Sustainability assessment of water resource systems using a novel hydro-socio-economic index (HSEI)

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Abstract

Sustainable management of water resources is an essential process for securing Earth's present and future generation life. This study offers development of a new comprehensive framework and index for socio-economic evaluation of water resource systems. The hydro-socio-economic index (HSEI) is made of several economic, demographic, technology and communication, and health and sanitation factors at different temporal and spatial scales. The major foci of this research are estimation of HSEI and the analysis of their socio-economic situation of those European countries with increasing renewable water per capita during 1998–2017 periods. The HSEI values for all of the studied European countries range from 0.480 to 0.521 based on the single and combined methods. According to the qualitative classification, the index values are classified in good level for all fourteen countries. The results show that the increase in renewable water per capita influences socio-economic parameters in those countries. The result of this study will further support future investigation of selecting underlying factors that can be used as a criterion for the future planning and decision-making processes to form sustainable policies.

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1 Introduction

Existence of water is essential for living organisms and bounty and beauty of the Earth. Providing adequate water supply is necessary for the development of human societies. Sustainable management of water resources is beyond the control of individuals, and it asks for multidisciplinary engagement of experts and stakeholders (Diep 2018). According to previous studies, natural and anthropogenic changes, such as climate change, will have considerable and inevitable impacts on global poverty and sustainability security (Agha-Kouchak et al. 2015; Seidl and Barthel 2017; Goharian et al. 2017; Vollmer et al. 2018). The development plans depend on various factors including social and cultural factors that can affect the fate of the projects (Aerts et al. 2018). In the next paragraphs, current state of socio-economic analysis of water resources is presented and discussed; then, existing gaps are identified, which are attempted to be addressed in this research.

Popovic et al. (2014) introduced indicators to evaluate various aspects of social sustainability; social capital, social equity and social welfare focused on the development of social sustainability indicators for wastewater treatment processes because they believed that the need for quantitative evaluation of social sustainability is an important research problem. Based on their results, the issue of stakeholders involved in decision-making, participativeness indicator, could be evaluated in different industries and efficiencies and evaluation of experts' networking was introduced as another example of generalized indicator. El-Gafy (2018) deployed the water poverty index (WPI) with the resources, access, capacity, use and environment components and applied it, as a holistic tool, for the conceptualization of the Egyptian's water management strategies. Based on her results, WPI supports prioritizing water system development strategies and evaluates the progress of development with respect to the planning strategies. Roboredo et al. (2016) developed an index for social–environmental sustainability assessment through conducting interviews with randomly selected 56 farmers' families in the Southern Amazon. They classified indicators into different groups: soil quality, water quality, vegetation quality, socio-economic quality and social organization quality. Dean et al. (2016) sought how social capital influences community support for alternative water resources in Australia. Their findings highlighted the importance of social capital such as location, employment status, life satisfaction and spoken language for building community engagement for water-related issues. Kotzee and Reyers (2016) looked at three flood events, occurred in South Africa, using principal component analysis and formed an index to evaluate the flood resilience. For this purpose, they selected 24 flood-related indicators with respect to their social, ecological and economic impacts. Pande and Sivapalan (2017) studied about the two-way feedback between human and water systems to explain the unplanned consequences of water management and suggest ways to overcome these challenges. They found that the extension of endogenization of human agency, in terms of values and norms, technology, economics and trade, as space and space–time, is a necessity and a challenge for water sustainability. Aerts et al. (2018) attempted to integrate the human behavior dynamics with the flood disaster risk assessment. They found that the behavior of individuals, businesses and government entities before, during and immediately after a disaster can improve the situation of flood damages, impacts and recovery time and inform flood risk management policy development, positively. Diaz et al. (2018) used the Driver-Pressure-State-Impact-Response (DPSIR) framework to explore the interactions between the river ecosystem and the social system that include demographic, economic, social–political and

cultural of Biobío Basin humans, Chile. Based on their results, the DPSIR model has three major gaps: exclusion of the human societies' diversity with various geo-cultural ideologies and beliefs, disregard of hidden and complex relationships between ecosystems and HWB, and underrepresentation of human and ecosystem relationship. Bui et al. (2018) assessed the social sustainability of groundwater resources in Hanoi, Vietnam, with respect to three main groundwater characteristics (quantity, quality and management). The sustainability indices, quantity, quality and management of groundwater were estimated good, poor and acceptable with the values 0.68, 0.27 and 0.52, respectively, which resulted in Hanoi being rated at an acceptable level with the value 0.49 for the social sustainability assessment. Jongman (2018), by considering effective adaptation strategies for flood risk, showed that social and economic changes were result of changes in weather and extreme rainfall. Liang et al. (2018) applied the Paddy Land-to-Dry Land (PLDL) program to the multi-indicator assessment of a water-saving agricultural engineering project in North Beijing, China. They found that agricultural engineering programs designed to alleviate water scarcity could potentially have a wide range of environmental, economic and social impacts on China's society. For example, based on ecological and social performance of this research, by 2015, households who participated in the PLDL program had much higher incomes (26,270 Yuan compared to 22,355 Yuan). Li et al. (2019) explored the changes in water resources and environment of a large freshwater Lake in Tai Lake, China. They defined the relationships between the socio-economic indicators and the lake during three decades (1980–2012). They found how socio-economic development affects the quality of water and how it has been improved by human activities and environmental remediation. During the past decades, the Gene Expression Programming (GEP), which is one of the most important soft computing methods, has been successfully employed in both quality and quantity water resource modeling. However, this method has not been applied for the hydro-socio-economic studies.

Even though multiple researchers have looked at the inclusion of social indicators in water resource evaluation, in order to understand how and which of the socio-economic parameters affect the water system the most, it is needed to consider the rationality of the relationship between socio-economic parameters and the water resource parameter and the level of interaction between these factors should be investigated more. This study offers a comprehensive and novel framework to form a hydro-socio-economic index (HSEI) using single linear (SL) and combined soft computing (CSC) methods. This will be the first use of these techniques in order to develop a hydro-socio-economic index. This framework has been applied to study socio-economic of the countries whose per capita renewable water has been raising over the last decades. Also, in this study, the effects of increasing renewable water per capita on the hydro-socio-economic index with respect to the four, economic, demographic, technology and communication, and health and sanitation, aspects and respective qualitative classifications are investigated. The unique features of this study are: (1) The hydro-socio-economic index contains crucial hidden and unique information about different aspects of a community; in general, HSEI results indicate that countries with better water resource systems experience lower risk of social, economic, political and environmental failures in their management plans. (2) Based on the value of the proposed index, different countries can be compared based on a combination of their unique social, cultural, economic and political characteristics. Therefore, international efforts can focus on targeting to gather required information and formulate a comprehensive water resource management plan under various socio-economic conditions.

2 Methodology

2.1 Hydro-socio-economic evaluation framework

The adaption of the best management methods requires the evaluation of different indicators such as social profile, infrastructure, and social capital, cultural and economic. The development and use of criteria and indicators support decision-making process in order to establish more appropriate water resource policies and inform managers and the public. These criteria and indicators can be systematically evaluated in order to represent the effectiveness of the current policies and assess the effectiveness of the future management activities and investments (Wilson et al. 2017; Vollmer et al. 2018). Figure 1 shows the underlying concept and key elements of proposed framework to socio-economic sustainability of the water system by this study. Underlying concept included economic, demographic, technology and communication, and health and sanitation. Figure 2 shows the steps to calculate the HSEI.

The overall procedures of hydro-socio-economic index calculation in this study include: (1) selecting suitable hydro-socio-economic aspects, economic, demographic, technology and communication, and health and sanitation, (2) selecting suitable parameters for each aspect, the GDP per capita, income index, vulnerable employment, unemployment rate, exports and imports (% of GDP) for economic aspect, HDI and population density
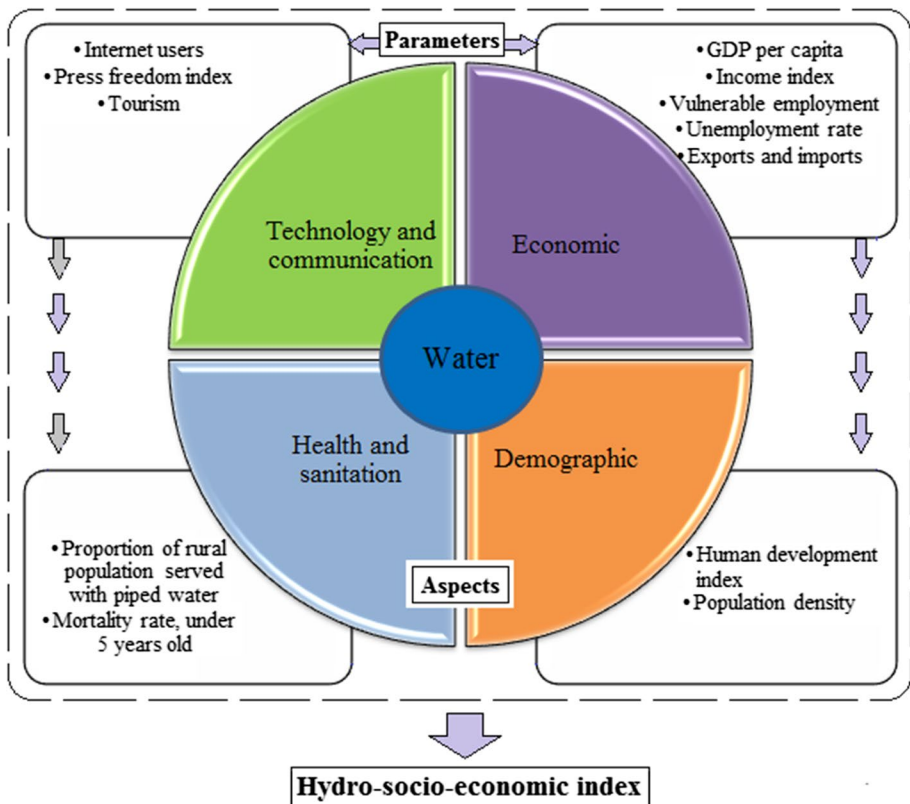

Fig. 1 Key elements of proposed framework in the study

- Evaluation of different aspects of societies and various socio-economic parameters.

- Determination the parameter representing the status of water resources.

- Normalizatin of the socio-economic parameters and the parameter that representing the status of water resources.

- Determination of the squared correlation coefficient of the socio-economic parameters with the parameter representing the status of water resources.

- Selection of suitable socio-economic aspect (A_i, A_{ik}) and parameters (P_{ij}, P_{ijk}) using single-linear and combined-soft computing methods. Where i is the number of aspects, j is the number of parameters and k is the number of studied cases ($i=1, 2, ..., m$ and $j=1, 2, ..., n$ and $k=1, ..., z$).

- Determination the weights of the socio-economic parameters that affect on water resources (W_{Ai}, W_{Pij}, W_{Aik} and W_{Pijk}) for studied aspects and parameters related to each aspect using both single-linear and combined-soft computing methods.

- Determination of the hydro-socio-economic index (HSEI, $HSEI_i$, $HSEI_k$ and $HSEI_{ik}$) with different temporal and spatial scale using single-linear and combined-soft computing methods.

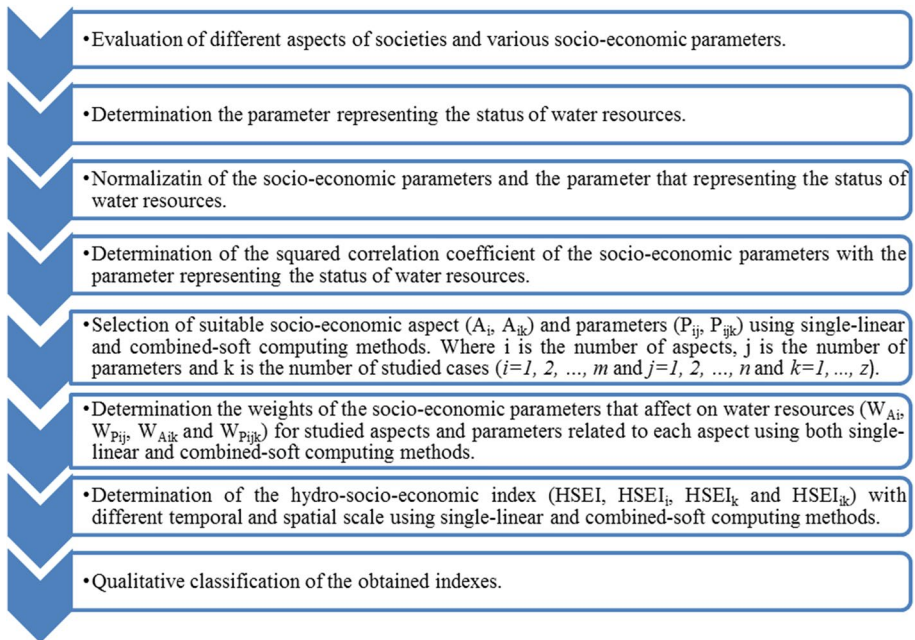- Qualitative classification of the obtained indexes.

Fig. 2 Novel framework for determining the hydro-socio-economic index

parameters for demographic aspect, Internet users, press freedom index and number of arrival tourism for technology and communication, and proportion of rural population served with piped water and mortality rate (under 5 years old) for health and sanitation aspect, (3) normalizing the parameters, (4) calculating the correlation coefficients between hydro-socio-economic parameters, (5) calculating the weights for each of the socio-economic parameters and (6) estimating the hydro-socio-economic index and classifying countries based on the above-mentioned aspects and whole HSEI with different spatial scales.

2.2 Selecting the key indicators for HSEI

In this study, renewable water per capita (RWPC) is considered as the main indicator to represent the water resource status in each system. This study further explores various socio-economic aspects of water systems and defines their relations with the RWPC in the system. It is not simply possible to consider and quantify all the internal and external socio-economic factors related to the management of water resource systems. These factors might vary from one to another water resource system. However, the most important and influential factors can be identified and then studied for particular water resource systems. Economics, demographic, technology and communication, health and sanitation are among most influential factors for each water resource system, regardless of the system type (Diaz et al. 2018; Bui et al. 2018). One of the main objectives of any water resource system is to guarantee the socio-economic prosperity for the society; thus, financial incentives and benefits are often considered as the foremost objective of any water resource projects. A prominent example of an economic

indicator is the gross domestic product (GDP) per capita, which shows the ratio of gross domestic product to the midyear population. A great example of a demographic indicator is the human development index (HDI). HDI is a composite index which measures the average achievement of the three factors, including human development, long and healthy life, knowledge and a decent standard of living. Population density, number of people per area, is another example of demographic indicator, which is often used by researchers (Adger 2003; Cutter et al. 2000, 2003; Dwyer et al. 2004; Brooks et al. 2005; Tunstall et al. 2007; Polsky et al. 2007; de Oliveira Mendes 2009; Tate et al. 2010; Ojerio et al. 2011; Schmidtlein et al. 2011; Khan 2012; Lee 2014).

The impact of water resources on technology and communications, including users of the Internet and the press, as well as the tourism industry, is also very important for development of sustainable water resource systems in smart and connected communities. "Water Internet" is a new term and concept which is relates the direct water and Internet connectivity. The Water Internet is an inclusive source of water supply information for involved organizations, scientists and citizens. The mutual utilization of Internet and the media is also very important. It raises the awareness of public and shows how optimal use of water resources could be reinforced by dissemination of suitable information. Water resources (i.e., seas, shores, lakes, rivers, ponds, springs and etc.) are one of the main attractions for tourism (Tunstall et al. 2007; Khan 2012; Diaz et al. 2018).

Communities need reliable water access with sufficient quantity. This is more crucial when population density is high, and people are exposed to the waterborne diseases. Water resource pollution is one of the causes of human mortality (Fawell and Nieuwenhuijsen 2003). According to the statistics, during the last decade, millions of people, especially children, died around the world due to the lack of environmental improvements and water pollution. Mortality rate (under 5 years old) can be used as an indicator to represent the accessible water quality for the communities (De Oliveira Mendes 2009; Lima et al. 2016; El-Gafy 2018).

Some of GDP per capita, income index, vulnerable employment, unemployment rate, exports and imports (% of GDP), HDI, population density, Internet users, press freedom index, number of arrival tourism, proportion of rural population served with piped water and mortality rate (under 5 years old) parameters have direct conceptual relationship with RWPC or might pose negative conceptual correlation. In order to calculate the HSEI, the socio-economic parameters and renewable water per capita should be normalized. Equations (1) and (2) will be used to normalize parameters that have direct or inverse relationship with the renewable water per capita, respectively (El-Gafy 2018):

$$P_{Nij} = \frac{P_{ij} - P_{ij}(\min)}{P_{ij}(\max) - P_{ij}(\min)} \tag{1}$$

$$P_{Nij} = 1 - \frac{P_{ij} - P_{ij}(\min)}{P_{ij}(\max) - P_{ij}(\min)} \tag{2}$$

where P_{ij}, $P_{ij}(\min)$, $P_{ij}(\max)$ and P_{Nij} are the actual parameter, the minimum value of the parameter, the maximum value of the parameter and the normalized value of the parameter, respectively.

2.3 Weighting parameters to calculate HSEI

In order to estimate the HSEI, the importance of different socio-economic factors and their associated parameters should be evaluated. Here, these factors and indicators are weighted based on the dependence of the actual parameter and RWPC. The weights for different factors, parameters and the values of hydro-socio-economic index were calculated using Eqs. (3)–(9):

$$W_{Ai}, W_{Aik} = (m)^{-1} \tag{3}$$

$$W_{Pij} = \frac{R^2_{ij,\text{RWPC}}}{\sum_{j=1}^{n} R^2_{ij,\text{RWPC}}}, \quad W_{Pijk} = \frac{R^2_{ijk,\text{RWPC}}}{\sum_{j=1}^{n} R^2_{ijk,\text{RWPC}}} \tag{4}$$

$$\sum_{i=1}^{m} W_{Ai} = 1; \sum_{j=1}^{n} W_{Pij} = 1, \quad \sum_{i=1}^{m} W_{Aik} = 1; \sum_{j=1}^{n} W_{Pijk} = 1 \tag{5}$$

where W_{Ai}, W_{Pij}, W_{Pijk} are the weights of the aspects (i) and parameters (j) for all selected countries and for each country (k), respectively. These weights vary between 0 and 1. n, m and z represent the total number of aspects, parameters and studied countries, respectively. $R^2_{ij,\text{RWPC}}$ and $R^2_{ijk,\text{RWPC}}$ are the square of correlation coefficient between the socio-economic parameters and the renewable water per capita for all selected countries and each country.

$$\text{HSEI}_i = \sum_{j=1}^{n} W_{Pij} * \overline{P_{Nij}} \tag{6}$$

$$\text{HSEI} = \sum_{i=1}^{m} W_{Ai} * \text{HSEI}_i \tag{7}$$

$$\text{HSEI}_{ik} = \sum_{i=1}^{m} W_{Aik} * \text{HSEI}_k \tag{8}$$

$$\text{HSEI}_k = \sum_{j=1}^{n} W_{Pijk} * \overline{P_{Nijk}} \tag{9}$$

where HSEI_i and HSEI_{ik} denote hydro-socio-economic index by aspects for all selected countries of Europe continent and for each country (k), respectively. HSEI and HSEI_k are the final hydro-socio-economic index for the all selected countries that are located in Europe continent and each studied country, respectively. The qualitative classifications of the hydro-socio-economic index are presented in Table 1.

Table 1 Classification level of hydro-socio-economic index (El-Gafy 2018)	Nos.	Classification level	Hydro-socio-economic index
	1	Very poor	$0 < \text{HSEI} \leq 0.2$
	2	Poor	$0.2 < \text{HSEI} \leq 0.4$
	3	Good	$0.4 < \text{HSEI} \leq 0.6$
	4	Very good	$0.6 < \text{HSEI} \leq 0.8$
	5	Excellent	$0.8 < \text{HSEI} \leq 1.0$

2.4 Gene expression programming (GEP)

GEP is a data mining method based on the generation and number of chromosomes. This method has many advantages over other data mining methods (Bozorg-haddad et al 2017). GEP algorithm can be used to represent the complex structure of a system using a flexible tree computer-based model structure. The important advantages of the GEP model are (Ferreira 2006): (1) The chromosomes are simple entities: linear, compact, relatively small and easy to be manipulated genetically (replicate, mutate, recombine, etc.), and (2) the expression trees are exclusively expressing their respective chromosomes. The process is repeated for a certain number of generations or until a good solution has been found (Ferreira 2006). In this study, different mathematical functions were utilized to evaluate the renewable water per capita estimation process: $(+, -, *, /, \ln x, e^x, x^2, x^3, \sqrt{x}, \sqrt[3]{x}, \sin x, \cos x, \arctan(x))$

The linking function must be chosen as a summation or multiplication for the algebraic sub-trees (Ferreira 2006). In GEP application, the chromosome might have one or more genes, while the gene can contain two types of information. The first type of information is stored in the head of the gene, which is used in the overall GEP model production. The head contains preselected function set "F" along with some terminals (variables and parameter constants) from the terminal set of "T." The second type of information is stored in the tail and only contains terminals (Ferreira 2006). The tail contains information that can be used for the generation of future GEP models. The arrangement of the functions and the terminals in head and tail of a GEP gene is called structural architecture. In the GEP system, several types of genetic operators from the function set of (F) and terminal set (T) can be adopted to build a chromosome. For this study, the terminal set of economic aspect contains GDP per capita, income index, vulnerable employment, unemployment rate and exports and imports (% of GDP) parameters. In this study, a powerful soft computing package called GeneXpro Tools 4.0 is used (Montaseri et al 2018). The number of chromosomes in GEP is assigned as 30, length of head (h) as 7 and genes per chromosome as 3 (default function set of GeneXpro). The sub-trees were linked by the summation function. The characteristics of applied GEP models in current study are listed in Table 2. As an example, the structure of GEP model for economic aspect is shown in Fig. 3.

2.5 Model performance

In this study, the performance of the models is evaluated by the statistical parameters of the correlation coefficient (R), root mean squared error (RMSE) and mean absolute error (MAE). Correlation coefficient (R) measures the strength and direction of the linear

Table 2 Characteristics of applied GEP models in the current study

General	
Linking function	Addition
Fitness function error type	RRSE
Penalizing tool	Parsimony pressure
Genetic operator	
Mutation rate	0.044
Inversion rate	0.1
IS transposition rate	0.1
RIS transposition rate	0.1
One-point recombination rate	0.3
Two-point recombination rate	0.3
Gene recombination rate	0.1
Gene transposition rate	0.1
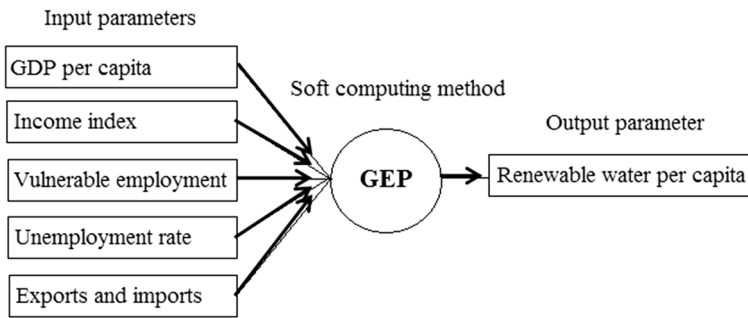
Fig. 3 Structure of used soft computing method, economic aspect, in the study

relationship between variables. The RMSE shows the goodness of fit relevant to the high values, whereas the MAE measures balanced distribution of goodness of fit at moderate values (Karunanithi et al. 1994). The R, RMSE and MAE are defined as:

$$R = \left[\frac{\sum_{i=1}^{N} (\text{RWPC}_{io} - \overline{\text{RWPC}}_o)(\text{RWPC}_{ie} - \overline{\text{RWPC}}_e)}{\sqrt{\sum_{i=1}^{N} (\text{RWPC}_{io} - \overline{\text{RWPC}}_o)^2 \sum_{i=1}^{N} (\text{RWPC}_{ie} - \overline{\text{RWPC}}_e)^2}} \right] \tag{10}$$

$$\text{RMSE} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (\text{RWPC}_{io} - \text{RWPC}_{ie})^2} \tag{11}$$

$$\text{MAE} = \frac{1}{N} \sum_{i=1}^{N} \left| \text{RWPC}_{io} - \text{RWPC}_{ie} \right| \tag{12}$$

where o is the observed values, e the estimated values and i the number of data sets that vary between 1 and N. So, $\overline{RWPC}_o$ and $\overline{RWPC}_e$ are the average of observed and estimated renewable water per capita values; $RWPC_{io}$ and $RWPC_{ie}$ are the observed and estimated renewable water per capita values. In general, the models' performances are optimum if R and $RMSE$ are closer to 1 and 0, respectively.

2.6 Calculating the HSEI for the European Countries

In this study, in order to determine the impacts of water resources on the socio-economic status, by reviewing the amount of renewable water per capita, fourteen countries that their renewable water per capita is in increased mode were selected as the case studies. These fourteen countries are located in Europe. Figure 4 shows the geographic locations of the studied countries. The data for this study are extracted from Knoema database (https://knoema.com). For more details, the statistical characteristics of used hydro-socio-economic parameters in the current study are presented in Table 3. Further discussion about the current and future socio-economic perspective and water resource status for each country is presented and discussed in the following sections.
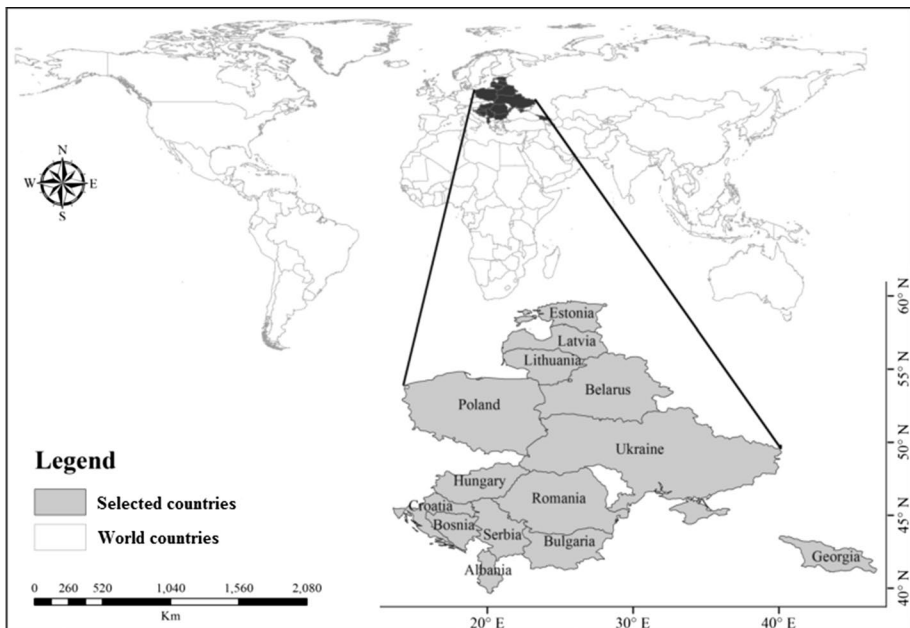

Fig. 4 Geographic location of the studied countries

Table 3 Statistical characteristics of used hydro-socio-economic parameters in current study

Aspects	Statistical specifications	Parameters					
		GDP (US dollars)	II (score)	VE (%)	UR (%)	EI (%)
Economic	Minimum	628.00	0.53	2.30	0.50	70.30
	Maximum	19,969.00	0.86	64.50	32.20	172.40
	Mean	6861.63	0.74	20.50	12.37	110.89
	S	4885.95	0.07	17.75	6.75	29.79
	CV	0.71	0.10	0.87	0.55	0.27
Demographic	Statistical specifications	HDI (score)	PD (persons per square km)			
	Minimum	1.56	31.00			
	Maximum	25.57	126.20			
	Mean	10.73	75.47			
	S	6.54	27.09			
	CV	0.61	0.36			
Technology and communication	Statistical specifications	IU (%)	PFI (score)	T (person)		
	Minimum	0.10	−9.00	60,000.00		
	Maximum	88.40	99.00	18,780,000.00		
	Mean	39.24	20.98	4,811,587.27		
	S	24.21	16.53	4,574,947.68		
	CV	0.62	0.79	0.95		
Health and sanitation	Statistical specifications	MR (deaths per thousand live births)	RPPW (%)			
	Minimum	2.90	17.40			
	Maximum	24.60	99.60			
	Mean	8.14	70.92			
	S	4.00	21.14			
	CV	0.49	0.30			

Table 3 (continued)

Aspects	Statistical specifications	Parameters				
		GDP (US dollars)	II (score)	VE (%)	UR (%)	EI (%)
Water resources	Statistical specifications	RWPC (billion cubic meters per year per person)				
	Minimum	1.56				
	Maximum	25.57				
	Mean	10.73				
	S	6.54				
	CV	0.61				

*GDP, II, VE, UR, EI, HDI, PD, IU, PFI, T, MR, RPPW, RWPC denote GDP per capita, income index, vulnerable employment, unemployment rate, exports and imports (% of GDP), human development index, population density, Internet users, press freedom index, tourism, proportion of rural population served with piped water, mortality rate (under 5 years old) and renewable water per capita, respectively

3 Results and discussion

3.1 Selecting effective parameters

First, it is necessary to select the most appropriate socio-economic parameters for different countries with increasing RWPC during the past 20 years (1998–2017). For this purpose, after independently normalizing the data for each country, the correlation of various socio-economic parameters with the per capita of renewable water is estimated. The parameters, namely the GDP per capita, income index, vulnerable employment, unemployment rate, exports and imports (% of GDP) parameters for economic aspect, HDI and population density parameters for demographic aspect, Internet users, press freedom index and number of arrival tourism for technology and communication, and proportion of rural population served with piped water and mortality rate (under 5 years old) for health and sanitation aspect, are selected as the most important parameters with high correlation with renewable water per capita. All selected parameters have a direct relation with the renewable water per capita, except the parameters of vulnerable employment, unemployment rate, population density and mortality rate (under 5 years old) (see Fig. 12).

By increasing the amount of renewable water per capita, the GDP per capita, the income index and export and import are increased. Increasing water per capita results in more employment in the agricultural sector, income tax, water-related industrial jobs, and reduction in vulnerable employment and unemployment rates. Considering the impacts of water resources on human development, the index of human development and life expectancy in societies have increased by the increase in water per capita. In selected countries, population density decreases with the increase in renewable water per capita, which improves people's life quality. By increasing the amount of renewable water resources per capita, the number of tourists has increased, which results in economic growth and cultural prosperity. Consequently, the need of societies to have access to better communication tools, such as the use of the Internet and press, has increased. The number of people using pipe water in the rural has increased, and consequently, the death rate of children under the age five has dropped significantly.

In the next step, the GEP model is used to determine the correlation between selected joint socio-economic parameters and renewable water per capita. By using nonlinear equations, the effective parameters were obtained for each aspect. Then, a comprehensive socio-economic model of soft computing was developed to determine the appropriate socio-economic parameters.

The results of R, RMSE and MAE for GEP models are presented in Table 4. The RMSE of economic, demographic, technology and communication, health and sanitation, and socio-economic aspects is 0.199, 0.103, 0.239, 0.172 and 0.012, respectively. The R value of the GEP models for socio-economic model is 0.999. As shown in Table 4, based on R, RMSE and MAE values, the socio-economic model has the best performance among other models to estimate renewable water per capita. Figure 5 shows the comparison between observed and estimated renewable water per capita during the test period. The main advantage of the GEP over other data-driven techniques (e.g., ANFIS and ANN) is that it produces explicit formulations of the relationship. Considering the best straight-line equations (assume the equation as $y = ax$) in the scatter plots, the coefficient for socio-economic model is close to 1 as $a_{\text{Socio-economic}} > a_{\text{Demographic}} > a_{\text{Economic}} > a_{\text{Health and sanitation}} > a_{\text{Technology and communication}}$. Figure 6 represents the observed and estimated renewable water per capita for socio-economic models

Table 4 Results and characteristics of soft computing optimal models during the test period

| Aspects	Input parameters	R	RMSE	MAE
Economic	GDP per capita, income index, vulnerable employment, unemployment rate, exports and imports (% of GDP)	0.829	0.199	0.133
Demographic	Human development index, population density	0.944	0.103	0.079
Technology and communication	Internet users, press freedom index, tourism	0.841	0.239	0.188
Health and sanitation	Proportion of rural population served with piped water, mortality rate (under 5 years old)	0.904	0.172	0.114
Socio-economic	Income index, unemployment rate, exports and imports (% of GDP), human development index, population density, Internet users, tourism, mortality rate (under 5 years old), proportion of rural population served with piped water	0.999	0.012	0.008
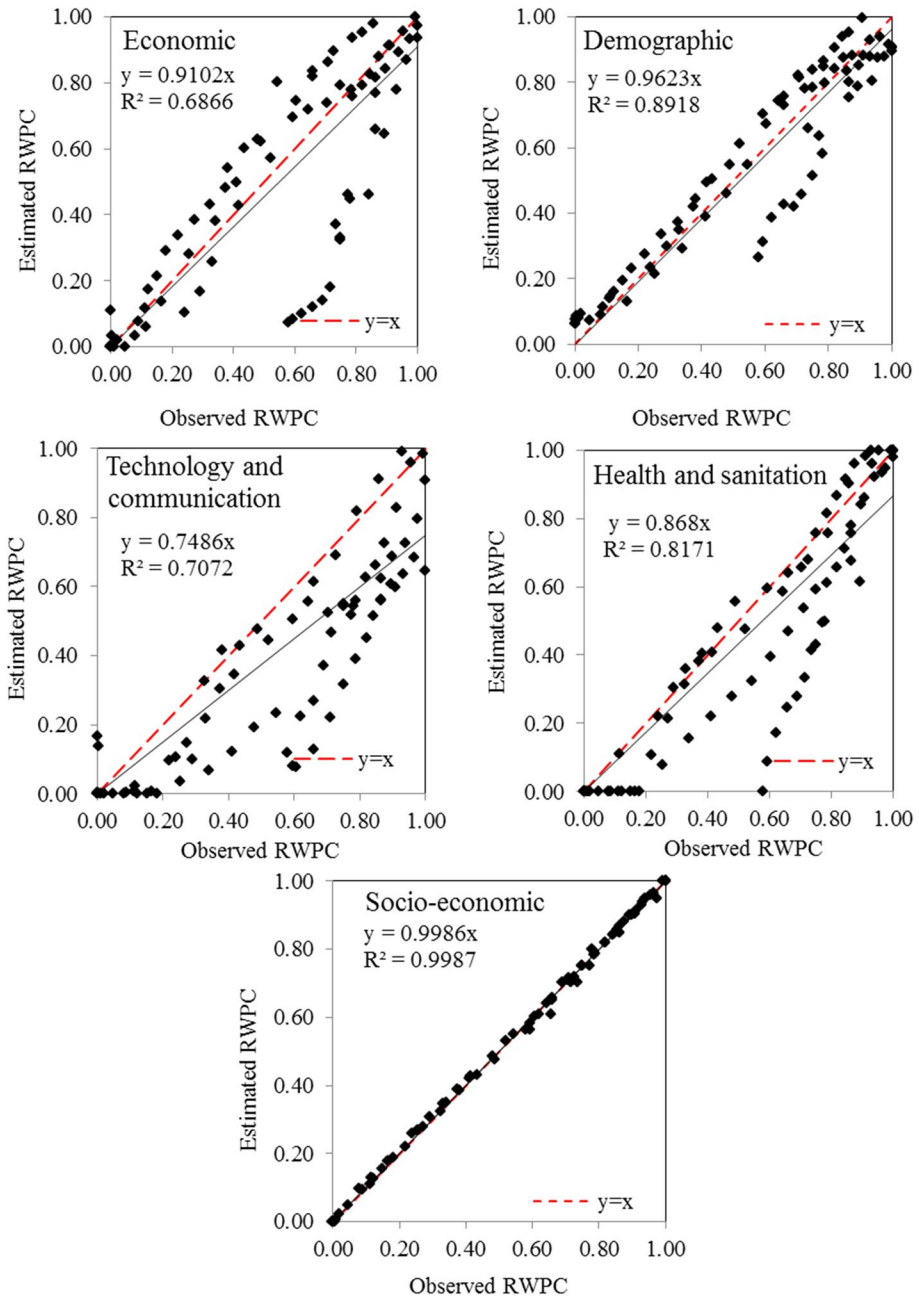
Fig. 5 Observed and estimated renewable water per capita (RWPC) of GEP models during the test period in European continent
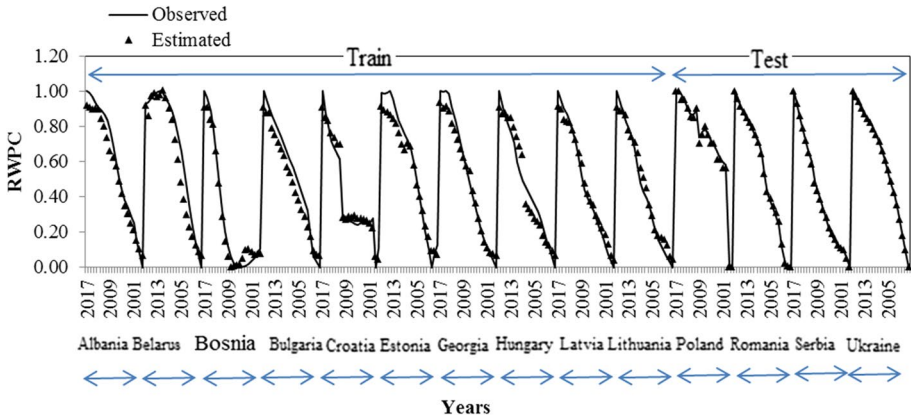
Fig. 6 Observed and estimated renewable water per capita of socio-economic models during 20-year period in European continent

Fig. 7 Sample Taylor diagram of economic, demographic, technology and communication, health and sanitation and socio-economic aspects models
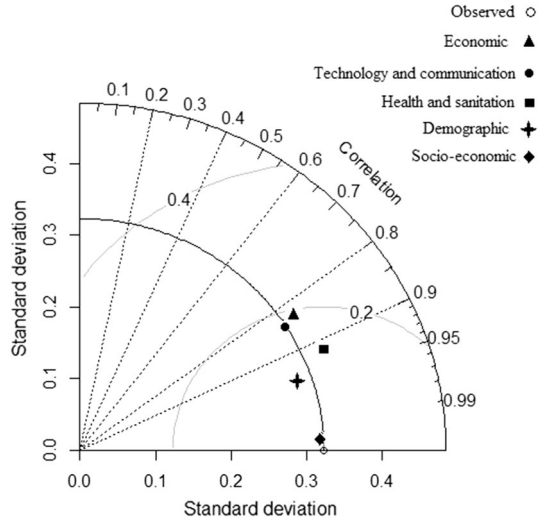
during 20-year period for fourteen European countries. As Fig. 6 shows, Poland, Romania, Serbia and Ukraine countries were used in the testing period. Sample Taylor diagram of five evaluated models for estimating the renewable water per capita during test periods is shown in Fig. 7. This figure displays the statistical comparison between the modeled and observed renewable water per capita data behavior based on three statistics: the Pearson correlation coefficient, the root mean square error and the standard deviation. Comparison of the results of estimated renewable water per capita models indicated that the socio-economic model (model no. 5) offers better results than other models (model no. 1 to 4). Equations used to design optimal GEP models are represented in Table 5. Thus, the income index, unemployment rate, HDI, population density, Internet users, tourism, mortality rate and proportion of rural population served piped water parameters are used to calculate the HSEI based on the combined soft computing (CSC) method (see Fig. 13 for the convergence curve of the GEP models).

Table 5 Equations of optimal GEP models

Nos.	Aspects (A_i)	Equations
1	Economics (A_1)	$RWPC_i = A\tan(A\tan(EI_i) + 0.50II_i + [\sin(II_i \times UR_i) - UR_i \times EI_i - 0.52]^3 \times EI_i$
2	Demographic (A_2)	$RWPC_i = (HDI_i)^6 \times (PD_i)^3 \times [\cos(Exp(HDI_i)^2] + Exp[((HDI_i) \times (PD_i))^6 \times (HDI_i)^{1/6}] + PD_i/\cos[Ln(Exp(\cos(PD_i) + 2.58)]$
3	Technology and communication (A_3)	$RWPC_i = IU_i \times [\cos(1.64(T_i)^{1/3})]^9 + \sin(\sin(A\tan(IU_i)))) + [\sin(T_i^2)] \times Exp(IU_i - 1.62)$
4	Health and sanitation (A_4)	$RWPC_i = RPPW_i - 4.25MR_i(MR_i + RPPW_i) \times [RPPW_i - \sin(RPPW_i)] + RPPW_i \times [\cos(MR_i) - (RPPW_i)^2]^2$
5	Socio-economic	$RWPC_i = A\tan(\sin[0.05 \times (II_i - T_i) \times (RPPW_i + UR_i \times IU_i)]$ $+ \sin(HDI_i) + 0.12[(\cos(PD_i + IU_i^2) - ((HDI_i)^{5/2} \times PD_i)] + \sin(\sin(PD_i) \times [0.08 \times (PD_i)^2 \times (HDI_i) \times A\tan(HDI_i)]$

Table 6 HSEI values with different aspects over the 20-year period in the European continent

Aspects (A_i)	Parameters (P_{ij})	W_{Ai}	$R^2_{ij,RWPC}$ $(y=ax+b)$	W_{Pij}		$\bar{P}_{ij}$	$HSEI_i$		$HSEI$	
				SL	CSC		SL	CSC	SL	CSC
Economics (A_1)	GDP per capita (P_{11})	0.25	0.625	0.271	0.000	0.530	0.480	0.571	0.480	0.521
	Income index (P_{12})		0.721	0.313	0.841	0.580				
	Vulnerable employment (P_{13})		0.241	0.105	0.000	0.400				
	Unemployment rate (P_{14})		0.136	0.059	0.159	0.520				
	Exports and imports (% of GDP) (P_{15})		0.582	0.252	0.000	0.330				
Demographic (A_2)	Human development index (P_{21})	0.25	0.791	0.443	0.443	0.570	0.550	0.550		
	Population density (P_{22})		0.994	0.557	0.557	0.530				
Technology and communication (A_3)	Internet users (P_{31})	0.25	0.729	0.439	0.604	0.480	0.427	0.451		
	Press freedom index (P_{32})		0.453	0.273	0.000	0.360				
	Tourism (P_{33})		0.479	0.288	0.396	0.400				
Health and sanitation (A_4)	Proportion of rural population served with piped water (P_{41})	0.25	0.726	0.510	1.000	0.510	0.461	0.511		
	Mortality rate, under 5 years old (P_{42})		0.698	0.490	0.000	0.410				

3.2 Hydro-socio-economic index results

3.2.1 Economic aspect (A_1)

The hydro-socio-economic index with economic aspect is estimated using the GDP per capita, income index, vulnerable employment, unemployment rate and exports and import by two methods: single linear (SL) and combined soft computing (CSC). The results of HSEI with the economics aspect based on the SL and CSC methods over the 20-year statistical period are represented in Table 6. The values of $R^2_{ij,\mathrm{RWPC}}$ for parameters P_{11}–P_{15} are 0.625, 0.721, 0.241, 0.136 and 0.582, respectively. Based on the linear equation ($y = ax + b$), the highest value of $R^2_{ij,\mathrm{RWPC}}$ is attained for the income index parameter. Also, the parameters P_{11}–P_{15} in the SL method were found suitable to be included in calculation of the HSEI with the weights (W_{Pij}) of 0.271, 0.313, 0.105, 0.059 and 0.252. Using the CSC method, the weights (W_{Pij}) for P_{12} and P_{14} were obtained as 0.841 and 0.159, respectively. This indicates the high impact of the income index on the hydro-socio-economic index compared to other parameters. Based on the results, the HSEI for the economic aspect in the European continent was estimated 0.480 and 0.571 for SL and CSC methods, respectively.

3.2.2 Demographic aspect (A_2)

The hydro-socio-economic index for the demographic aspect is calculated using HDI and population density parameters with both SL and CSC methods. The results of HSEI for the demographic aspect by the SL and CSC methods over the 20-year statistical period are represented in Table 6. The values of $R^2_{ij,\mathrm{RWPC}}$ for parameters P_{21}–P_{22} are 0.443 and 0.557, respectively. Also, in demographic analysis, the parameters P_{21} and P_{22} in the SL and the CSC methods are found effective with weights (W_{Pij}) of 0.443, 0.557 and 0.570, 0.530, respectively. Based on the results, the HSEI for demographic aspect was estimated 0.550 with both methods.

3.2.3 Technology and communication aspect (A_3)

The hydro-socio-economic index for the technology and communication aspect is calculated using based on Internet users, press freedom index and number of arrival tourism parameters. The results of determining the HSEI with the technology and communication aspect based on the SL and CSC methods over the 20-year statistical period are represented in Table 6. The values of $R^2_{ij,\mathrm{RWPC}}$ for parameters P_{31}–P_{33} are 0.729, 0.453 and 0.479, respectively. Based on the linear equation, the highest value of $R^2_{ij,\mathrm{RWPC}}$ is related to the Internet user parameter. Also, for the technology and communication aspect, the parameters P_{31}–P_{33} in the SL and CSC methods have weights (W_{Pij}) of 0.439, 0.273, 0.288 and 0.604, 0.000, 0.396, respectively. That shows the significant impact of the Internet user parameter on estimation of the HSEI considering the technology and communication aspect compared to the other parameters. Based on the results, the value of the HSEI with the technology and communication aspect was estimated 0.427 and 0.451 for the SL and CSC method, respectively.

3.2.4 Health and sanitation aspect (A_4)

The hydro-socio-economic index for the health and sanitation aspect is estimated using the proportion of rural population served with piped water and mortality rate (under 5 years old) parameters with both SL and CSC methods. The results of HSEI for the technology and communication aspect by the SL and CSC methods over the 20-year statistical period are represented in Table 6. The values of $R^2_{ij,\text{RWPC}}$ for parameters P_{41} and P_{42} are 0.726 and 0.698, respectively. Proportion of rural population served with piped water has the highest impact on HSEI for the health and sanitation aspect. In the SL method, the effect weight (W_{Pij}) for P_{41} and P_{42} parameters was estimated 0.510 and 0.490, respectively. Based on the results, the values of the HSEI for the health and sanitation aspect are 0.461 and 0.511 for the SL and CSC method, respectively. According to the qualitative classification, the index values for studied aspect are evaluated at good level.

3.2.5 Hydro-socio-economic index (HSEI)

Finally, the hydro-socio-economic index was calculated by considering various aspects for the case studies with increasing renewable water per capita via both SL and CSC methods. Table 6 shows the index values, based on the single and combined methods for the European continent. HSEI is estimated 0.480 for the SL method and 0.521 for CSC method. According to the qualitative classification, the index values for all studied aspects are evaluated at a good level using both methods.

The HSEI values for different aspects for all studied countries during the 20-year period are represented in Table 7. Figure 8 shows the ranking of the HSEI for different aspects in the studied countries via SL and CSC methods. According to Table 6 and Fig. 8, with both methods, the Estonia has the highest HSEI, and Georgia and Bosnia have a minimum HSEI. For the economic aspect, Belarus and Serbia HSEIs are estimated about 0.540 and 0.682 (highest values) and Croatia and Bosnia HSEIs are 0.355 and 0.442 (lowest values). Also, using both methods, Poland and Bosnia pose the highest and lowest HSEI for demographic aspect, respectively. Considering the technology and communication aspect, Estonia and Latvia have the highest HSEIs, and Georgia has the lowest HSEI. For the health and sanitation aspect, Bosnia and Romania have the highest HSEI values and Serbia and the lowest HSEI belongs to Belarus.

Figures 9 and 10 show the values of HSEI of the six European countries for different aspects using SL and CSC methods, respectively (see Figs. 14, 15 for the rest countries). For example, in Bulgaria the HSEI is lower than the European continent based on both methods. Still, HSEI of this country is placed at a good level. Also, the HSEI of Estonia is higher than the index value for the European continent, and therefore, Estonia offers a better status compared to Europe.

Figure 11 shows the time series of annual HSEI values with economic aspect for each country and based on SL and CSC method (see Fig. 16 for the rest aspects including demographic, technology and communication, and health and sanitation). According to the results of the single linear method, the lowest value of index in 1998 was for Albania, Hungary and Romania and the highest value of index in 2017 was for Croatia, Hungary and Romania. Thus, the Hungary and Romania countries have the most progress in terms of

Table 7 HSEI values with different aspects for studied countries during the 20-year period

| Country (k=1,…,7) | Albania | | Belarus | | Bosnia | | Bulgaria | | Croatia | | Estonia | | Georgia | |
SL.A_i	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$
A_1	0.508	0.487	0.540	0.478	0.410	0.441	0.481	0.468	0.355	0.457	0.522	0.534	0.407	0.419
A_2	0.571		0.631		0.376		0.528		0.509		0.613		0.509	
A_3	0.412		0.325		0.411		0.452		0.463		0.534		0.319	
A_4	0.459		0.415		0.567		0.411		0.501		0.467		0.442	

| Country (k=8,…,14) | Hungary | | Latvia | | Lithuania | | Poland | | Romania | | Serbia | | Ukraine | |
SL.A_i	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$
A_1	0.489	0.478	0.483	0.483	0.487	0.490	0.456	0.510	0.445	0.495	0.497	0.442	0.531	0.490
A_2	0.543		0.572		0.539		0.640		0.580		0.480		0.618	
A_3	0.402		0.469		0.447		0.482		0.422		0.429		0.364	
A_4	0.477		0.410		0.486		0.464		0.531		0.362		0.446	

| Country (k=1,…,7) | Albania | | Belarus | | Bosnia | | Bulgaria | | Croatia | | Estonia | | Georgia | |
CSC.A_i	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$
A_1	0.619	0.525	0.630	0.497	0.442	0.444	0.549	0.525	0.607	0.536	0.559	0.563	0.533	0.464
A_2	0.571		0.631		0.376		0.528		0.509		0.613		0.509	
A_3	0.387		0.341		0.392		0.478		0.486		0.560		0.321	
A_4	0.523		0.387		0.564		0.545		0.541		0.519		0.493	

| Country (k=8,…,14) | Hungary | | Latvia | | Lithuania | | Poland | | Romania | | Serbia | | Ukraine | |
CSC.A_i	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$	$HSEI_{ik}$	$HSEI_k$
A_1	0.574	0.522	0.589	0.551	0.549	0.537	0.518	0.560	0.528	0.540	0.682	0.492	0.627	0.522
A_2	0.543		0.572		0.539		0.640		0.580		0.480		0.618	
A_3	0.442		0.566		0.530		0.552		0.429		0.405		0.348	
A_4	0.527		0.476		0.529		0.531		0.624		0.401		0.497	

the HSEI among other countries during the 20-year study period. According to the results of the soft computing method, Romania has the most progress in terms of the hydro-socio-economic index among other countries during the 20-year study period. In 2017, Romania has the highest value of HSEI with economic aspect, which is classified as excellent level, and Belarus has the lowest HSEI with demographic, technology–communication, and health and sanitation aspects (for details, see Tables 8, 9, 10, 11, 12).

3.3 Social, economic and political evaluation of results

- *Albania* Albania's economy relies more on agriculture industry. In 2009, the country had a fruit and vegetable supply of 886 grams per capita per day, the fifth highest supply in Europe (Nutrition, Physical Activity and Obesity Albania, 2013). In 2009, the government approved the national strategy for science, technology and innovation in Albania covering the period 2009–2015 (Strategy of Science, Technology and Innovation, 2010), which could be the reasons of relationships between the value of the HSEI and these factors (in 2009–2015, the HSEI values changed from 0.62 to 0.87).
- *Belarus* Belarus has three major rivers, the Pripyat, Neman and Dnieper. These Rivers have a profound impact on the country's socio-economic status, which is the main reason why the HSEI value with economic aspect is improving in this country.
- *Bosnia* The Neum Port in Bosnia has a huge impact on the country's economy and the rate of import and export from the country. The deepest river canyon in Europe, the Tara River Canyon that is located in Bosnia, is one of the most important attractions of tourists. Therefore, the amount of HSEI values and economic and tourism factors has relationship, significantly.
- *Bulgaria* The main rivers of Bulgaria are Maritsa and Danube which help in agriculture productions, which tie the economy growth of Bulgaria to the water resources (The economies of Bulgaria and Romania 2007), and the change of HSEI values depends on itself.
- *Croatia* The existence of ports in different sizes on the Adriatic coast has led to the improvements in economy of Croatia and brought in a large expansion in tourism industry. Tourism is one of the main sources of income for this country with 20% of total economic production (Prihodi 2017). Hence, the country has a significant HSEI with technology and communication aspect.
- *Estonia* Soil of Estonia is not suitable for cultivation, and as the HSEI for the economic aspect has a high relation with agriculture, the index has a relatively low value. The United Nations also ranked Estonia in the high value category of human development indexes (HDI). Therefore, the HSEI of the country is relatively high compared to the others, too.
- *Georgia* Georgia's rivers pose an economic significance. The country's hot springs are one of the major tourist attractions. Tourism is one of the most important sectors of the Georgian service, which plays an important role in the country's economy and HSEI values, finally.
- *Hungary* Nearly one-fifth of the country's Hungary workforce is engaged in agriculture and animal husbandry (Watkins 2014). In 2008, the Hungarian economy was under severe debt pressures and deficit. Hungary has sought economic development in the wake of economic reforms in 2010 and has strengthened international capabilities and the number of active human resources in the economy (World Bank Country Classification 2008; Global 500—Countries: Hungary–Fortune 2013; Research and development
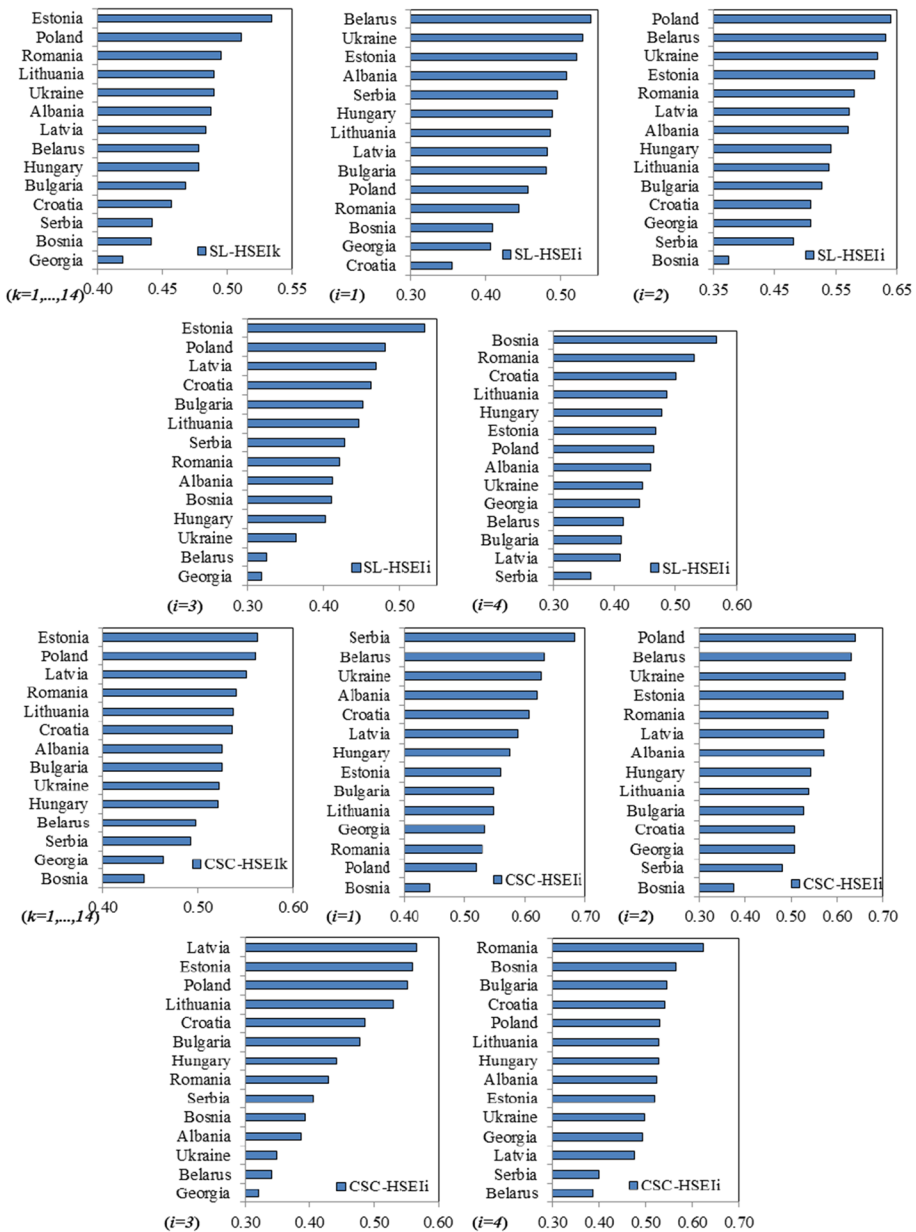
Fig. 8 Ranking of the HSEI with different aspects ($i = 1, …, 4$) in the studied countries ($k = 1, 2, …, 14$) using SL and CSC methods

2016). These factors can be considered as one of the reasons for the increase in the slope of the HSEI time series for the economic aspect (in 2010–2011, the HSEI values of economic aspects changed from 0.0.62 to 0.66). There are many tourist attractions
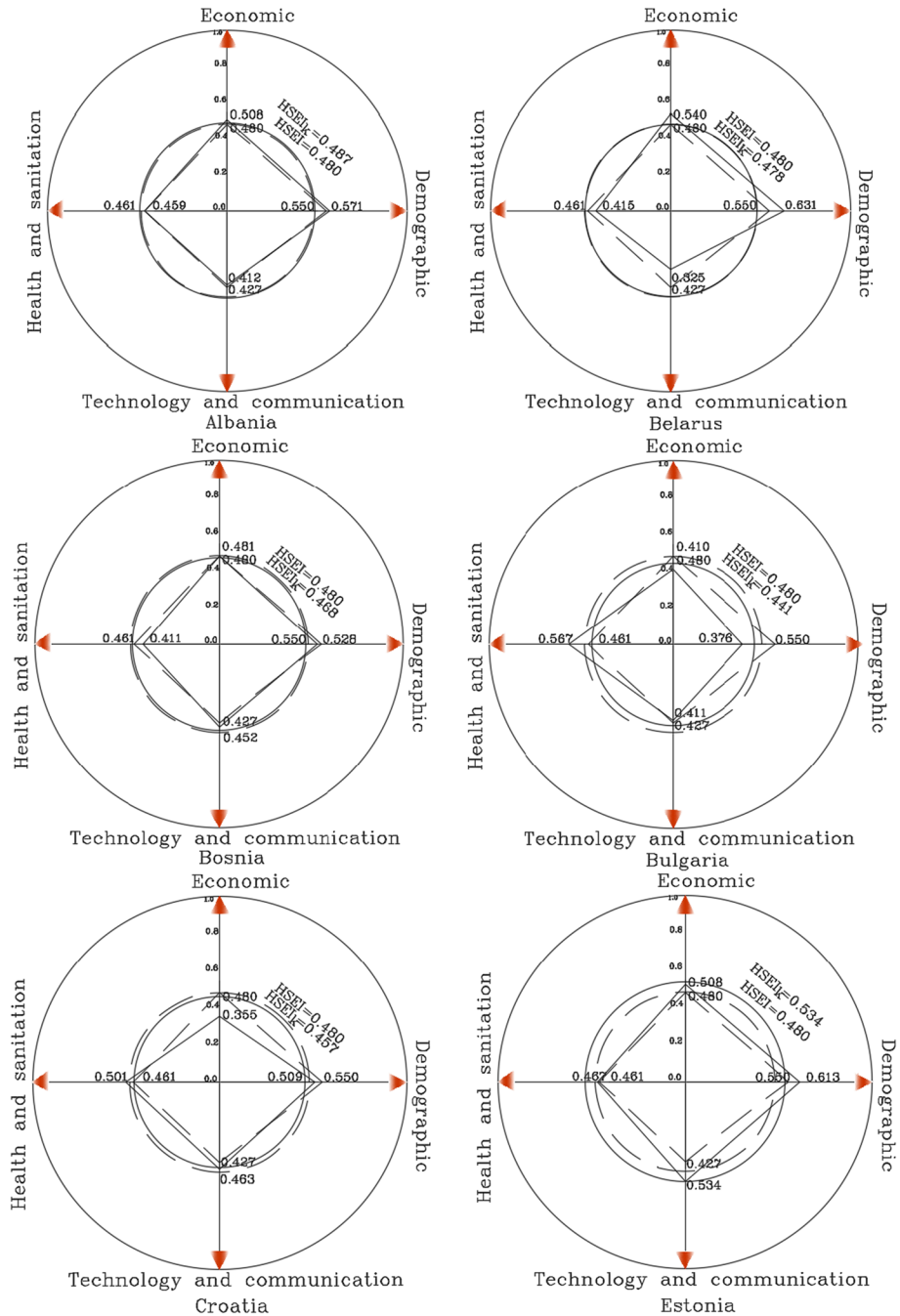
Fig. 9 Values of HSEI in European continent with different aspects by country using the single linear (SL) method
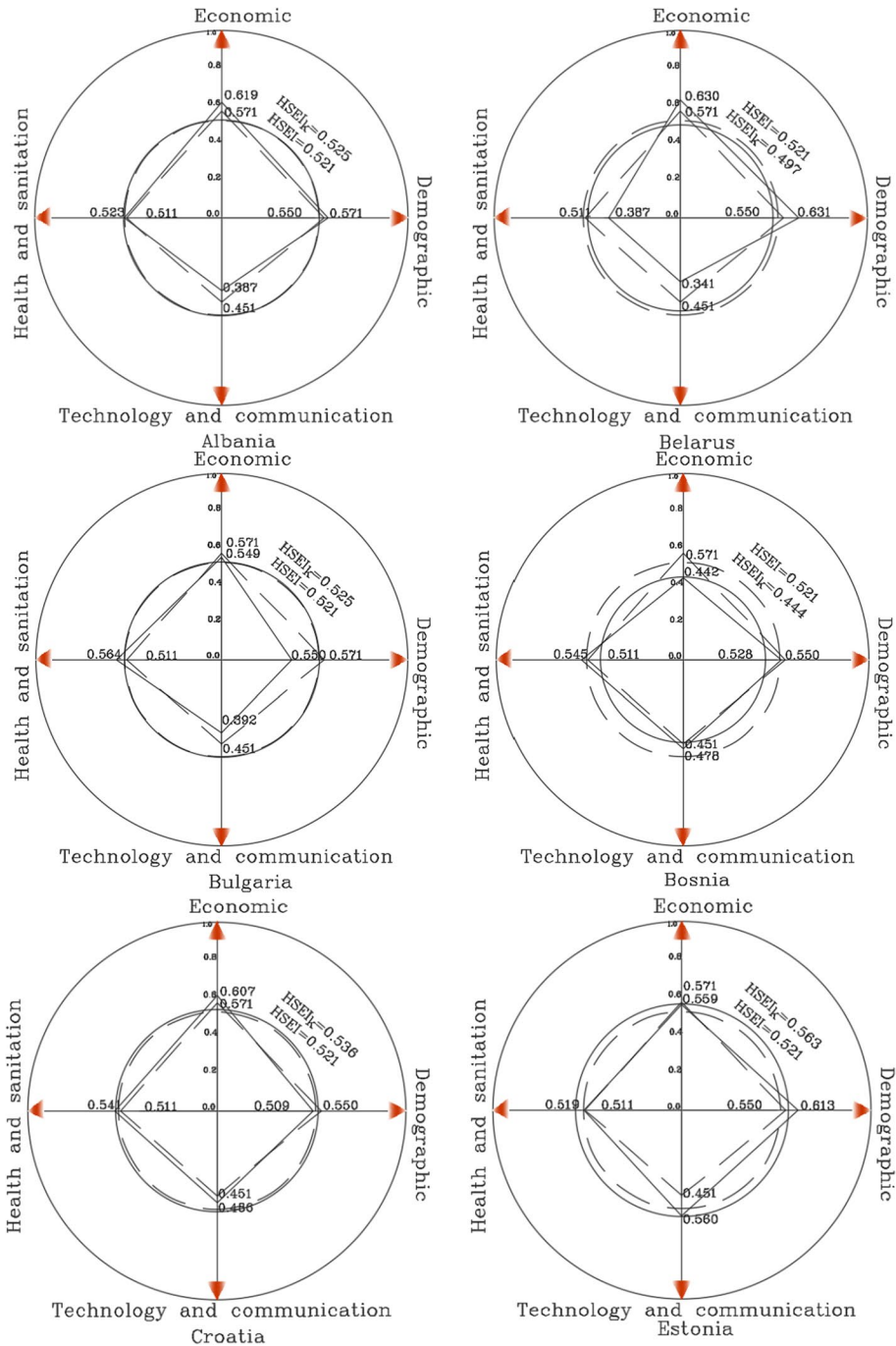
Fig. 10 Values of HSEI in European continent with different aspects by country using the combined soft computing (CSC) method
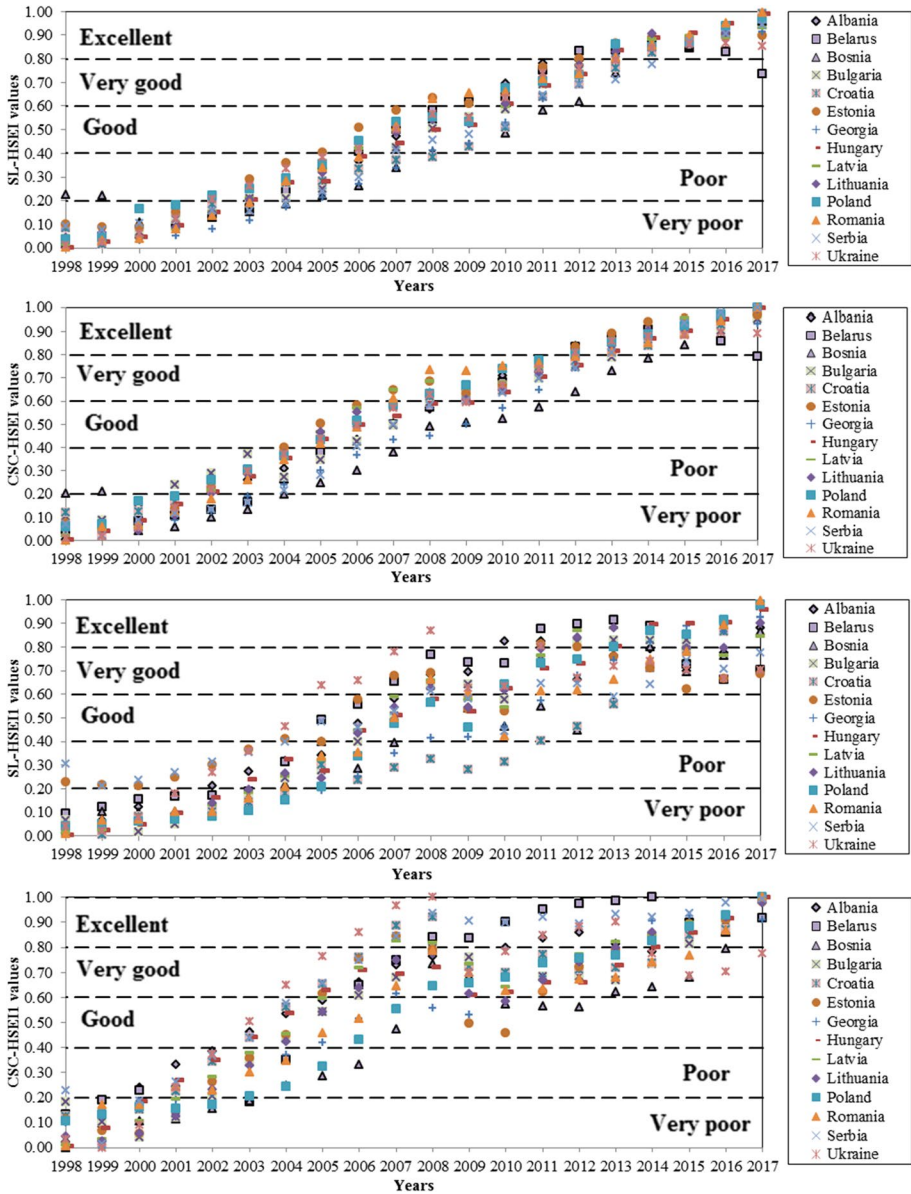
Fig. 11 Value of HSEI with economics aspect and annual scale by country, using SL and CSC methods

that can be found at Hévíz and Balaton Lakes, which have a significant impact on the HSEI value of technology and communication aspect.

- *Latvia* In 2012, Latvia agreed to a Financial Arbitration Agreement (Lannin and Bra-slina 2010; Public Information Notice 2012). The purpose of the treaty is to strength the coordination of the economic policies. This treaty could be one of the reasons for

the increase in the HSEI values for economic aspect after the year (in 2012–2013, the HSEI values of economic aspects changed from 0.77 to 0.82).

- *Lithuania* In the Lithuania, international shipments are carried out from the port of Klaipeda. The currency was Litas, which changed to Euro at the beginning of 2015. The change of the country's currency is one of the main reasons for the increase in the amount of the HSEI of the economic aspect. Lithuania became a full member of the Schengen Treaty in 2007 and was selected as the European cultural capital in 2009 (Lietuvos makroekonomikos apžvalga 2014; GDP—composition 2018), which could be the reasons of the ascending rise of the HSEI of demographic and technology and communication aspects after 2009 (in 2009–2010 and 2015–2016, the HSEI values changed from 0.52 to 0.61 and 0.91 to 0.95, respectively). Agriculture is also important in this country.
- *Poland* Poland has a diverse economy. The largest component of the economy is the services sector, industry and agriculture (PAP 2013). After joining the European Union in 2004, the number of arrival tourism increased sharply. The value of HSEI of technology and communication aspect also shows increasing trend after 2004. In addition, tourism serves as a great support for the economy of this country. One of the attractions of the tourist is the sandy beaches in the north of the country.
- *Romania* Romanian officials believe that start of the European Union membership from 2007 (IMF World Economic Outlook Database 2011), in the long term, will bring lots of benefits for Romanians, which is one of the reasons of the appropriate amount of HSEI (in 2006–2007, the HSEI values changed from 0.49 to 0.61).
- *Serbia* The Danube River provides agricultural water for many cultivated lands and increases the amount of agricultural exports and influences the economy of the Serbia, which is one of the reasons of the appropriate amount of HSEI.
- *Ukraine* The economic–social crisis of 2014 has had a dramatic impact on Ukraine's economy (in 2013–2014, the HSEI values of economic aspects changed from 0.90 to 0.78). Against most mineral-rich countries, Ukraine has a very fertile soil (Baliuk et al. 2017). This soil is known as the "black soil," which is the most fertile soil in the world. This exceptional and fertile soil is one of the national assets of Ukraine. Agriculture in this soil is without fertilizer, which is one of the reasons for reducing the pollution of water resources and, consequently, reducing the mortality rate (under 5 years old) in the country and the appropriate values of the HSEI with health and sanitation aspect.

The results of this study, in the context of the relationship between water and social capital, are consistent with the findings from Forouzani et al. (2013), Carey et al. (2014), Lima et al. (2016), Pande and Sivapalan (2017) and Diep (2018).

4 Conclusions

In previous studies, the hidden and rational relationships between different socio-economic and environmental parameters and aspects have been overlooked. Diaz et al. (2018) discussed about the importance and better understanding hidden and complex relationships between ecosystems and HWB. Limited aspects of the proposed management plans but not comprehensively have been addressed, not comprehensively, or different social dimensions of a phenomenon such as floods or droughts have been merely explored. For example,

Liang et al. (2018) investigated the expected amount of water saving in agricultural project or Aerts et al. (2018) examined the human behavior effects on flood disaster risk assessment. The need to examine the interaction of water and societies systems is not only about how the socio-economic status affects aquatic systems. Rather, it is more about how decisions for management of water systems lead the community toward responses and social movements. The economy is influenced by various economic factors, in which the welfare of the individual and society should be maximized through the optimal use of natural resources as well as the equitable distribution of resources. The relation between income from agriculture and industry with the amount of allocated water is not linear and proportional. This relationship changes over time, as the price of manufactured products associated with the future uncertainties, making economic evaluations for the future become more difficult. It should also be noted that any local or global incidents can significantly alter the values that matter to a community over the times; so, considering cultural values is also important in decision-making process. Determining the hydro-socio-economic index using underlying socio-economic parameters supports decision-making process and planning for the future changes. Since in this study the socio-economic parameter selection has been comprehensively and rationally performed, it considerably resolves the deficiencies associated with previous studies. Previous studies rarely accounted for the involvement and impacts of relationship rationality between socio-economic parameters and the water resource parameter for development of hydro-socio-economic indicators.

Data availability All of the required data have been presented in our article.

Compliance with ethical standards

Conflict of interests The authors declare that they have no conflict of interest.

Appendix

See Tables 8, 9, 10, 11 and 12 and Figs. 12, 13, 14, 15 and 16.

Table 8　Value of HSEI with annual scale by country using SL and CSC method

SL Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2017	0.94	0.74	0.96	0.98	0.99	0.90	0.91	0.99	0.93	0.98	0.97	0.99	0.94	0.85
2016	0.91	0.83	0.92	0.93	0.93	0.89	0.90	0.95	0.89	0.91	0.94	0.95	0.90	0.86
2015	0.87	0.84	0.85	0.89	0.87	0.88	0.89	0.91	0.89	0.89	0.87	0.90	0.87	0.86
2014	0.87	0.86	0.84	0.85	0.82	0.89	0.84	0.89	0.88	0.91	0.85	0.86	0.78	0.84
2013	0.83	0.84	0.74	0.80	0.76	0.86	0.81	0.84	0.86	0.83	0.86	0.81	0.71	0.79
2012	0.79	0.83	0.62	0.75	0.69	0.80	0.72	0.74	0.77	0.77	0.73	0.74	0.69	0.76
2011	0.78	0.75	0.58	0.69	0.64	0.76	0.63	0.69	0.71	0.72	0.70	0.71	0.64	0.74
2010	0.69	0.64	0.48	0.59	0.51	0.66	0.53	0.61	0.60	0.61	0.67	0.66	0.52	0.63
2009	0.62	0.62	0.43	0.55	0.43	0.61	0.44	0.52	0.54	0.52	0.53	0.66	0.48	0.55
2008	0.53	0.58	0.40	0.50	0.38	0.64	0.41	0.50	0.55	0.54	0.55	0.63	0.45	0.56
2007	0.47	0.50	0.34	0.42	0.37	0.58	0.34	0.44	0.50	0.49	0.53	0.51	0.41	0.50
2006	0.37	0.41	0.26	0.33	0.33	0.51	0.27	0.39	0.42	0.45	0.45	0.38	0.30	0.42
2005	0.28	0.34	0.22	0.25	0.28	0.40	0.21	0.28	0.33	0.32	0.35	0.34	0.24	0.38
2004	0.23	0.24	0.18	0.21	0.27	0.36	0.17	0.28	0.27	0.28	0.30	0.28	0.19	0.34
2003	0.18	0.16	0.15	0.21	0.25	0.29	0.11	0.21	0.21	0.21	0.25	0.19	0.16	0.26
2002	0.15	0.13	0.15	0.16	0.19	0.22	0.08	0.15	0.15	0.15	0.22	0.14	0.16	0.20
2001	0.12	0.10	0.11	0.12	0.17	0.15	0.05	0.10	0.08	0.09	0.18	0.08	0.13	0.13
2000	0.07	0.07	0.11	0.07	0.16	0.09	0.03	0.05	0.04	0.04	0.16	0.04	0.10	0.06
1999	0.04	0.05	0.22	0.03	0.02	0.09	0.02	0.03	0.04	0.06	0.04	0.03	0.08	0.02
1998	0.00	0.03	0.23	0.04	0.08	0.10	0.01	0.00	0.02	0.04	0.03	0.00	0.09	0.01

Table 8 (continued)

CSC Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2017	0.98	0.79	1.00	0.95	1.00	0.97	0.93	1.00	0.99	0.99	1.00	1.00	1.00	0.89
2016	0.95	0.86	0.91	0.90	0.93	0.94	0.94	0.95	0.96	0.95	0.97	0.94	0.98	0.89
2015	0.91	0.91	0.84	0.89	0.89	0.95	0.92	0.90	0.96	0.91	0.93	0.89	0.93	0.88
2014	0.88	0.91	0.78	0.86	0.84	0.94	0.88	0.87	0.90	0.90	0.89	0.85	0.87	0.88
2013	0.85	0.87	0.73	0.79	0.81	0.89	0.82	0.82	0.84	0.84	0.85	0.81	0.81	0.86
2012	0.84	0.83	0.64	0.75	0.77	0.83	0.74	0.76	0.79	0.79	0.80	0.79	0.74	0.81
2011	0.77	0.74	0.57	0.70	0.75	0.77	0.65	0.70	0.75	0.72	0.77	0.76	0.70	0.74
2010	0.71	0.68	0.52	0.66	0.64	0.67	0.57	0.64	0.68	0.65	0.74	0.75	0.64	0.67
2009	0.65	0.62	0.51	0.63	0.60	0.63	0.50	0.59	0.67	0.60	0.67	0.73	0.60	0.59
2008	0.57	0.57	0.49	0.59	0.62	0.68	0.45	0.59	0.68	0.64	0.63	0.73	0.58	0.63
2007	0.50	0.50	0.38	0.50	0.58	0.65	0.44	0.54	0.65	0.58	0.59	0.61	0.50	0.57
2006	0.43	0.43	0.30	0.42	0.51	0.58	0.37	0.50	0.57	0.55	0.51	0.49	0.40	0.49
2005	0.37	0.38	0.25	0.35	0.43	0.50	0.30	0.44	0.47	0.46	0.43	0.41	0.28	0.44
2004	0.31	0.27	0.20	0.27	0.38	0.40	0.24	0.35	0.38	0.37	0.36	0.35	0.21	0.37
2003	0.26	0.16	0.13	0.37	0.30	0.30	0.19	0.28	0.29	0.28	0.30	0.26	0.16	0.30
2002	0.21	0.13	0.10	0.29	0.24	0.23	0.12	0.21	0.22	0.20	0.26	0.18	0.13	0.22
2001	0.16	0.11	0.06	0.24	0.16	0.14	0.09	0.16	0.11	0.11	0.19	0.13	0.12	0.14
2000	0.10	0.08	0.04	0.16	0.12	0.05	0.06	0.08	0.06	0.04	0.17	0.07	0.08	0.06
1999	0.05	0.06	0.21	0.09	0.02	0.05	0.04	0.04	0.04	0.07	0.07	0.06	0.02	0.02
1998	0.01	0.03	0.20	0.10	0.12	0.07	0.02	0.01	0.02	0.05	0.06	0.00	0.07	0.01

Table 9 Value of HSEI with economic aspect with annual scale by country using SL and CSC method

SL Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2017	0.88	0.70	0.86	0.98	0.97	0.69	0.93	0.96	0.84	0.90	0.98	1.00	0.78	0.70
2016	0.78	0.66	0.76	0.88	0.87	0.66	0.86	0.90	0.76	0.80	0.91	0.89	0.71	0.67
2015	0.70	0.73	0.69	0.83	0.79	0.62	0.89	0.90	0.79	0.79	0.85	0.78	0.74	0.70
2014	0.79	0.89	0.80	0.83	0.71	0.71	0.82	0.90	0.88	0.87	0.87	0.75	0.64	0.74
2013	0.76	0.91	0.56	0.83	0.55	0.76	0.74	0.80	0.88	0.88	0.80	0.66	0.59	0.72
2012	0.66	0.90	0.45	0.82	0.46	0.80	0.68	0.73	0.87	0.84	0.75	0.62	0.65	0.67
2011	0.83	0.88	0.55	0.75	0.40	0.81	0.57	0.71	0.76	0.79	0.73	0.61	0.64	0.80
2010	0.82	0.73	0.46	0.58	0.31	0.53	0.46	0.63	0.54	0.62	0.64	0.42	0.44	0.63
2009	0.70	0.73	0.54	0.64	0.28	0.53	0.42	0.53	0.57	0.54	0.46	0.61	0.58	0.63
2008	0.68	0.77	0.56	0.63	0.32	0.69	0.42	0.58	0.66	0.62	0.56	0.66	0.61	0.87
2007	0.58	0.65	0.39	0.51	0.29	0.68	0.35	0.51	0.59	0.55	0.47	0.50	0.53	0.78
2006	0.47	0.56	0.29	0.40	0.23	0.58	0.25	0.45	0.44	0.43	0.34	0.35	0.46	0.66
2005	0.34	0.49	0.40	0.28	0.30	0.40	0.19	0.28	0.32	0.24	0.21	0.34	0.48	0.64
2004	0.31	0.31	0.21	0.25	0.18	0.41	0.15	0.33	0.25	0.26	0.15	0.21	0.40	0.46
2003	0.27	0.19	0.16	0.17	0.14	0.36	0.12	0.24	0.18	0.20	0.11	0.16	0.35	0.36
2002	0.21	0.17	0.13	0.09	0.10	0.30	0.08	0.16	0.13	0.14	0.08	0.10	0.31	0.27
2001	0.18	0.16	0.10	0.05	0.07	0.25	0.07	0.10	0.09	0.09	0.07	0.10	0.27	0.18
2000	0.12	0.16	0.10	0.01	0.08	0.21	0.06	0.05	0.05	0.06	0.06	0.07	0.23	0.08
1999	0.06	0.12	0.10	0.04	0.00	0.21	0.04	0.02	0.03	0.05	0.05	0.07	0.21	0.02
1998	0.01	0.10	0.06	0.07	0.03	0.23	0.04	0.00	0.01	0.05	0.04	0.01	0.30	0.04

Table 9 (continued)

CSC Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2017	0.98	0.92	1.00	0.99	1.00	0.98	0.91	1.00	0.99	0.98	1.00	1.00	0.99	0.77
2016	0.91	0.86	0.80	0.90	0.87	0.91	0.93	0.92	0.94	0.92	0.93	0.87	0.98	0.70
2015	0.82	0.90	0.68	0.81	0.85	0.89	0.93	0.86	0.90	0.88	0.88	0.77	0.94	0.69
2014	0.78	1.00	0.64	0.73	0.74	0.84	0.91	0.80	0.85	0.86	0.82	0.74	0.92	0.78
2013	0.81	0.99	0.62	0.67	0.72	0.79	0.80	0.73	0.82	0.80	0.77	0.68	0.93	0.90
2012	0.86	0.98	0.56	0.68	0.71	0.72	0.76	0.66	0.77	0.74	0.76	0.67	0.89	0.88
2011	0.83	0.95	0.57	0.68	0.77	0.62	0.68	0.66	0.73	0.67	0.74	0.63	0.92	0.85
2010	0.80	0.90	0.57	0.70	0.70	0.46	0.59	0.62	0.64	0.58	0.68	0.63	0.90	0.78
2009	0.76	0.84	0.68	0.76	0.72	0.50	0.53	0.61	0.73	0.61	0.66	0.70	0.91	0.70
2008	0.76	0.84	0.73	0.79	0.92	0.79	0.56	0.72	0.82	0.77	0.64	0.79	0.94	1.00
2007	0.73	0.75	0.47	0.68	0.89	0.84	0.61	0.70	0.83	0.75	0.55	0.64	0.85	0.97
2006	0.66	0.65	0.33	0.61	0.76	0.75	0.52	0.71	0.72	0.64	0.43	0.51	0.75	0.86
2005	0.59	0.54	0.29	0.54	0.65	0.61	0.42	0.63	0.60	0.54	0.32	0.46	0.66	0.76
2004	0.53	0.35	0.25	0.44	0.56	0.45	0.37	0.54	0.46	0.42	0.24	0.35	0.57	0.65
2003	0.46	0.18	0.18	0.34	0.44	0.36	0.33	0.44	0.38	0.33	0.20	0.30	0.44	0.50
2002	0.38	0.20	0.15	0.20	0.34	0.26	0.21	0.35	0.28	0.23	0.17	0.23	0.37	0.38
2001	0.33	0.23	0.11	0.12	0.22	0.15	0.19	0.27	0.19	0.13	0.16	0.25	0.26	0.24
2000	0.24	0.23	0.11	0.04	0.15	0.06	0.19	0.19	0.10	0.06	0.16	0.17	0.18	0.09
1999	0.12	0.19	0.10	0.10	0.01	0.07	0.12	0.08	0.03	0.02	0.13	0.17	0.01	0.00
1998	0.02	0.13	0.00	0.18	0.12	0.11	0.10	0.01	0.01	0.04	0.11	0.01	0.23	0.03

Table 10 Value of HSEI with demographic aspect with annual scale by country using SL and CSC method

SL Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2017	1.00	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2016	0.98	0.95	0.97	0.96	0.92	0.99	0.98	0.95	0.97	0.96	0.98	0.96	0.95	0.95
2015	0.96	0.95	0.88	0.92	0.88	0.98	0.96	0.92	0.94	0.92	0.93	0.93	0.89	0.93
2014	0.93	0.98	0.82	0.85	0.82	0.97	0.92	0.89	0.91	0.89	0.87	0.91	0.83	0.94
2013	0.90	0.97	0.71	0.81	0.78	0.93	0.85	0.88	0.87	0.82	0.88	0.88	0.77	0.91
2012	0.88	0.98	0.58	0.76	0.74	0.89	0.79	0.82	0.82	0.78	0.79	0.85	0.72	0.88
2011	0.82	0.95	0.42	0.72	0.72	0.84	0.71	0.76	0.78	0.74	0.80	0.85	0.69	0.84
2010	0.76	0.91	0.32	0.68	0.51	0.78	0.65	0.71	0.72	0.67	0.81	0.82	0.58	0.80
2009	0.69	0.86	0.30	0.63	0.47	0.73	0.60	0.66	0.67	0.61	0.68	0.81	0.55	0.75
2008	0.63	0.81	0.26	0.60	0.47	0.74	0.55	0.55	0.64	0.62	0.69	0.76	0.52	0.76
2007	0.57	0.73	0.21	0.54	0.45	0.70	0.53	0.51	0.60	0.57	0.69	0.64	0.45	0.71
2006	0.49	0.64	0.17	0.47	0.42	0.62	0.44	0.48	0.55	0.51	0.64	0.53	0.40	0.64
2005	0.43	0.54	0.13	0.42	0.37	0.54	0.37	0.43	0.51	0.44	0.59	0.46	0.34	0.58
2004	0.36	0.43	0.10	0.37	0.36	0.46	0.29	0.36	0.43	0.36	0.56	0.39	0.27	0.49
2003	0.32	0.34	0.09	0.31	0.32	0.37	0.22	0.32	0.36	0.31	0.52	0.32	0.21	0.42
2002	0.26	0.26	0.07	0.24	0.30	0.29	0.14	0.25	0.29	0.24	0.49	0.25	0.16	0.32
2001	0.23	0.18	0.04	0.18	0.27	0.20	0.09	0.18	0.21	0.18	0.43	0.14	0.13	0.23
2000	0.14	0.11	0.03	0.06	0.25	0.08	0.04	0.12	0.12	0.11	0.41	0.06	0.09	0.13
1999	0.08	0.05	0.19	0.02	0.03	0.08	0.03	0.06	0.06	0.05	0.04	0.03	0.03	0.06
1998	0.00	0.00	0.21	0.00	0.08	0.08	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00

CSC Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2017	1.00	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2016	0.98	0.95	0.97	0.96	0.92	0.99	0.98	0.95	0.97	0.96	0.98	0.96	0.95	0.95
2015	0.96	0.95	0.88	0.92	0.88	0.98	0.96	0.92	0.94	0.92	0.93	0.93	0.89	0.93

Table 10 (continued)

CSC Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2014	0.93	0.98	0.82	0.85	0.82	0.97	0.92	0.89	0.91	0.89	0.87	0.91	0.83	0.94
2013	0.90	0.97	0.71	0.81	0.78	0.93	0.85	0.88	0.87	0.82	0.88	0.88	0.77	0.91
2012	0.88	0.98	0.58	0.76	0.74	0.89	0.79	0.82	0.82	0.78	0.79	0.85	0.72	0.88
2011	0.82	0.95	0.42	0.72	0.72	0.84	0.71	0.76	0.78	0.74	0.80	0.85	0.69	0.84
2010	0.76	0.91	0.32	0.68	0.51	0.78	0.65	0.71	0.72	0.67	0.81	0.82	0.58	0.80
2009	0.69	0.86	0.30	0.63	0.47	0.73	0.60	0.66	0.67	0.61	0.68	0.81	0.55	0.75
2008	0.63	0.81	0.26	0.60	0.47	0.74	0.55	0.55	0.64	0.62	0.69	0.76	0.52	0.76
2007	0.57	0.73	0.21	0.54	0.45	0.70	0.53	0.51	0.60	0.57	0.69	0.64	0.45	0.71
2006	0.49	0.64	0.17	0.47	0.42	0.62	0.44	0.48	0.55	0.51	0.64	0.53	0.40	0.64
2005	0.43	0.54	0.13	0.42	0.37	0.54	0.37	0.43	0.51	0.44	0.59	0.46	0.34	0.58
2004	0.36	0.43	0.10	0.37	0.36	0.46	0.29	0.36	0.43	0.36	0.56	0.39	0.27	0.49
2003	0.32	0.34	0.09	0.31	0.32	0.37	0.22	0.32	0.36	0.31	0.52	0.32	0.21	0.42
2002	0.26	0.26	0.07	0.24	0.30	0.29	0.14	0.25	0.29	0.24	0.49	0.25	0.16	0.32
2001	0.23	0.18	0.04	0.18	0.27	0.20	0.09	0.18	0.21	0.18	0.43	0.14	0.13	0.23
2000	0.14	0.11	0.03	0.06	0.25	0.08	0.04	0.12	0.12	0.11	0.41	0.06	0.09	0.13
1999	0.08	0.05	0.19	0.02	0.03	0.08	0.03	0.06	0.06	0.05	0.04	0.03	0.03	0.06
1998	0.00	0.00	0.21	0.00	0.08	0.08	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00

Table 11 Value of HSEI with technology and communication aspect with annual scale by country using SL and CSC method

SL Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2017	0.92	0.62	0.99	1.00	1.00	0.97	0.78	1.00	0.87	1.00	0.89	0.98	0.98	0.73
2016	0.90	0.89	0.93	0.96	0.92	0.97	0.80	0.95	0.82	0.93	0.86	0.95	0.96	0.87
2015	0.85	0.71	0.86	0.86	0.84	0.93	0.72	0.86	0.88	0.86	0.73	0.88	0.91	0.85
2014	0.82	0.65	0.77	0.85	0.82	0.92	0.69	0.83	0.86	0.86	0.70	0.80	0.81	0.79
2013	0.78	0.62	0.76	0.78	0.78	0.88	0.80	0.78	0.87	0.65	0.86	0.73	0.75	0.71
2012	0.83	0.67	0.59	0.76	0.69	0.69	0.65	0.56	0.68	0.57	0.57	0.56	0.74	0.73
2011	0.75	0.47	0.57	0.72	0.66	0.65	0.53	0.51	0.68	0.52	0.54	0.50	0.68	0.63
2010	0.56	0.30	0.46	0.59	0.53	0.68	0.37	0.42	0.57	0.44	0.60	0.52	0.56	0.50
2009	0.51	0.27	0.36	0.53	0.49	0.60	0.22	0.36	0.49	0.39	0.56	0.45	0.41	0.28
2008	0.31	0.22	0.32	0.46	0.31	0.61	0.24	0.39	0.55	0.44	0.51	0.44	0.40	0.16
2007	0.37	0.20	0.32	0.43	0.36	0.52	0.13	0.33	0.53	0.43	0.56	0.40	0.47	0.14
2006	0.24	0.16	0.19	0.31	0.34	0.51	0.12	0.27	0.47	0.51	0.50	0.30	0.20	0.10
2005	0.16	0.26	0.19	0.26	0.31	0.49	0.12	0.23	0.34	0.40	0.43	0.30	0.09	0.14
2004	0.10	0.19	0.10	0.22	0.29	0.41	0.11	0.20	0.28	0.31	0.32	0.32	0.08	0.24
2003	0.03	0.12	0.07	0.13	0.31	0.31	0.02	0.10	0.21	0.21	0.24	0.12	0.07	0.17
2002	0.05	0.08	0.15	0.11	0.15	0.21	0.03	0.12	0.15	0.14	0.21	0.09	0.16	0.15
2001	0.02	0.04	0.08	0.05	0.18	0.12	0.02	0.07	0.02	0.04	0.18	0.03	0.11	0.05
2000	0.01	0.01	0.10	0.02	0.15	0.07	0.02	0.02	0.00	0.00	0.19	0.03	0.09	0.03
1999	0.01	0.01	0.20	0.00	0.03	0.06	0.01	0.02	0.06	0.12	0.09	0.02	0.07	0.01
1998	0.00	0.01	0.21	0.01	0.11	0.07	0.00	0.01	0.05	0.11	0.10	0.00	0.04	0.01

CSC Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2017	0.96	0.69	1.00	1.00	1.00	0.98	0.89	1.00	0.98	1.00	0.99	0.99	1.00	0.81
2016	0.94	1.00	0.89	0.95	0.92	0.97	0.91	0.94	0.93	0.94	0.98	0.95	0.97	0.99
2015	0.88	0.80	0.80	0.83	0.84	0.94	0.81	0.83	1.00	0.85	0.89	0.84	0.91	0.92

Table 11 (continued)

CSC Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2014	0.81	0.73	0.68	0.84	0.79	0.95	0.76	0.79	0.91	0.85	0.86	0.76	0.83	0.86
2013	0.74	0.70	0.66	0.78	0.74	0.90	0.75	0.73	0.81	0.81	0.81	0.69	0.71	0.77
2012	0.75	0.62	0.57	0.74	0.68	0.86	0.62	0.68	0.77	0.77	0.78	0.64	0.63	0.66
2011	0.63	0.40	0.52	0.69	0.63	0.81	0.47	0.60	0.76	0.70	0.75	0.56	0.54	0.53
2010	0.57	0.32	0.50	0.65	0.59	0.73	0.37	0.52	0.71	0.61	0.74	0.55	0.52	0.43
2009	0.49	0.27	0.42	0.62	0.53	0.65	0.27	0.46	0.69	0.55	0.68	0.53	0.49	0.33
2008	0.30	0.23	0.40	0.57	0.48	0.64	0.16	0.50	0.78	0.58	0.62	0.58	0.51	0.20
2007	0.21	0.19	0.33	0.47	0.46	0.54	0.13	0.44	0.74	0.50	0.60	0.46	0.44	0.12
2006	0.16	0.15	0.28	0.41	0.41	0.52	0.12	0.37	0.66	0.63	0.56	0.30	0.29	0.07
2005	0.11	0.26	0.22	0.32	0.36	0.50	0.07	0.34	0.47	0.52	0.48	0.25	0.04	0.08
2004	0.07	0.20	0.15	0.29	0.36	0.40	0.04	0.23	0.41	0.42	0.38	0.25	0.00	0.07
2003	0.05	0.13	0.04	0.18	0.28	0.27	0.02	0.13	0.29	0.29	0.27	0.11	0.00	0.06
2002	0.03	0.08	0.03	0.11	0.22	0.22	0.01	0.11	0.22	0.19	0.22	0.03	0.00	0.03
2001	0.02	0.03	0.00	0.08	0.16	0.12	0.00	0.10	0.03	0.06	0.09	0.02	0.07	0.02
2000	0.01	0.00	0.02	0.02	0.10	0.08	0.01	0.04	0.00	0.00	0.10	0.04	0.06	0.00
1999	0.02	0.00	0.17	0.00	0.04	0.06	0.01	0.03	0.09	0.17	0.11	0.03	0.05	0.00
1998	0.00	0.01	0.18	0.02	0.13	0.06	0.00	0.01	0.08	0.15	0.13	0.00	0.02	0.00

Table 12 Value of HSEI with health and sanitation aspect with annual scale by country using SL and CSC method

SL Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2017	0.97	0.67	1.00	0.94	1.00	0.93	0.95	1.00	1.00	1.00	1.00	1.00	1.00	0.99
2016	0.99	0.81	1.00	0.93	1.00	0.96	0.96	1.00	1.00	0.95	1.00	1.00	1.00	0.96
2015	0.97	0.99	0.98	0.93	0.97	0.98	0.98	0.96	0.97	0.98	0.97	0.99	0.94	0.97
2014	0.94	0.93	0.98	0.86	0.94	0.96	0.91	0.94	0.89	1.00	0.95	0.97	0.83	0.91
2013	0.87	0.85	0.93	0.77	0.91	0.88	0.84	0.88	0.80	0.96	0.90	0.95	0.73	0.84
2012	0.79	0.78	0.85	0.67	0.87	0.81	0.77	0.83	0.72	0.90	0.83	0.92	0.65	0.76
2011	0.72	0.70	0.78	0.58	0.77	0.74	0.70	0.77	0.63	0.82	0.74	0.89	0.56	0.68
2010	0.64	0.62	0.70	0.49	0.68	0.67	0.63	0.69	0.55	0.71	0.65	0.86	0.48	0.60
2009	0.60	0.62	0.53	0.41	0.47	0.57	0.52	0.54	0.44	0.55	0.44	0.76	0.37	0.55
2008	0.49	0.53	0.47	0.32	0.42	0.51	0.43	0.48	0.34	0.48	0.45	0.65	0.29	0.46
2007	0.38	0.41	0.43	0.22	0.38	0.43	0.35	0.42	0.27	0.41	0.42	0.50	0.21	0.37
2006	0.27	0.28	0.39	0.12	0.34	0.33	0.27	0.36	0.21	0.34	0.33	0.36	0.13	0.28
2005	0.19	0.08	0.16	0.04	0.15	0.19	0.17	0.19	0.15	0.18	0.20	0.26	0.05	0.18
2004	0.15	0.04	0.32	0.00	0.27	0.15	0.14	0.23	0.11	0.17	0.15	0.20	0.00	0.15
2003	0.11	0.00	0.29	0.22	0.23	0.11	0.10	0.16	0.07	0.11	0.13	0.15	0.00	0.11
2002	0.07	0.00	0.26	0.21	0.19	0.08	0.07	0.08	0.04	0.07	0.09	0.10	0.00	0.07
2001	0.04	0.00	0.23	0.20	0.15	0.04	0.03	0.04	0.00	0.04	0.04	0.05	0.00	0.04
2000	0.00	0.00	0.21	0.18	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.00	0.40	0.08	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.42	0.07	0.12	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00

CSC Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2017	0.99	0.61	1.00	0.83	1.00	0.92	0.93	1.00	1.00	1.00	1.00	1.00	1.00	0.98
2016	0.98	0.62	1.00	0.80	1.00	0.92	0.93	1.00	1.00	1.00	1.00	1.00	1.00	0.93
2015	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 12 (continued)

CSC Years/country	Albania	Belarus	Bosnia	Bulgaria	Croatia	Estonia	Georgia	Hungary	Latvia	Lithuania	Poland	Romania	Serbia	Ukraine
2014	1.00	0.92	1.00	1.00	1.00	1.00	0.94	1.00	0.93	1.00	1.00	1.00	0.91	0.94
2013	0.93	0.83	0.93	0.89	0.99	0.93	0.87	0.93	0.86	0.93	0.96	1.00	0.82	0.87
2012	0.86	0.75	0.85	0.80	0.95	0.86	0.80	0.86	0.79	0.86	0.88	1.00	0.73	0.80
2011	0.79	0.67	0.78	0.70	0.86	0.79	0.73	0.79	0.71	0.79	0.81	1.00	0.64	0.74
2010	0.72	0.58	0.72	0.59	0.78	0.71	0.67	0.72	0.64	0.72	0.73	1.00	0.55	0.67
2009	0.65	0.50	0.64	0.50	0.69	0.64	0.60	0.65	0.57	0.64	0.65	0.89	0.46	0.60
2008	0.57	0.42	0.57	0.41	0.61	0.57	0.53	0.58	0.50	0.57	0.58	0.80	0.37	0.53
2007	0.50	0.33	0.50	0.30	0.52	0.50	0.47	0.51	0.43	0.50	0.50	0.70	0.28	0.47
2006	0.43	0.25	0.43	0.20	0.43	0.43	0.40	0.44	0.36	0.43	0.42	0.60	0.18	0.40
2005	0.35	0.17	0.35	0.11	0.34	0.36	0.33	0.37	0.29	0.36	0.35	0.50	0.09	0.33
2004	0.28	0.08	0.28	0.00	0.26	0.29	0.26	0.30	0.22	0.29	0.27	0.40	0.00	0.27
2003	0.21	0.00	0.22	0.65	0.17	0.21	0.20	0.21	0.14	0.21	0.23	0.30	0.00	0.20
2002	0.14	0.00	0.14	0.61	0.09	0.14	0.13	0.14	0.07	0.14	0.15	0.20	0.00	0.14
2001	0.07	0.00	0.07	0.57	0.00	0.07	0.06	0.07	0.00	0.07	0.08	0.10	0.00	0.07
2000	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.00	0.39	0.23	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.42	0.20	0.15	0.04	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
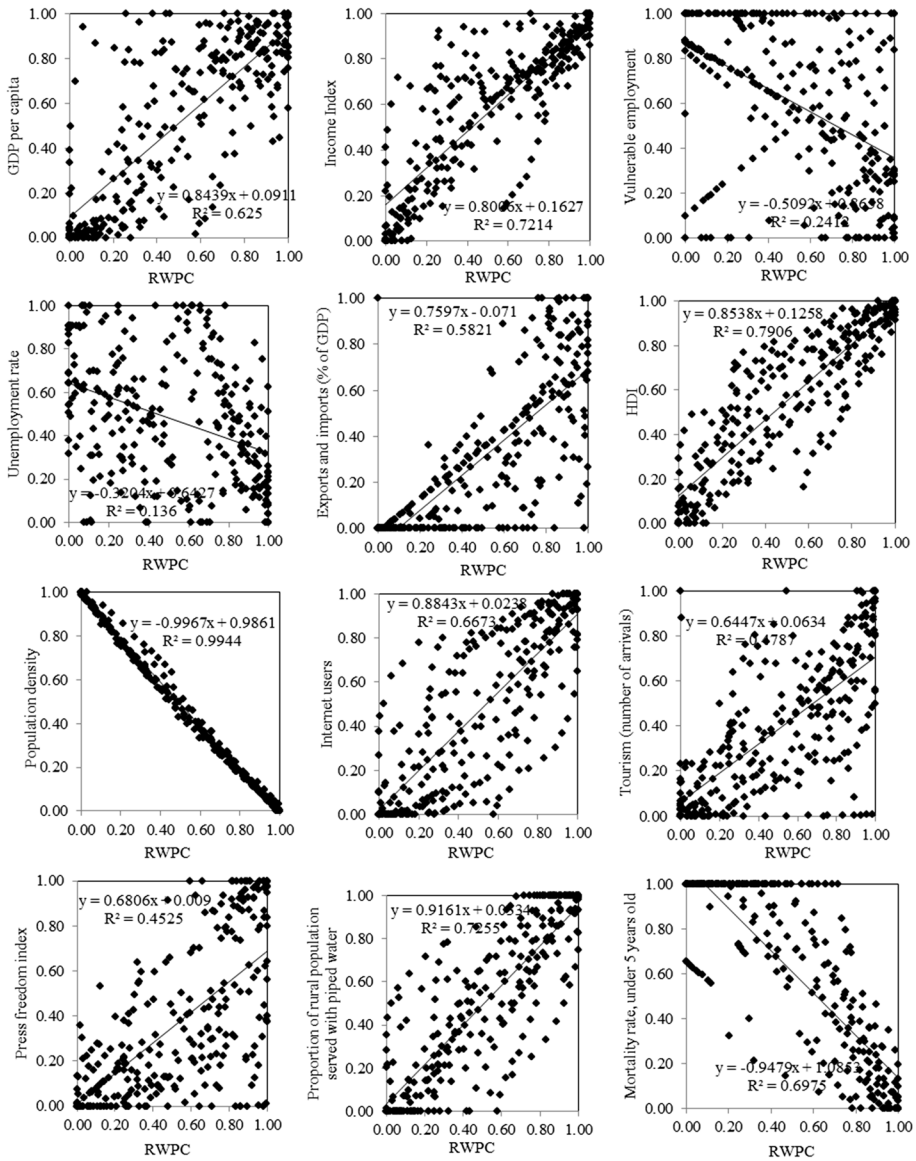
Fig. 12 Correlation of socio-economic and RWPC parameters

Fig. 13 Convergence curve of the GEP models
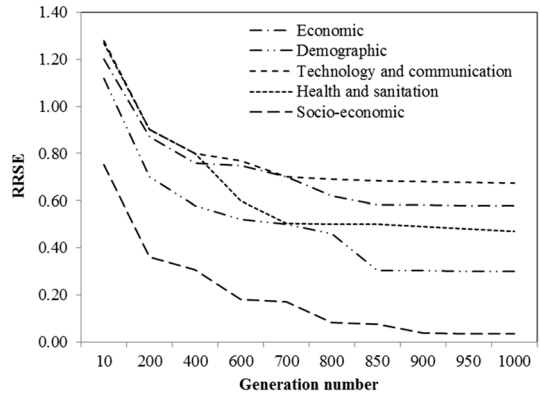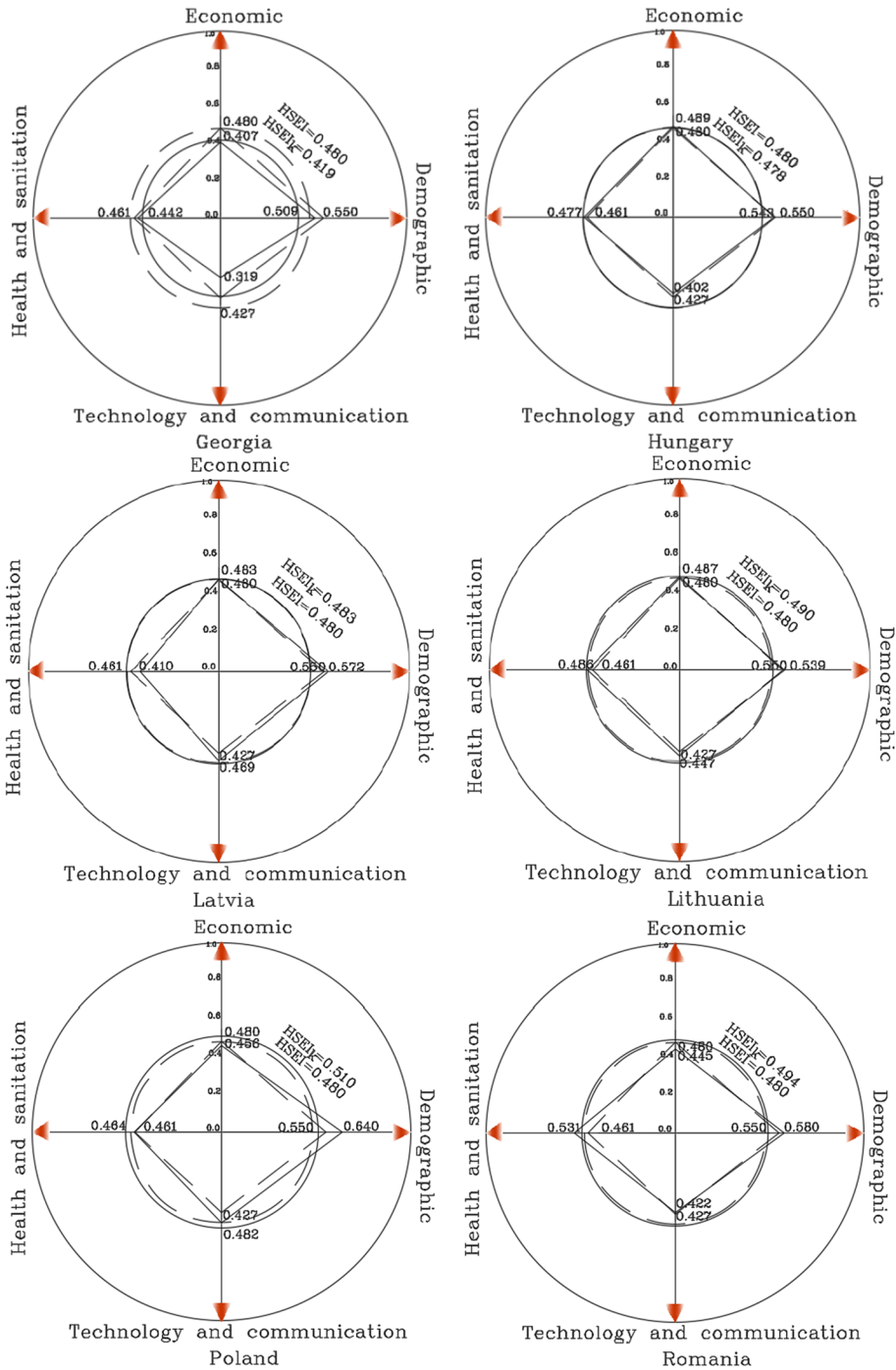
Fig. 14 Values of HSEI in European continent with different aspects by country using the single linear (SL) method
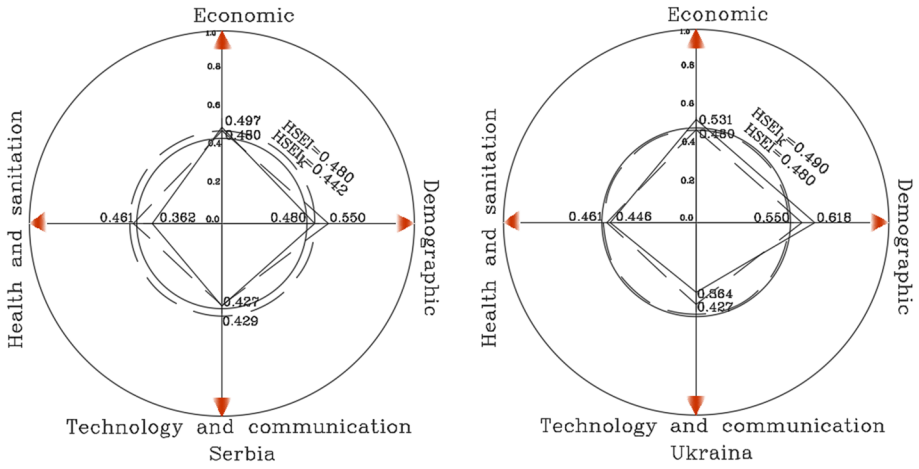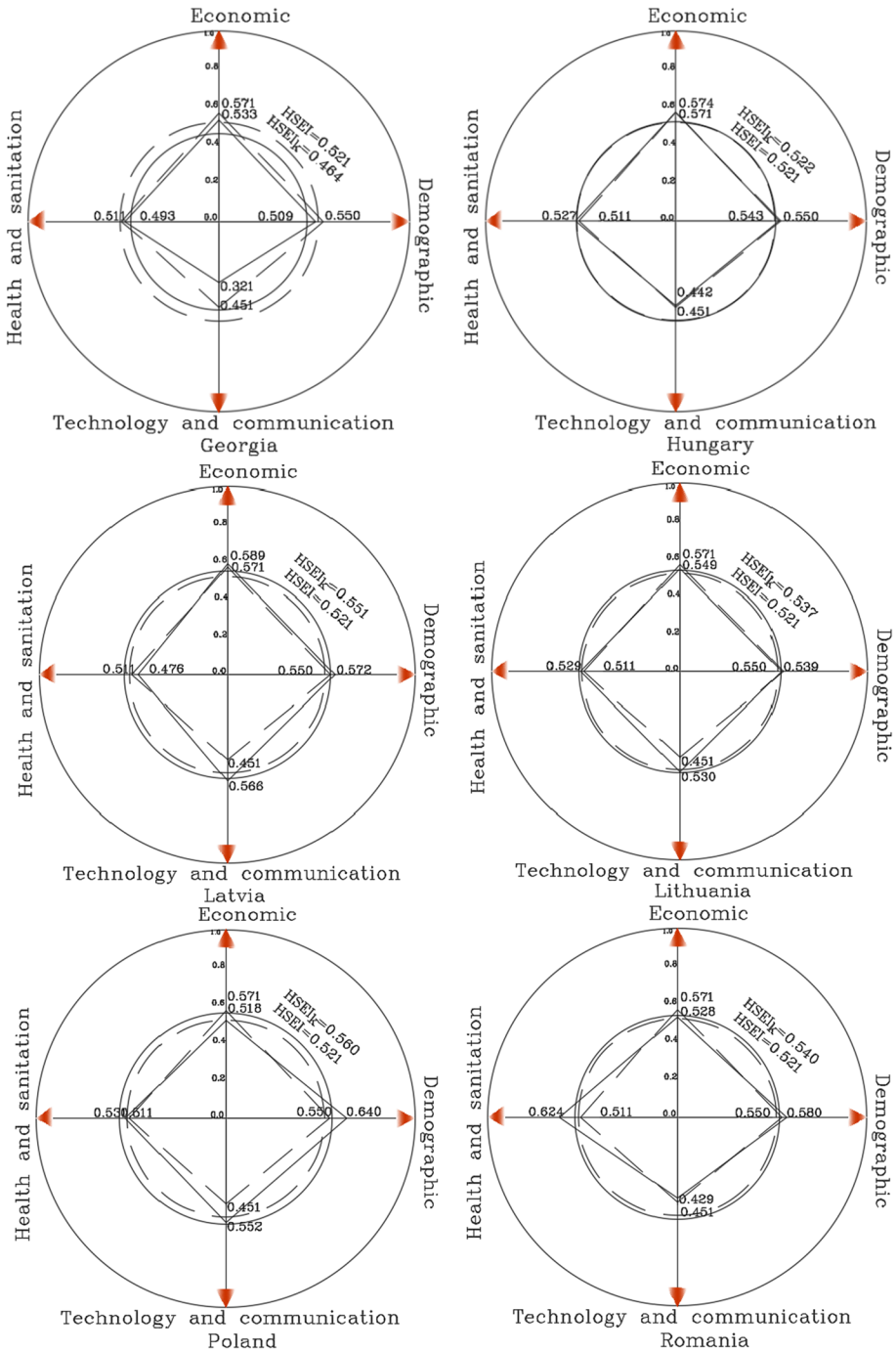
Fig. 14 (continued)

Fig. 15 Values of HSEI in European continent with different aspects by country using the combined soft computing (CSC) method
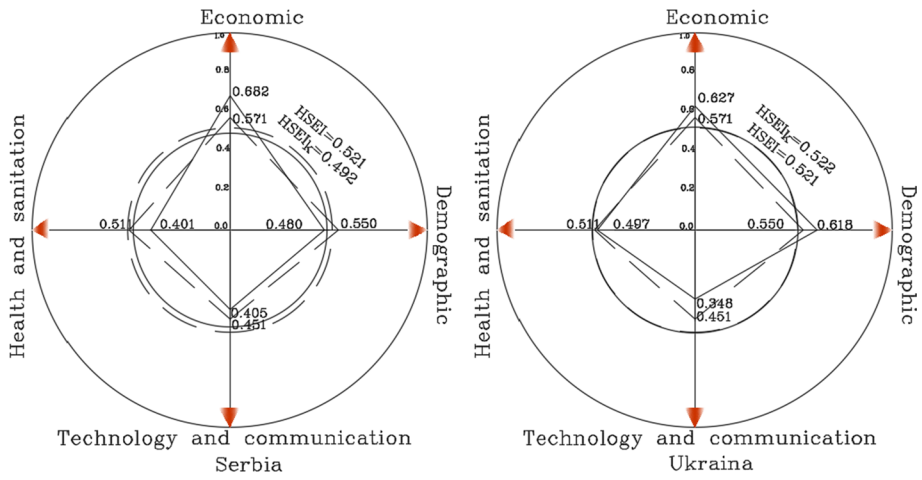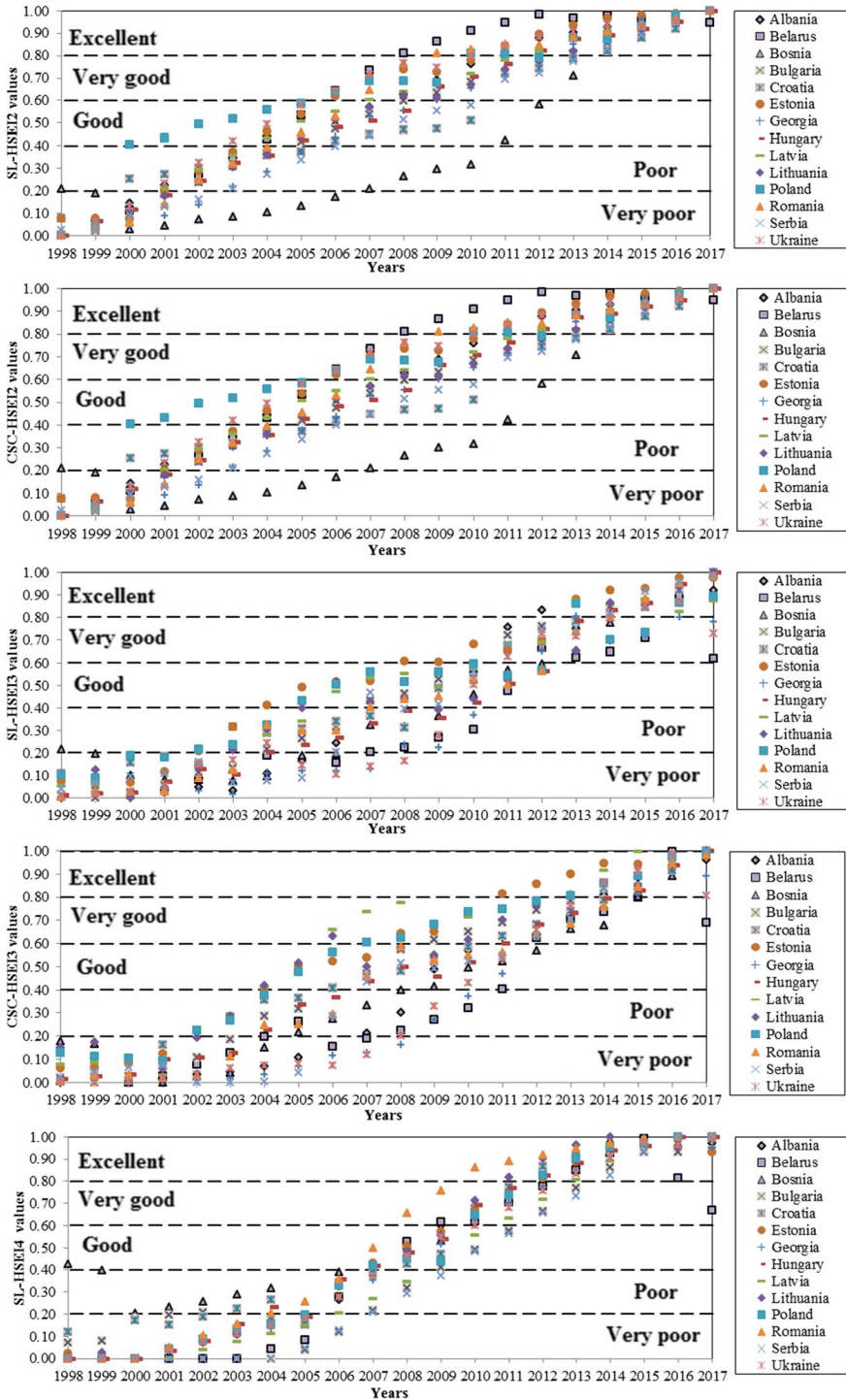
Fig. 15 (continued)

Fig. 16 HSEI value of demographic, technology and communication, and health and sanitation aspects and annual scale by country, using SL and CSC methods
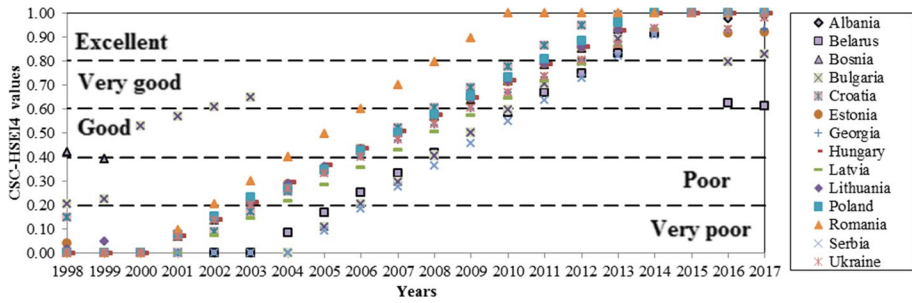
Fig. 16 (continued)

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