

In order to standardize the information on a single scale, the results have been normalized on the scale, with values from 0 to 100. The procedure for standardizing the scale or score of the indicators is described in the following sections: 2.9, 2.10 and 2.11.

2.9 Information on the SiE indicators

Intrinsic indicator 1 corresponds to water productivity, which was determined by relating water availability in each basin to the departmental GDP. Standardization was performed using a threshold value of USD 40.00/m³, above which water productivity is considered optimal (Cai et al., 2021). That is, in basins with water productivity equal to or greater than USD 40.00/m³, the indicator result is 100; and then, proportionally, the results are estimated (0 to 100 according to the economic productivity of water in the basin). The results are presented in Table 4.

**Table 4. Change in Water Use Efficiency
(Standardized SDG Indicator 6.4.1)**

Scope / Year	National	Chili	Caplina	Chancay Lambayeque	Urubamba
2012	33.86	43.51	100.00	100.00	100.00
2015	18.54	38.78	100.00	50.18	100.00
2016	26.60	44.70	100.00	37.89	90.10
2017	26.37	43.86	100.00	37.75	78.39
2018	22.33	41.66	100.00	36.37	68.84
2019	33.04	41.02	100.00	36.77	61.62
2020	23.70	33.48	100.00	34.30	50.46
2021	23.31	37.13	100.00	39.09	44.60

Source: Own elaboration, based on data from INEI, BCRP, SNIRH ANA, and PADH at the basin level.

The extrinsic economic indicator 1 (IextE1) is GDP per capita. Table 5 shows the national and departmental GDP per capita. Considering that cities (more than river basins) are the primary drivers of the human development indicator (UNDP, 2009), departmental and respective river basin GDP have been treated as equivalent. Table 5 presents the GDP per capita information in Peruvian soles (S/).

Table 5. National and Departmental Per Capita GDP (S/.)

Scope / Year	National	Chili	Caplina	Chancay Lambayeque	Urubamba
2012	14 341	17 491	17 558	8320	14 314
2015	15 581	17 726	19 970	8943	16 666
2016	15 949	21 823	19 270	9035	17 106
2017	16 056	22 070	19 036	9115	16 602
2018	16 379	22 053	20 051	9319	16 433
2019	16 446	21 442	24 0570	9375	16 417
2020	14 433	17 691	22 9210	8664	14 241
2021	16 726	19 644	23 517	9884	15 034

Source: own elaboration, based on INEI data

The values were normalized by considering the lowest and highest departmental GDP per capita values for all departments in Peru. Table 6 presents the normalized national and departmental GDP per capita (adapted to the basin) for the period 2012–2021, which is the extrinsic economic indicator 1.

Table 6. Indicator: Normalized Per Capita GDP at National and Basin Levels

Scope / Year	National	Chili	Caplina	Chancay Lambayeque	Urubamba
2012	20.94	27.97	28.12	7.50	20.88
2015	21.75	26.74	31.96	6.29	24.27
2016	22.60	36.28	30.33	6.51	25.30
2017	22.85	36.85	29.79	6.69	24.12
2018	23.60	36.81	32.15	7.17	23.73
2019	23.76	35.39	41.48	7.30	23.69
2020	19.07	26.66	38.83	5.64	18.63
2021	24.41	31.20	40.22	8.48	20.47

Source: own elaboration, based on INEI data

2.10 SiS indicator information

The indicator “proportion of the population with access to piped water” (SDG indicator 6.1.1) constitutes intrinsic social indicator 1 (IntS1). Information for the departmental or basin level comes from SUNASS (2016, 2017, 2018, 2019, 2020, 2021), and for the national level from INEI (2022). Table 7 presents the correspondence between the scope of public sanitation service companies (EPS) and the basins under study.

Table 7. Relationship Between Basins and Water and Sanitation Service Providers (EPS)

River basin	Public Sanitation Services Company (Utility) EPS
Chili	Sedapar Arequipa
Caplina	EPS Tacna
Chancay-Lambayeque	EPSEL Lambayeque
Urubamba	SEDACUSCO EMPSAPPAL Sicuani EMAQ Quillabamba EMSAPA Calca

Source: own elaboration

For the Chili, Caplina, and Chancay-Lambayeque River basins, the indicators of the water and sanitation service providers (EPS) serving the departmental capitals were considered: SEDAPAR in Arequipa, EPS Tacna in Tacna, and EPSEL in Chiclayo. For the Urubamba basin, the indicator was determined using a weighted average (based on the population served) between the SEDACUSCO EPS and the other three EPSs (EMPSAPPAL EPS in Sicuani, EMAQ EPS in Quillabamba, and EMSAPA EPS in Calca). Table 8 presents the values for the proportion of the population with access to water through the public network, corresponding to intrinsic social indicator 1.

Table 8. Proportion of the Population with Access to Water Through a Public Network

Scope / Year	National	Chili	Caplina	Chancay Lambayeque	Urubamba
2012	82.30	91.20	95.93	89.19	96.44
2015	88.20	93.92	96.33	89.42	97.37
2016	89.20	86.12	95.80	89.44	97.68
2017	89.40	90.27	96.03	89.45	98.11
2018	90.70	91.97	94.57	85.72	95.55
2019	90.80	90.97	94.90	86.17	96.38
2020	91.20	88.90	94.59	86.34	96.57
2021	90.50	88.22	93.86	85.68	95.83

Source: National level – INEI; Basin level – SUNASS. The 2021 data for the basins were estimated based on national data for 2020 and 2021 and basin-level data for 2020.

The intrinsic social indicator 2 (IintS2) corresponds to the proportion of the population using safely managed sanitation services, including a handwashing facility with soap and water (SDG indicator 6.2.1). It should be noted that the information for the river basin level comes from the same sources as intrinsic social indicator 1 (IintS1).

For the Chili, Caplina, and Chancay-Lambayeque River basins, the indicators of the water and sanitation service providers (EPS) serving the departmental capitals (SEDAPAR in Arequipa, EPS Tacna in Tacna, and EPSEL in Chiclayo) were considered. For the Urubamba basin, the indicator was determined using a weighted average of the EPS SEDACUSCO and the other companies within the basin (EPS EMPSAPPAL in Sicuani, EPS EMAQ in Quillabamba, and EMSAPA in Calca). The indicator values are presented in Table 9.

Table 9. Proportion of the Population Using Safely Managed Sanitation Services

Scope / Year	National	Chili	Caplina	Chancay Lambayeque	Urubamba
2012	77.80	80.48	95.11	80.36	91.32
2015	71.90	81.59	95.03	81.55	93.54
2016	73.70	78.89	94.59	84.00	93.82
2017	74.50	78.05	94.80	84.62	94.14
2018	76.80	79.39	92.84	80.67	89.86
2019	77.20	78.90	93.65	80.93	90.57
2020	76.80	76.90	93.34	79.06	90.77
2021	76.50	76.90	93.34	79.06	90.42

Source: National level – INEI; Basin level – SUNASS. The 2021 data for the basins were estimated based on national data for 2020 and 2021 and basin-level data for 2020.

The extrinsic social indicator 1 (IextS1) is the inequality index, based on the Gini index (Castillo, 2020), at the national and departmental levels in Peru. The inequality index proposed here corresponds to the Gini index adapted according to formula (4), where the range of inequality values goes from 0, the most unfavorable value of social equality, to 100, the highest value of social equality.

$$\text{inequality index} = 100 - \text{Gini Index}$$

The Gini Index has been obtained from INEI (2016), for the period 2012 - 2015, from Castillo (2020) for the period 2016 - 2019 and from the World Bank (2023) for the period 2020 - 2021, as presented in Table 2.

Table 10 presents the standardized results of the IextS1 indicator "social inequality" at the national level and at the departmental or river basin level for the period 2012-2021.

Table 10. Indicator: National Social Inequality, and Departmental or Basin-Level Inequality

Scope / Year	National	Chili	Caplina	Chancay Lambayeque	Urubamba
2012	55.30	59.50	60.60	60.70	57.60
2015	56.50	63.70	58.10	60.60	58.80
2016	56.30	61.80	60.10	62.60	55.80
2017	56.70	65.20	59.80	61.80	55.90
2018	57.60	65.92	60.64	62.59	56.82
2019	58.40	66.63	61.45	63.37	57.71
2020	56.20	67.33	62.25	64.13	58.59
2021	56.20	67.33	62.25	64.13	58.59

Source: Own elaboration, using data from INEI, World Bank, Castillo (2020), and Statista

2.11 Information on the SiA indicators

The intrinsic environmental indicator 1 (IintA1) represents the proportion of wastewater treated safely (SDG indicator 6.3.1). The values for the proportion of wastewater treated safely correspond to those reported by the water service providers located within the basins. The information comes from the same sources as the intrinsic social indicator 1 (IintS1); for the national level, the information comes from INEI (2023).

Table 11. Proportion of Wastewater Safely Treated

Scope / Year	National	Chili	Caplina	Chancay Lambayeque	Urubamba
2012	32.05	14.97	77.47	90.58	77.25
2015	65.44	10.79	75.33	96.60	79.80
2016	66.40	15.83	71.77	58.89	78.53
2017	78.59	94.11	68.09	99.38	66.49
2018	79.20	94.01	65.49	98.97	79.03
2019	77.91	94.15	67.15	99.15	75.18
2020	77.47	94.12	67.29	99.18	75.78
2021	77.47	94.12	67.29	99.18	75.78

Source: SUNASS. The 2021 data had not yet been published by SUNASS at the time this research was conducted. Thus, 2021 values were assumed to be the same as those reported for 2020.

The intrinsic environmental indicator 2 (IintA2) corresponds to the proportion of water bodies of good quality (SDG indicator 6.3.2), and the information from the technical document "Situational status and report of indicator 6.3.2. Percentage of water bodies of good environmental quality of sustainable development goal 6" (ANA, 2020) was used. Table 12 presents the information corresponding to IintA2.

Table 12. Proportion of Water Bodies of Good Environmental Quality

Scope / Year	National	Chili	Caplina	Chancay Lambayeque	Urubamba
2012	8.53	17.60	0.00	0.00	31.60
2015	8.53	17.60	0.00	0.00	31.60
2016	8.53	17.60	0.00	0.00	31.60
2017	8.53	17.60	0.00	0.00	31.60
2018	8.53	17.60	0.00	0.00	31.60
2019	8.53	17.60	0.00	0.00	31.60
2020	8.53	17.60	0.00	0.00	31.60
2021	8.53	17.60	0.00	0.00	31.60

Source: own elaboration based on ANA (2020)

The intrinsic environmental indicator 3 (IintA3) corresponds to the level of stress due to water scarcity (SDG indicator 6.4.2). The information for the basins was obtained from the web portal of the National Water Resources Information System (SNIRH) of the ANA and from the Water Availability Utilization Plans (PADH) that are prepared in the basins; for the national level, the information was obtained from the INEI.

Regarding the proportion of the flow that should remain in the river, the values or proportions estimated in the "Synthesis Study of the Final Report of the Integrated Monitoring Project of SDG 6 targets related to Water and Sanitation (GEMI)" (ANA, 2017) have been considered. Table 13 presents the values of the water stress level.

Table 13. Level of Water Stress

Scope / Year	National	Chili	Caplina	Chancay Lambayeque	Urubamba
2012	97.68	37.18	0.00	91.40	99.89
2015	97.11	24.75	0.00	73.39	99.73
2016	97.86	17.78	0.00	63.87	99.60
2017	97.68	13.09	0.00	62.79	99.54
2018	97.93	6.17	0.00	59.80	99.48
2019	97.72	5.02	0.00	59.30	99.41
2020	97.59	1.87	0.00	59.10	99.37
2021	97.69	0.11	0.00	58.69	99.24

Source: own elaboration, based on data from INEI, ANA, SNIRH, and PADH in basins

The extrinsic environmental indicator 1 (IextA1) constitutes the water scarcity indicator—an adapted Falkenmark index (Falkenmark et al., 1989). For its application, it was necessary to transform or adapt the scale proposed by Falkenmark to one where 100 represents the most favorable situation (no stress, availability > 1700 m³-capita/year), with a scale ranging from 0 to 100 for the proportional range of values from 0 to 1700 m³-capita/year. Table 14 presents the values for the water stress indicator.

Table 14. Falkenmark Water Stress Indicator (Adapted Falkenmark Index)

Scope / Year	National	Chili	Caplina	Chancay Lambayeque	Urubamba
2012	100.00	57.89	5.89	61.85	100.00
2015	100.00	54.94	5.62	60.17	100.00
2016	100.00	53.72	5.50	59.30	100.00
2017	100.00	52.38	5.36	58.29	100.00
2018	100.00	51.04	5.23	57.25	100.00
2019	100.00	49.79	5.11	56.28	100.00
2020	100.00	48.69	5.00	55.48	100.00
2021	100.00	47.76	4.91	54.85	100.00

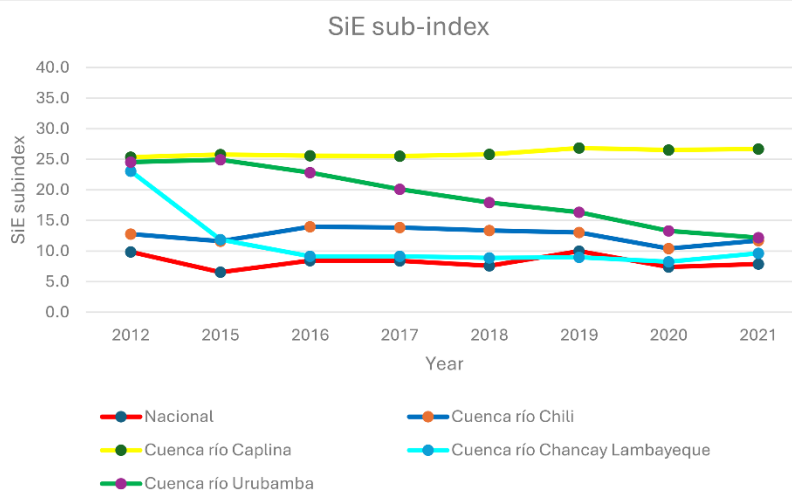
Source: own elaboration based on data from SNIRH ANA, PADH in basins, and INEI

3. Results and discussion

3.1 SiE results

Figure 3 presents the results of the SiE for the national level and for the basins in the period 2012-2021.

Figure 3. Economic Development Sub-Index (SiE) at the National and Basin Levels

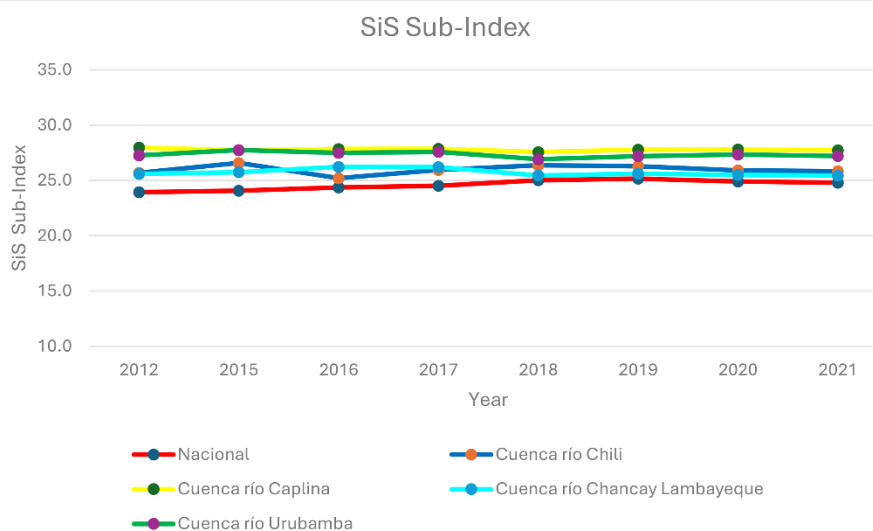


Source: own elaboration

3.2 SiS results

Figure 4 presents the results of the SiS at the national level and for the basins for the period 2012 - 2021.

Figure 4. Social Equity Sub-Index (SiS) at the National and Basin Levels

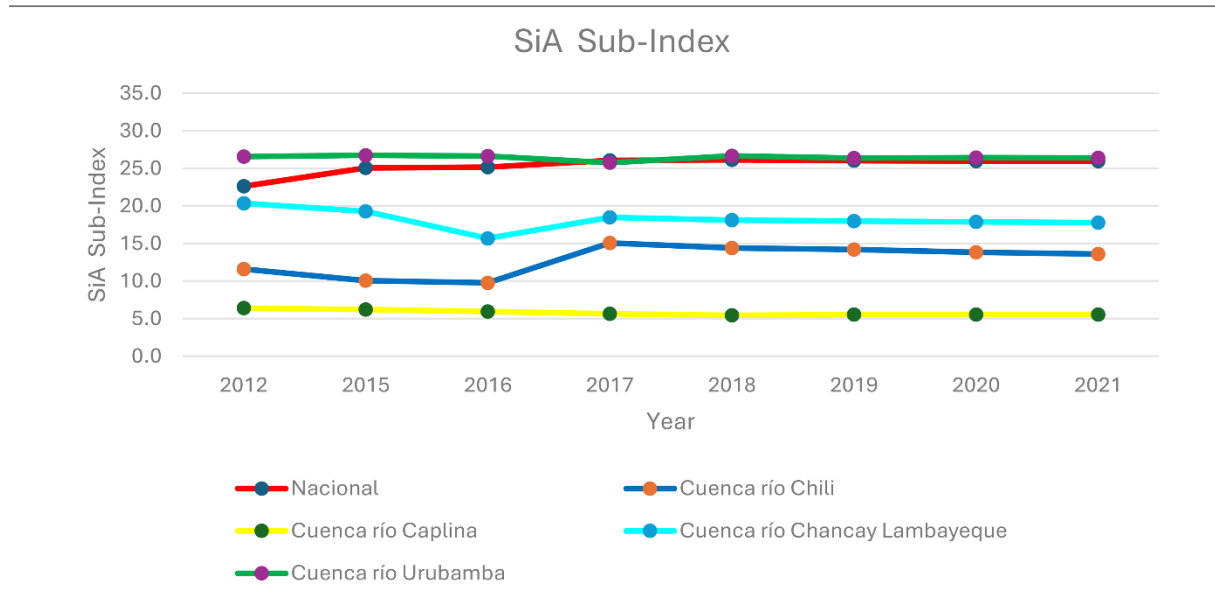


Source: own elaboration

3.3 SiA Results

Figure 5 presents the results of the SiA for the national and basin levels in the period 2015-2021.

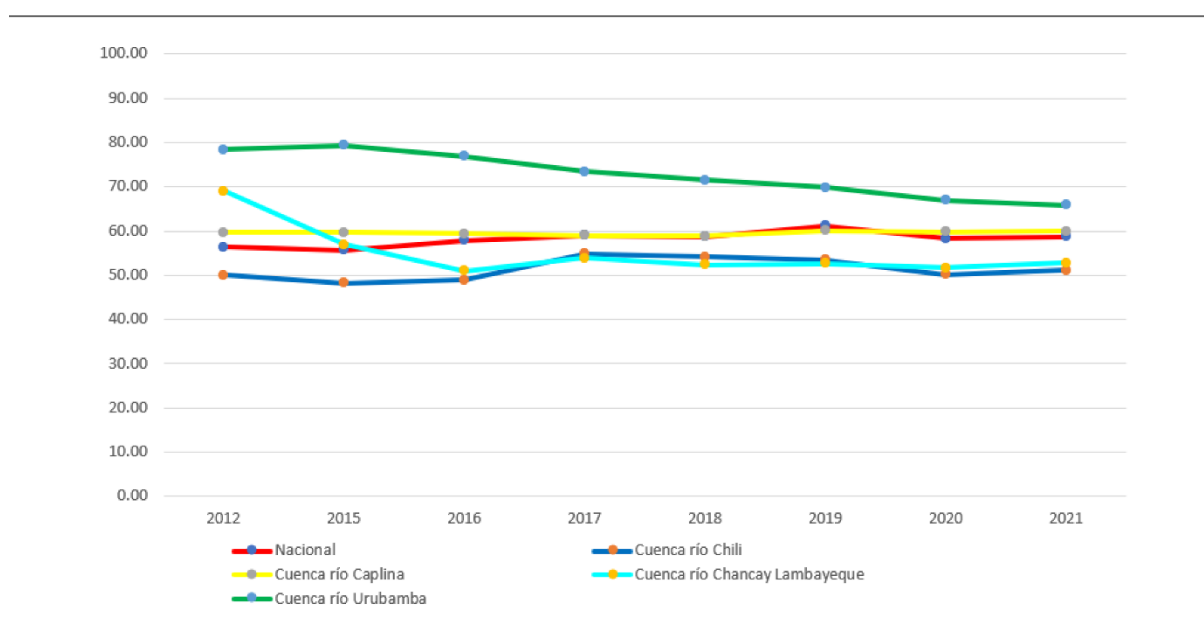
Figura 5. SiA en el ámbito nacional y de cuencas



Source: own elaboration

3.4 ISA results, national and basin scope

Using information from the results of the social, economic, and environmental sub-indices, the Water Environmental Sustainability Index (ISA) has been determined for the national level and for the basin level in the period 2012 to 2021. Figure 6 presents the results of the ISA for that period.

Figure 6. Water Sustainability Index WSI (ISA)

Source: own elaboration

3.5 Discussion of WSI (ISA) results in the Chili River basin

As can be seen in Table 15, the disaggregated results of the WSI (ISA), with their respective sub-indices, in the Chili River basin show that the social component (SiS) is the one that demonstrates the best performance (25.2 to 26.58), while the social inequality indicator had a significant favorable evolution from 59.50 in 2012 to 67.33 in 2021, although the challenge of reducing inequality remains.

The environmental component shows lower comparative values and greater differences. The SiA (Safe Wastewater Index) increased from 9.76 in 2016 to 15.06 in 2017, due to the implementation of the La Enlozada Wastewater Treatment Plant (the indicator of the proportion of wastewater treated safely increased from 15.83 in 2016 to 94.11 in 2017). The economic component also shows lower comparative values, but smaller differences (10.40 for 2020 and 13.96 for 2016).

The WSI (ISA) results for the Chili River basin show the lowest performance in 2015 (48.21) and the highest in 2017 (54.85). Year-on-year ISA values have remained roughly the same, at 50.06 in 2012 and 51.14 in 2021. Therefore, the Chili River basin requires reducing the pressure (intensive use and deterioration of water quality) exerted on its water resources, improving the economic efficiency of water use, and reducing social inequality between urban and rural areas.

Table 15. WSI (ISA) Index and Sub-Indices for the Chili River Basin

Year	SiE	SiS	SiA	WSI
2012	12.78	25.69	11.60	50.06
2015	11.59	26.58	10.04	48.21
2016	13.96	25.20	9.76	48.93
2017	13.84	25.95	15.06	54.85
2018	13.35	26.36	14.40	54.11
2019	13.05	26.28	14.18	53.51
2020	10.40	25.90	13.82	50.13
2021	11.72	25.83	13.59	51.14

Source: own elaboration

3.6 Discussion of results of the WSI (ISA) Index for the Caplina River basin

As shown in Table 16, the disaggregated results of the WSI (ISA), with their respective sub-indices, in the Caplina basin indicate that the social component (SiS) shows the best performance (27.56 to 27.96). However, further reductions in social inequality are needed, which have improved from 60.60 in 2012 to 62.25 in 2021. The economic component also shows good performance (25.35 to 26.83), while the environmental component shows low values (SiE from 5.43 to 6.39) mainly due to the physical scarcity of water and the pressure exerted by its use. Therefore, greater attention must be paid to the environmental component in the Caplina basin to prevent deterioration that could eventually lead to collapse. The ISA results in the Caplina basin show a small variability throughout the analyzed period (59.70 in 2012 and 59.94 in 2021).

Table 16. WSI (ISA) Index and Sub-Indices for the Caplina River basin

Year	SiE	SiS	SiA	WSI
2012	25.35	27.96	6.39	59.70
2015	25.77	27.72	6.20	59.70
2016	25.59	27.83	5.93	59.35
2017	25.53	27.85	5.64	59.02
2018	25.79	27.56	5.43	58.79
2019	26.83	27.78	5.54	60.15
2020	26.54	27.80	5.54	59.87
2021	26.69	27.72	5.53	59.94

Source: own elaboration

3.7 Discussion of results of the WSI (ISA) Chancay-Lambayeque River basin

The results of the WSI (ISA), with their respective sub-indices, in the Chancay-Lambayeque basin demonstrate that the economic component has the lowest performance (SiE from 8.25 to 23.06), attributed to the fact that water use in the basin is primarily for low-profit agriculture. The social component shows the highest comparative performance (SiS from 25.43 to 26.23); however, further reductions in social inequality are needed, which improved from 60.70 in 2012 to 64.13 in 2021. The environmental component shows intermediate performance (SiA from 15.68 to 20.35), requiring improvement in the proportion of water bodies of good environmental quality (which is 0 in the analyzed period). In this regard, the Chancay-Lambayeque basin needs to improve the economic component through, for example, improving the economic efficiency of water, as well as improving the performance of the environmental component with respect to water quality.

Table 17. WSI (ISA) Index and Sub-Indices for the Chancay-Lambayeque River Basin

Year	SiE	SiS	SiA	WSI
2012	23.06	25.58	20.35	59.70
2015	11.85	25.73	19.28	59.70
2016	9.14	26.23	15.68	59.35
2017	9.13	26.21	18.49	59.02
2018	8.88	25.44	18.12	58.79
2019	8.98	25.61	17.99	60.15
2020	8.25	25.50	17.89	59.87
2021	9.63	25.43	17.79	59.94

Source: own elaboration

3.8 Discussion of WSI (ISA) results in the Urubamba River basin

The results of the WSI (ISA), with their respective sub-indices, in the Urubamba basin indicate that the economic component is the one that presents the lowest and most different performance (SiE from 12.19 to 24.54), due to the change in the values of the indicator "change in the efficiency of water use" from 100 in 2012 to 44.60 in 2021, which is due to the realization in the use of water volumes, considering the results of 2021 to be closer to reality. The "GDP per capita" indicator has shown slight variations during this period, from 20.88 in 2012 to 20.47 in 2021. The social component shows the highest comparative performance (SiS from 26.91 to 27.75); however, the social inequality indicator has shown a favorable trend, from 57.60 in 2012 to 58.59 in 2021, and requires

further improvement. The environmental component shows high and less varied results (SiA from 25.75 to 26.75), due to a comparatively better performance in the "proportion of water bodies of good environmental quality" indicator, which is 31.60 throughout the period, as well as the low level of water scarcity stress.

Table 18. WSI Index and Sub-Indices for the Urubamba River Basin

Year	SiE	SiS	SiA	WSI
2012	24.54	27.26	26.57	78.38
2015	24.92	27.75	26.75	79.41
2016	22.83	27.48	26.65	76.96
2017	20.10	27.57	25.75	73.42
2018	17.93	26.91	26.67	71.52
2019	16.33	27.18	26.38	69.89
2020	13.28	27.33	26.43	67.03
2021	12.19	27.20	26.42	65.81

Source: own elaboration

3.9 Discussion of WSI (ISA) results at the national level

The WSI (ISA), and the analysis of their respective sub-indices, show that the environmental component (SiA) had the strongest performance at the national level during the analyzed period (except for 2012), followed by the social component (SiS). The economic component (SiE) shows a more limited performance (7.58 to 9.98). The ISA was 56.40 in 2012, and 55.65 in 2015 (SDG baseline), reaching 58.67 in 2021 (most recent reference year). reflecting gradual year-on-year variations, as shown in Table 19. The lowest ISA value was 55.65 in 2015), while the highest reached 61.15 in 2019.

The most significant decline in the WSI (ISA) occurred between 2019 (61.15) and 2020 (58.27), mainly due to the impacts of the COVID-19 pandemic. During this period, the economic component fell from 9.98 in 2019 to 7.89 in 2021, while the social component slightly declined from 25.16 in 2019 to 24.80 in 2021. Meanwhile, the environmental component (SiA) showed practically no variation, rising marginally from 25.97 in 2019 to 25.98 in 2021.

The national WSI (ISA) increased from 56.40 in 2012 to 58.67 in 2021, indicating a slight improvement. However, national-level results can differ significantly from those at the basin level, as we may observe from the results obtained in the basins analyzed in this study. At the national level, the environmental sub-index records the strongest performance (SiA of 25.98 in 2021), mainly due to the significant water availability in the

Amazonian watershed and the relatively low pressure on water resources in its basins. However, SiA values in the Caplina (5.53 in 2021) and Chili River (13.59 in 2021) basins are significantly lower. The social sub-index at the national level (SiS of 24.80 in 2021) is slightly below the values recorded in the four basins analyzed (SiS of 25.83 in the Chili River basin, 27.72 in the Caplina River basin, 25.43 in the Chancay-Lambayeque basin and 27.20 in Urubamba basin), suggesting a relatively similar performance of the social component at the national level, as compared to that of the basins analyzed.

The economic sub-index at the national level had the weakest performance (SiE of 7.89 in 2021), a value that is well below that recorded in the Caplina River basin (SiE of 26.69 in 2021). This result highlights the significant challenges that remain in improving the performance of the economic component and in achieving sustainability (by enhancing water use efficiency) at the national level.

Table 19. WSI (ISA) Index and Sub-Indices at the National Level

Year	SiE	SiS	SiA	WSI
2012	9.85	23.93	22.62	56.40
2015	6.54	24.07	25.05	55.65
2016	8.42	24.36	25.17	57.95
2017	8.40	24.51	26.06	58.97
2018	7.58	25.01	26.13	58.72
2019	9.98	25.16	26.02	61.15
2020	7.38	24.91	25.97	58.27
2021	7.89	24.80	25.98	58.67

Source: own elaboration

National-level results consolidate those recorded in the basins and may substantially differ from the situation observed in each basin. This is the case in the Caplina basin, where the economic component shows a higher performance than that at the national level, while the environmental component records a considerable lower result. These nuances can be identified through a disaggregated analysis of the sub-indices (SiE, SiS and SiA), since the WSI (ISA) values do not reflect such differences (national ISA = 58.67 ; Caplina ISA = 59.94). The analysis could even consider indicators such as access to water and sanitation between urban and rural areas, at both basin and national levels.

4. Conclusions

This research proposes a Water Sustainability Index (WSI ISA), applied both at the national level and in the areas of the of the Chili, Caplina, Chancay-Lambayeque and Urubamba River basins. The ISA enabled the evaluation of water sustainability, considering its economic, social and environmental components (analyzed through the SiE, SiS and SiA sub-indices), across both spatial (basins and national levels) and temporal scales (2012 to 2021).

Furthermore, the WSI (ISA) demonstrated in practice the applicability of the sustainable development concept with a focus on water sustainability through a quantitative analysis of the balanced contributions of its three dimensions -economic, social, and environmental-, taking into account intrinsic and extrinsic indicators. This research confirms that achieving water sustainability in watersheds requires adequate performance in all these components of sustainable development, and that poor performance in any of them—for example, the environmental component in the Caplina basin or the economic component in the Chancay-Lambayeque basin— may jeopardize sustainability in the corresponding area.

The results demonstrate that the social component recorded improved performance, both within the analyzed basins and at the national level. However, significant challenges remain in the environmental component (notably in the Caplina and Chili River basins) and in the economic component (Chancay-Lambayeque, Chili, and Urubamba River basins). Furthermore, the risk of water unsustainability is associated to both physical aspects (water scarcity in the Caplina basin) and management-related factors (Chancay-Lambayeque basin). The results also show that the social component -assessed by the SiS- performed better at the basin than at the national level. However, improving the social inequality indicator remains a major challenge in all cases.

The conceptual framework, mathematical formulations, and availability of official information supporting the indicators make the Water Sustainability Index (WSI ISA) proposed in this research a useful tool, applicable both at the national and international river basin levels.

Additionally, it is recommended to establish minimum threshold scores for the ISA (e.g., 50, 40 or 30) and for the SiE, SiS and SiA sub-indices (e.g., 16, 14 or 12), below which the water situation in a basin could be considered unsustainable.

References

- Aguirre-Núñez, M. (2023). *Indicadores de Sostenibilidad del Agua en cuencas del Perú*. Tesis doctoral. UNALM.
- Atkinson, A. B. (1970). On the Measurement of Inequality. *Journal of Economic Theory* 2, pp. 244-263.
- ANA (2023). *Tercera Medición Nacional del Indicador ODS 6.5.1: Grado de Implementación de la Gestión Integrada de los Recursos Hídricos en el Perú 2023*. Lima, Perú.
- ANA (2020). *Estado situacional y reporte del indicador 6.3.2. «Porcentaje de cuerpos de agua de buena calidad ambiental» del objetivo de desarrollo sostenible 6. Documento Técnico*. Lima, Perú.
- ANA (2019a). *Reporte prueba piloto de Indicadores de los Principios de Gobernanza del Agua de la OCDE, Escala Nacional (Perú) y escala regional (Autoridad Administrativa del Agua)*. Lima, Perú.
- ANA (2019b). *Segunda encuesta nacional sobre grado de implementación de la GIRH en el Perú – 2019*. Lima, Perú.
- ANA (2017). *Síntesis del Informe Final del Proyecto Monitoreo Integrado de las metas del ODS 6 relacionadas con Agua y Saneamiento (GEMI)*. Lima, Perú.
- Banco Mundial (2023). *Datos Índice de Gini Perú*. <https://datos.bancomundial.org/indicador/SI.POV.GINI?locations=PE> [consultado en enero de 2023].
- BCRP (2020). BCRPData. <https://estadisticas.bcrp.gob.pe/estadisticas/series/anuales/resultados/PM05000AA/html> [consultado en febrero de 2023].
- Bertule, M.; Glennie, P.; Bjørnse, P. K.; Lloyd, G. L.; Kjellen, M.; Dalton, J.; Rieu-Clarke, A.; Romano, O.; Tropp, H.; Newton, J. & Harlin, J. (2018). Monitoring Water Resources Governance Progress Globally: Experiences from Monitoring SDG Indicator 6.5.1 on Integrated Water Resources Management Implementation. *Water*, 10(12), 1744. doi:10.3390/w10121744.
- Bezerra, M.; Vollmer, D.; Acero, N.; Marques, M.; Restrepo, D.; Mendoza, E.; Coutinho, B.; Encomenderos, I.; Zuluaga, L.; Rodríguez, O.; Shaad, K.; Hauck, S.; González, R.; Hernández, F.; Montelongo, R.; Torres, E. & Serrano, L. (2022). Operationalizing Integrated Water Resource Management in Latin America: Insights from Application of the Freshwater Health Index. *Environmental Management*, 69, pp. 815-834. <https://doi.org/10.1007/s00267-021-01446-1>
- Breuer, A. & Spring, U. O. (2020) The 2030 agenda as agenda setting event for water governance? Evidence from the Cuautla river basin in Morelos and Mexico. *Water*, 12(2), p. 314. doi:10.3390/w12020314
- Cai, J.; Zhao, D. & Varis, O. (2021). Match words with deeds: Curbing water risk with the Sustainable Development Goal 6 index. *Journal of Cleaner Production*, 318, 128509. <https://doi.org/10.1016/j.jclepro.2021.128509>
- Castillo, L. E. (2020). *Dinámica Regional de la Desigualdad de Ingresos en Perú*. Banco Central de Reserva del Perú.
- CODS (2020). *Índice ODS 2019 para América Latina y el Caribe*. Centro de los Objetivos de Desarrollo Sostenible para América Latina y el Caribe: Bogotá, Colombia. <https://cods.uniandes.edu.co/indice-ods/>
- Di Vaio, A.; Trujillo, L.; D'Amore, G. & Palladino, R. (2021). Water governance models for meeting sustainable development Goals: A structured literature review. *Utilities Policy*, 72, 101255. <https://doi.org/10.1016/j.jup.2021.101255>
- Falkenmark, M.; Lundqvist J. & Widstrand, C. (1989). Macro-scale water scarcity requires micro-scale approaches Aspects of vulnerability in semi-arid development. *Natural Resources Forum*, 13(14), pp. 258-267. <https://pubmed.ncbi.nlm.nih.gov/12317608/>
- INEI (2023). *Perú: sistema de monitoreo y seguimiento de los indicadores de los Objetivos de Desarrollo Sostenible*. <https://ods.inei.gob.pe/ods/objetivos-de-desarrollo-sostenible/agua-limpia-y-saneamiento> [consultado en febrero del 2023]
- INEI (2022). *Perú: Producto Interno Bruto por Departamentos 2007 -2021*. Lima, Perú.
- INEI (2016). *Evolución de la Pobreza Monetaria 2009 – 2015. Informe Técnico*. Lima, Perú.

- Juwana, I.; Muttill, N. & Perera, B. (2012). Indicator-based water sustainability assessment - A review. *Science of the Total Environment*, 438, pp. 357-371. <http://dx.doi.org/10.1016/j.scitotenv.2012.08.093>
- Munda, G. & Nardo, M. (2005). *Constructing Consistent Composite Indicators: The Issue of Weights*. European Commission.
- ONU (2015). *Transformar nuestro mundo: la Agenda 2030 para el Desarrollo Sostenible*. Resolución aprobada por la Asamblea General el 25 de septiembre de 2015. AA/RES/70/1. Nueva York.
- OCDE (2021). *Gobernanza del Agua en el Perú*. OCDE.
- PNUD (2009). *Informe sobre Desarrollo Humano Perú 2009*. PNUD: Lima, Perú.
- Sachs, J.; Schmidt-Traub, G.; Kroll, C.; Durand-Delacre, D. & Teksoz, K., (2018). *SDG Index & Dashboards 2018*. New York, USA: Global responsibilities implementing de Goal. Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN).
- SUNASS (2016). Benchmarking regulatorio de las EPS 2015. Datos 2015. Lima, Perú.
- SUNASS (2017). Benchmarking regulatorio de las EPS 2016. Datos 2016. Lima, Perú.
- SUNASS (2018). Benchmarking regulatorio de las Empresas Prestadoras EPS 2018. Datos 2017. Lima, Perú.
- SUNASS (2019). Benchmarking regulatorio de las Empresas Prestadoras EP 2019. Datos 2018. Lima, Perú.
- SUNASS (2020). Benchmarking regulatorio 2020 de las Empresas Prestadoras (EP). Datos 2019. Lima, Perú.
- SUNASS (2021). Benchmarking regulatorio 2021 de las Empresas Prestadoras (EP). Datos 2020. Lima, Perú.
- Taka, M.; Ahopelto, L.; Fallon, A.; Heino, M.; Kallio, M., Kinnunen, P., Niva, V. and Varis, O., (2021). The potential of water security in leveraging Agenda 2030. *One Earth* 4, pp. 258-268. <https://doi.org/10.1016/j.oneear.2021.01.007>
- Tinoco, C.; Julio N.; Meirelles, B.; Pineda, R.; Figueroa, R.; Urrutia, R. & Parra, O. (2022). Water Resources Management in Mexico, Chile and Brazil. Comparative Analysis of Their Progress on SDG 6.5.1 and the Role of Governance. *Sustainability*, 14(10), 5814. <https://doi.org/10.3390/su14105814>
- UN-Water (2016). *Seguimiento en Materia de Agua y Saneamiento en la Agenda 2030 para el Desarrollo Sostenible Una introducción*. Switzerland.
- Vollmer, D.; Regan, H. M. & Andelman, S. J. (2016). Assessing the sustainability of freshwater systems: A critical review of composite indicators. *Ambio*, 45, pp. 765-780. doi:10.1007/s13280-016-0792-7

Declaration of potential conflicts of interest

The authors declare that they have no conflict of interest.

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