Water resources sustainability model for wetland conservation based on anonymous expert elicitation

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Abstract

Wetlands play a key role in preserving biodiversity and preventing climate change. Their conservation poses an important and pressing challenge. In the Mediterranean region, one of the key threats to wetland survival is the lack of water due to competition for resources. The selection of the most sustainable water resources for wetland conservation is a complex elicitation problem. A novel Water Resources Sustainability Model (WRSM) focused on water quality has been developed to support the decision-making. This collaborative elicitation model is based on the analytical hierarchy process and uses the reference environmental status of the wetland. The model can be used to discriminate which water resources are more sustainable for the conservation of the wetland. The WRSM has been applied successfully to Las Tablas de Daimiel National Park. The framework enables establishing priorities when analyzing in terms of water quality any surface, recycled or underground water resources.

Keywords: sustainability model; wetlands conservation; hydrological restoration; physico-chemical indicators; expert elicitation

1. Introduction

On the World Water Day 2018, the Director-General of UNESCO, Ms Audrey Azoulay called for urgent solutions to be found to protect Earth's natural resources. Wetlands conservation was among the list of solutions proposed to address contemporary water management challenges in an effective and sustainable manner, improving the well-being of individuals and preserving biodiversity resources (UN-Water, 2018). Unfortunately, 50 % of the world wetland surface disappeared in the 20th century (Millennium Ecosystem Assessment, 2005). Consequently, protecting and restoring wetlands has become not only a critical policy, but an urgent issue as well (Alafifi and Rosenberg, 2020). Among the UN Sustainable Development Goals (UN, 2015), Target 15.1 is to ensure the conservation, restoration, and sustainable use of wetlands. Resilience forecasting and modelling are required to achieve this target for wetlands (Hess and Dam, 2019; O'Neil et al., 2020). When wetlands resilience is overcome, its restoration implies supplying water from external sources (Tooth, 2018). For this purpose, water is often provided by nearby reservoirs, aquifers, wastewater recycling plants and inter-basin water transfers (Xu et al., 2018). For any of the available alternatives, water allocation must ensure that wetlands water requirements are fulfilled. Physico-chemical water quality is among the most important factors for the selection and allocation of water resources (Wang et al., 2017). There are several physico-chemical parameters that must be considered when evaluating wetlands water inflow (Sagar et al., 2015). Determining what source of water has the most adequate physico-chemical water quality features for wetland conservation poses a decision-making problem. A comparison is made between the reference environmental status for the wetland and the actual values for the water resources. Water resources recovery facilities could be built to remove and reuse excess nutrients, such as phosphorus, recovering them into fertilizers. The uncertainty about the benefits and conflicting goals among available water inflows presents a complex elicitation problem. Therefore, decisions should be undertaken based on a systematic and comprehensive procedure with enough consensus and transparency to avoid lack of acceptance (Canto-Perello et al., 2017; Curiel-Esparza et al., 2019). This becomes an issue of more concern if the wetland is under water stress due to overexploitation of water resources and climate change (Sapriza-Azuri et al. 2015; Lefebvre et al, 2019).

A novel collaborative elicitation model based on Analytical Hierarchy Process (AHP) to evaluate physico-chemical indicators has been developed in this research. The AHP (Saaty, 1980) is a universally recognized mathematical method in continuous development and has been used in numerous environmental applications. The AHP method is based on paired comparison judgments from a panel of experts through a hierarchical structure of several levels (Saaty, 2012). The panelists have interacted by anonymous feedback. The collaborative elicitation model needs to provide detailed information and practical guidelines to select the most sustainable water resources. AHP has been successfully applied to other decision-making procedures in water and environmental management. Zhang (2013) analyzed the importance of different factors affecting the stability of the wetland ecosystem for the Yinchuan Plain. Yuan et al. (2014) ranked the indicators weights in the assessment of wetland coastal ecosystems for the Yangtze Estuary. Martinez-Martinez et al. (2015) studied the environmental benefits and economic cost of wetland restoration scenarios for sediment reduction in the Raisin River, in the southeastern of Michigan and northeastern of Ohio. Zhang (2016) performed the evaluation of water requirements based on regionalization and prioritization methods in China´s western Jilin Province. Sutadian (2017) prioritized the water quality criteria for the West Java Province. Singh et al. (2018) assigned weights in a model-based assessment of suitability of water quality for irrigation purpose in India. And Sun et al. (2019) assessed the ecosystem health of the Jiaozhou Bay wetland using weights for each environmental indicator.

The proposed elicitation is applied to the Las Tablas de Daimiel National Park (TDNP), a wetland that needs hydrological restoration. TDNP is the core area of La Mancha Húmeda, a 25,000 hectares region in central Spain designated Biosphere Reserve by the UNESCO in 1980. The presence of a great number of wetlands and lagoons was a key enabler for this status. TDNP is a floodplain wetland at the junction of the Guadiana River and its Cigüela tributary (Fig. 1). The floodable area covers approximately 1,900 hectares. The TDNP is in the Mountreux Data Base since 1990 (Mountreux Record, 1990). This list of wetlands of international importance highlights specific cases facing immediate challenges threatening their biodiversity. Moreover, TDNP is contributing to the mitigation of climate change through its ability for carbon sequestration as a peatland. Spain signed the Paris Agreement on Climate Change (UN, 2015) stating that the parties in the agreement should take actions to conserve and enhance sinks of greenhouse gases.

The greatest threat to the continued existence and preservation of this wetland is the lack of water, which is caused by unsustainable agriculture that has led the groundwater to stop flowing to the wetland. TDNP is a good example of a highly sensitive wetland in a Mediterranean semiarid region, which is linked to groundwater system. This wetland has experienced a degradation process due to water scarcity and inappropriate management (Aguilera et. al., 2016). In the 1980s, the Guadiana River dried up because of the overexploitation of the western Mancha karstic aquifers. Since then, only the Cigüela River is providing water to the wetland. The soils are rich in carbon and can self-ignite by self-heating because of its propensity to smouldering (Restuccia et al., 2017). In 2004 the wetland dried up, and this situation persisted until 2009, when a peat fire broke out in August during a very hot summer after a long period of drought (Moreno et al., 2011). The lack of water from Cigüela River and the disconnection of the wetland with the groundwater resources caused the situation described above. In addition, TDNP is severely affected by desertification. The Mediterranean region is a well-known global desertification hotspot. Within this area, Spain is by far the European country most threatened by the desertification process (Prăvăliea et al., 2017). An objective of the United Nation Convention to Combat Desertification (UNCCD, 1994) is the rehabilitation, conservation and sustainable management of land and water resources. Spain as a subscriber of this convention is bound to mitigate the effects of drought and allocate adequate resources in a sustainable manner. Biodiversity and key ecosystem services should be protected. For the region the external water supply is an imperative need for the survival of the wetland. Therefore, a minimum content of water in the park soil must be guaranteed to prevent the peat from smouldering again and avoid desertification. Aguilera & Moreno (2018) have identified organic carbon content as key controlling factor for smouldering peat fires in the TDNP area. Identifying the most relevant water resources for sustainability is the main goal of this research. As shown in Table 1, the water resources assessed in this study and located in the vicinity of the TDNP pertain to four different categories: reservoirs, interbasin water transfers, pumping wells and wastewater recycling plants (Fig. 2).

In this paper, the water resources allocation elicitation problem for the hydrological restoration of a wetland is addressed by defining a Wetland Resources Sustainability Model (WRSM). The goal is to find the most adequate water source from the point of view of the wetland sustainability. This WRSM will help to prioritize the various available water sources in five consecutive steps. First, most relevant physico-chemical indicators are selected. Secondly, their relative importance is determined. To that end, weights are assigned to the indicators by collaborative elicitation based on AHP to evaluate the wetland water inflow quality. Thirdly, indicator rating functions are formulated using national and international guidelines assessed by the panel of experts. Rating curves are constructed as trapezoidal linear functions. The closer are the physico-chemical parameters of the water resources to the reference environmental status in the wetland, the higher are their ratings. Fourthly, for each water source, the average of physico-chemical indicator rating is calculated. Finally, the best water allocation for the hydrological restoration of the wetland under water stress is identified (Lefebvre et al, 2019).

2. Methodology

2.1. Data elicitation from experts

The proposed elicitation model is based on a hybrid procedure constructed by applying consecutively AHP and rating curves (Fig. 3). There is consensus in the literature that the optimum number of experts per panel should be between eight and twelve panelists (Okoli and Pawlowski, 2004; Novakowski and Wellar, 2008; Alvarez et al., 2015). A panel of ten environmental experts, civil engineers and water authority officers has been gathered to undertake the elicitation procedure. The panelists have all recognized competence, worked on or studied issues related with the wetland under study. Firstly, an anonymous open-ended survey is sent to the panel of experts, requesting them to propose a list of physico-chemical water parameters and potential water resources for the restoration of the wetland (Norouzian-Maleki et al., 2015). The indicators are the physico-chemical parameters in the AHP hierarchy framework as shown in the workflow diagram (Fig. 4). There is an anonymous feedback to achieve consensus by resending these data to the panel of expert to reconsider their judgments (Martin-Utrillas et al., 2015). This feedback is used to develop consensus on the indicators and alternatives proposed (Canto-Perello et al., 2018). Indicators and water resources agreed by the panelists as being of low importance are removed, after reaching agreement between the experts (Curiel-Esparza et al., 2015). The indicators and the alternatives make up the AHP decision hierarchy framework. The survey and data collection lasted four months, while processing them and reaching consensus took just two months. The elicitation for the wetland under study has provided the following nine physico-chemical parameters:

- Temperature (TPT): Aquatic organisms are sensitive to temperature. Dallas and Ross-Gillispie (2015) studied sublethal effects of temperature on aquatic organisms and an optimum thermal regime. When incoming water temperature is inadequate, aquatic life is adversely affected. The limit for the temperature difference between the water inflow and the wetland water has been determined to be four degrees Celsius (Rivers-Moore et al, 2013).
- pH (PHH): The acidity has an important effect on natural waters chemistry and on aquatic life. The toxicity of many substances like copper, ammonia, aluminum, or

nutrients depends on the concentration of hydrogen ions (Brandt et al., 2017). These effects can be worsened in wetlands, for example phosphorous could be released from sediments when pH increases in anoxic environments (Gu et al., 2019).

- Dissolved Oxygen (DOO): The concentration of dissolved oxygen in water is essential to evaluate the overall quality and the health of water bodies (Feld et al., 2014). The level of this parameter must be high enough to guarantee the well-being of aquatic life. Treated wastewater provides nutrients along with a deficit of dissolved oxygen and may pose a risk of eutrophication for receiving water bodies (Nagisetty et al., 2019).
- Electrical Conductivity (ECN): Water conducts electricity only if contains dissolved ionic solids. The conductivity increases as the ionic solids content of the water rises. This parameter is considered as a crude indicator of water quality (Kumar and Sinha, 2010). ECN provides information on the total ionic strength, and salinity of water as it is related to the total dissolved solids content (Rusydi, A.F., 2017). These factors are decisive for the survival of many wetlands that are threatened by salinization changes and hydrological alterations.
- Total Suspended Solids (TSS): Excessive amounts of suspended solids could lead to the ecological degradation of the aquatic environment. Suspended solids can diminish light penetration, cause temperature changes, infill reservoirs, and have undesirable aesthetics effects (Bilotta et al., 2012). Phytoplankton, macrophytes, aquatic invertebrates and fish are affected by suspended solids concentration (Bilotta and Brazier, 2008). Wetlands remove suspended solids from water by different mechanisms like sedimentation, interception, flocculation, filtration, and bacterial decomposition (Koskiaho and Puustinen, 2019).
- Biological Oxygen Demand (BOD): This indicator has been included among the physicochemical parameters because BOD affects the evolution of dissolved oxygen. BOD is closely related to the chemical oxygen demand, and correlations can be established with other physicochemical parameters such as pH, NH_3, and temperature (Man et al., 2019). Additionally, BOD provides information on the organic matter content of water. Large amounts of organic matter in the water can cause oxygen depletion and anoxic conditions which severely affect aquatic biota. (Feld et al., 2014). BOD is also considered an indicator of pollution (Li and Liu, 2018).
- Nitrates (NTT): An excess of nitrate in water is harmful to aquatic life (Pottinger, 2017; Camargo et al., 2006). Air pollution, agricultural nitrogen fertilizers and wastewater effluents are some examples of how human activities can increase nitrogen levels in

water bodies. Wetlands can withstand higher levels of dissolved nitrate, as they behave as nitrogen sinks by recycling and eliminating the excess of this nutrient (Mayo et Muraza, 2018). However, the consequences of nitrogen water pollution can also be an overgrowth of algae, eutrophication, hypoxia, and other undesirable effects that can deteriorate aquatic habitats and ecosystems (Haas et al., 2017).

- Total Phosphorous (TPH): The cycle of phosphorus in wetlands consist of physical, chemical, and biological processes in an equilibrium among plants, water, and soil (Caen et al., 2019; Juston and Kadlec, 2019). An excess of phosphorus can lead to eutrophication and the reduction of the ecological status because of plant and algal overgrowth (Blaas and Kroeze, 2016). Fertilizers, sewage discharges and urban runoff are main phosphorus sources. Climate change also contributes to increase the eutrophication risk, because higher temperatures and decreased summer flows are expected (Sperotto et al., 2019).
- Un-Ionized Amonia (UIA): This indicator evaluates the concentration in water of the most toxic inorganic nitrogenous compound. If the concentration of ammonia exceeds the lethal threshold, the entire aquatic ecosystem could be damaged or endangered (Liu et al., 2019). Wetlands can withstand higher concentrations of ammonia compared with other water bodies, removing large amounts of UIA under appropriate aerobic conditions (Lin-Lan et al., 2019).

2.2. AHP procedure

The AHP method prioritizes the different physico-chemical indicators to determine the relative importance of every one of them. The strength of this process is that it organizes indicators in a systematic way and provides a structured yet relatively affordable procedure to the prioritization of water resources. The AHP method is based on a pairwise comparison technique to reduce the complexity of the decision making, since only two indicators are compared simultaneously. This pairwise comparison procedure is developed in three steps: elaborating a elicitation matrix, computing the priorities for each indicator and analyzing the consistency. In the AHP method, elicitation matrices are constructed using multiplicative priority relations to express the decision makers' preferences. Several methods can be used to aggregate the panel's judgements. This research applies the Aggregation of Individual Judgments (AIJ) using the geometric mean method (Dong et al., 2010). Treating the panel of experts as a new individual with AIJ requires satisfaction of the reciprocity condition for the elicitation (Curiel-Esparza et al., 2016). The 9-point Saaty's scale is applied to compute the physico-chemical indicator's priorities (Saaty, 2012). The aggregation yields a reciprocal symmetric n-by-n matrix $P = [p_{ij}]$, where $p_{ii} = 1$, since each element of the diagonal compares an indicator with itself, and $p_{ij} = 1/p_{ji}$, as reciprocals are placed in symmetrical positions. If the physico-chemical indicator i has a 1 to 9 point value in Saaty's scale assigned to it when compared with indicator j, then j has the reciprocal value when compared with i. Forman and Peniwati (1998) have shown that the geometric mean is the only method which preserves the reciprocally symmetric structure of the elicitation matrices and satisfies the unanimity condition (Pareto principle). If all panelists prefer indicator i to indicator j, then the panel of experts should prefer i to j. This elicitation applies the geometric mean method to aggregate individual physico-chemical priorities for n panelists $\left(p_{ij}^{(k)}\right)$ in order to obtain the collaborative elicitation matrix as follows in Equation (1):

$$p_{ij} = \prod_{k=1}^{n} \left(p_{ij}^{(k)}\right)^{1/n} \qquad (1)$$

The elicitation matrix $[P]$ is constructed as shown in Table 2. The most important indicators have the higher priorities, the weight increases with the importance of the indicator. The priority of each individual physico-chemical indicator is evaluated using the eigenvector method. The principal eigenvector of the elicitation matrix $[P]$ is the physico-chemical indicators priority vector $[IPV]$. To find IPV, the linear system $[P] \cdot [IPV] = \lambda \cdot [IPV]$ must be solved as follows in Equation (2):

$$det([P] - \lambda \cdot [I]) = 0 \qquad (2)$$

where λ are the elicitation matrix eigenvalues and $[I]$ is the identity matrix. Eigenvalues can be ranked from the greatest to the smallest according to their absolute value. Principal eigenvalue is the one with the greatest absolute value.

The panelists' priorities may contain bias and misinterpretation that could lead to inconsistencies in the elicitation procedure (Saaty, 1980). The AHP method allows the evaluation of the consistency of the elicitation matrix. To this end, a maximum consistency ratio (CR) must be guaranteed. The CR measures the degree of deviation from pure inconsistency. The CR is obtained by the ratio between the consistency index (CI) and the random consistency index (RCI) defined in Equation (3):

$$CR = CI/RCI \qquad (3)$$

The RCI is computed from a large number of simulation runs and depends upon the order of matrix, as shown in Table 3. Maximum CR, which should not be exceeded, for elicitation matrices with order upper than four is 0.10 to guarantee consistency. CI is computed using the maximum eigenvalue for the elicitation matrix $[P]$, as follows in Equation (4):

$$CI = \frac{\lambda_{max} - 1}{n-1} \quad (4)$$

where λ_{max} is the maximum eigenvalue of the elicitation matrix and n is the order of matrix. The RCI value depends on the order of the matrix (Saaty, 2012). As shown in Table 2, the consistency analysis of the results is within the tolerance range.

2.3. Rating curves for the physico-chemical indicators

The last step to address in the elicitation model for water allocation is to evaluate the quality of water resources, in order to determine which, one is the most sustainable to the hydrological conservation of the wetland. Hanh et al. (2011) and Singh et al. (2015) have successfully applied linear rating functions in water quality evaluation. In the WRSM model, the rating curves for each indicator are constructed using linear functions. These functions assign a rate for the water quality status between 0 and 1 to the physico-chemical parameters depending on their values in the water resources as depicted in Fig. 3. The proposed curves are based on the continuous rescaling method (Juwana et al., 2012; Tyagi et al., 2013).

The parameter rating functions are based on reference values and on permissible limits to preserve the good status of aquatic life in the wetland (Fig. 5). The functions used are piecewise linear membership functions. If the actual value of the parameter is between the minimum and maximum for the reference range, the index value is 1. As shown in Fig. 3, between permissible limits and reference range the index is obtained by linear interpolation. The reference values are representative for unaltered natural conditions. These values have been calculated by means of a statistical analysis of the historical data of the TDNP wetland (Cirujano et al., 1996; Sutadian et al., 2016). Assuming that the statistical distribution of the reference values is Gaussian (PHG, 2018). The maximum and minimum reference values are set at a distance of a standard deviation from the mean (CHG-CSIC, 2010). This criterion is stricter than considering the 25th percentile as the threshold reference value. (USEPA, 2000; Sánchez-Montoya et al., 2012). The permissible limits are threshold values, which should not be exceeded by physical-chemical parameters to protect aquatic life. Except for total phosphorus and electrical conductivity, all permissible limits of physicochemical parameters are established in accordance with international standards (IWQGES, 2016; EPA, 2019; EU Directive 2006/44/EC, 2006). Phosphorus limits have been obtained from local studies, which are compiled and summarized in the Tablas de Daimiel Plan of Gradual Restoration (REGATA, 2010). Finally, the electrical conductivity permissible limits are estimated using the 25th percentile. As an example, sample rating pH (pH_{sr}) as function of water sample pH (pH_{samp}) can be written as is defined in Equation (5):

$$\begin{cases} pH_{min} \leq pH_{samp} \leq pH_{ref\ min} & pH_{sr} = \frac{pH_{samp} - pH_{min}}{pH_{ref\ min} - pH_{min}} \\ pH_{ref\ min} \leq pH_{samp} \leq pH_{ref\ max} & 1 \\ pH_{ref\ max} \leq pH_{samp} \leq pH_{max} & pH_{sr} = \frac{pH_{max} - pH_{samp}}{pH_{max} - pH_{ref\ max}} \end{cases} \qquad (5)$$

Finally, the wetland resources sustainability index is obtained from Equation (6):

$$WRSM = \sum_i W_i \cdot RF_i \qquad (6)$$

where W_i are the physico-chemical parameters weights obtained applying AHP, and RF_i are the output of the rating functions evaluated for the physico-chemical parameter i.

The evaluation of WRSM for the different water resources under study is shown in the workflow diagram of Fig. 6, and the results in Table 4.

3. Results

In general, the best WRSM ratings correspond to reservoirs, as shown in Table 4. These values vary from 0.9415 for the PVAR reservoir to 0.8307 for the VICR reservoir. Water from the Tagus-Segura interbasin transfer is stored in reservoirs and is conveyed by a canal first and a pipeline secondly to the TDNP (Lobanova et al., 2017). In consequence, the characteristics of this water are like those of superficial waters. The WRSM rating of the TASE water transfer is 0.9237, which is consistent with the range of values recorded in the reservoirs. Groundwater shows clearly lower WRSM ratings than surface water. Additionally, three of the five pumping well areas have been considered not acceptable due to their high content of dissolved nitrates. Pollution caused by agricultural activity is a non-sustainable problem in most aquifers of the area under study (Perez-Martin et al., 2016). Only the VILW and FUFW pumping well areas are considered acceptable. Their WRSM ratings are 0.7364 and 0.5961, respectively. This last value is the lowest acceptable water resource. Finally, many wastewater recycling plants are considered non-acceptable as water resources because the limits of organic matter and nutrient content are exceeded. Only two water recycling plants of the five under study have all the indicators within the acceptable rating.

The preferred water source for TDNP hydrological restoration is the PVAR reservoir, followed by the PARR reservoir (0.9272), the TASE water transfer and the GASR reservoir (0.9195). Among the reservoirs, VICR is the one with the lowest WRSM rating due to its high values of TSS, BOD and TPH. Groundwater WRSM show a low degree of sustainability. The best rated pumping well area (VILW) has a WRSM rating of 0.7364, significantly lower than reservoir ratings. DAIW, CDEW and CIRW are considered non-acceptable due to their high nitrate content. FUFW is considered as an acceptable water resource, but its WRSM rating of 0.5961 is the worst among all sources. Wastewater recycling plants are classified as the least sustainable water resources. Only two plants of the five under study have all the indicator within the acceptable ratings. VIRP is the best rated wastewater recycling plant (0.6780), but it is not much better than MARP (0.6027), the only other wastewater recycling plant considered acceptable. The MARP and VIRP wastewater recycling plants have been improved and expanded in recent years, becoming acceptable water sources (Sanchez-Ramos et al., 2016), although their WRSM ratings are still low when compared to other resources. The acceptable limits are exceeded in three recycling plants. DARP and ALRP wastewater recycling plants record high values of BOD while the FURP recycling plant has high levels of phosphorus. The non-acceptable recycled wastewater plants would have to be expanded by implementing additional treatments to allow the reuse of their effluents for the restoration of the TDNP. In conclusion, the most sustainable water resources for the restoration of the TDNP are reservoirs and the Tagus-Segura aquaduct. All resources of surface water are acceptable and are by far the best ones. There is a remarkable variability in the groundwater and recycling plant resources. The use of the proposed WRSM makes possible to establish a clear preference for any surface, recycled or groundwater resource.

4. Discussion and conclusions

The proposed collaborative elicitation model has been successfully applied to the Tablas de Daimiel National Park wetland. Four categories of possible water resources for the hydrological restoration of TDNP are evaluated in this research: reservoirs, interbasin water transfer, groundwater, and recycled water. To prioritize these heterogeneous water resources from the point of view of sustainability, the novel WRSM has been developed and applied. This model rates each of the proposed water resources under nine physico-chemical indicators. When compared to other methods, the WRSM advantage is it that allows assigning a score to new water resources without repeating the complete elicitation process each time a decision needs to be made. Once the values of the physicochemical parameters are known for any water resource, the water resource can be ranked immediately by performing the WRSM model. Other elicitation procedures involve long and sometimes complex techniques that must be revaluated each time a decision has to be made. In addition, there is no limit on the number of water resources under study in the WRSM decision-making process. WRSM compares the parameters of water resources with the sustainable status of the TDNP wetland. When the conservation and restoration of the wetland requires supplying water from external sources, the sustainability criterion is achieved if the indicators of the water inflow are as close as possible to the original water in the wetland in its sustainable state. In that case, the WRSM rating tends to 1. Water indicators are quite different depending on their origin and the stage of the hydrologic cycle considered. Reservoirs store surface water in the runoff step of the hydrologic cycle. Consequently, surface water is less mineralized than groundwater because the renewal periods of reservoirs are shorter than those of aquifers (Ajami, 2020). Another important aspect is that groundwater is found inside the pores and fractures of the rocks, in prolonged contact with minerals (Zhang et al., 2020). Furthermore, because of the differences in the geology of the pumping well areas there is a high variability in the characteristics of groundwater (Mejias-Moreno et al., 2012). Hydrogeological features like permeability, recharge and discharge zones and water budget of the aquifer have an impact in the indicators (Viaroli et al, 2020). Moreover, anthropogenic activities can cause a long-lasting contamination of groundwater. Long-term cumulative effects of pollution are more likely in groundwater than in surface water because residence times of pollutants could be decades (Zektser and Everett, 2004). This is the case of dissolved nitrate, which show records with high values in groundwater due to the cumulative effect of diffuse pollution from fertilizers used in agricultural activity (Kløve et al., 2011). The indicators of the recycled water depend on the constituents added to the water supply through use, and the efficiency of the treatment applied in the recycling process. Consequently, there is great variability in these water resources (Navarro et al., 2011). The treatment process must be expanded and improved before the effluent can be reused in the TDNP (Sánchez-Ramos et al., 2011). Excess phosphorus, nitrogen and organic matter are serious problems detected in recycled waters. Most water recycling plants in the area under study cannot be used as a water resource for the wetland. Political and economic considerations could actually reject the transfer of water from any of the resources under study. However, this model focused on physico-chemical indicators is open to evaluate any possible alternative. The political and economic framework should be considered when selecting any water resource from the WRSM model results. The added value of the WRSM model is to systematize and clarify the collaborative elicitation process in the selection of water resources.

The Paris climate change agreement outlined the role wetlands play as the most powerful carbon sinks. Their loss is inadmissible in a world under alarming environmental threats. Consequently, wetlands conservation has become a very high priority goal in preventing and combating climate change. The hydrological restoration of wetlands most often involves the reallocation of water resources. The key criterion must be sustainability to guarantee the well-being of the ecosystem. The environmental indicators of wetlands should be kept as close as possible to their sustainable state. Developing decision support systems and elicitation techniques contributes to the sustainable allocation of water resources. The elicitation model should guarantee traceability and transparency in achieving consensus among the panelists. The variability of water indicators and their different impact requires a systematic method of elicitation. In this research, a novel water resources sustainability model based on environmental indicators has been developed for wetlands conservation.

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Table 1. Water resources under study

Water resource	Description	Type	Distance (km)	Location
VICR	Vicario reservoir	Superficial Water	22.08	39° 3' 32'' N 4° 0' 10'' W
GASR	Gasset reservoir	Superficial Water	27.12	39° 7’ 43.60'' N 3° 56' 15.30'' W
TOAR	Torre de Abraham reservoir	Superficial Water	61.47	39° 24' 20'' N 4° 15' 0.50'' W
PVAR	Puerto de Vallehermoso reservoir	Superficial Water	58.56	38° 52' 20'' N 3° 10' 00'' W
PARR	Peñarroya reservoir	Superficial Water	85.35	38° 3' 40'' N 3° 16' 30'' W
TASE	Tagus-Segura interbasin water transfer	Superficial Water	165.42	39° 58' 35.62'' N 2° 44' 11.69'' W
VILW	Villarrubia pumping wells area	Groundwater	6.19	39° 13' 51.10'' N 3° 36' 55.77'' W
DAIW	Daimiel Casas Pico pumping wells area	Groundwater	23.41	39° 6.49' 0.79'' N 3° 34.30' 0.60'' W
FUFW	Fuente Fresno pumping wells area	Groundwater	16.12	39° 14.20' 11 ’’ N 3° 47' 26.30'' W
CDEW	Casas Encinas pumping wells area	Groundwater	25.35	39° 5´ 36.37'' N 3° 39' 9.42'' W
CIRW	Ciudad Real pumping wells area	Groundwater	10.92	39° 4.54 ' 33 '' N 3° 54 ' 19.76'' W
POBW	Poblete pumping wells area	Groundwater	33.36	38° 56' 12.33'' N 3° 58' 8.11'' W
DARP	Daimiel recycling plant	Treated wastewater	10.87	39° 6’ 0.20'' N 3° 37' 18.10'' W
MARP	Manzanares wastewater recycling plant	Treated wastewater	35.47	39° 0' 15'' N 3° 24' 01''W
FURP	Fuente Fresno wastewater recycling plant	Treated wastewater	17.58	39° 12' 11.50'' N 3° 46' 18''W
VIRP	Villarrubia wastewater recycling plant	Treated wastewater	12.85	39° 12' 11.50'' N 3° 13' 50.31'' W

Table 2. Elicitation matrix constructed to compute the physico-chemical indicator's priorities and consistency analysis of the results

	PHH	TPT	ECN	TSS	UIA	DOO	TPH	NTT	BOD	Priority vector
PHH	1.00	3.26	3.05	2.32	3.58	0.32	0.85	1.13	1.12	0.1385
TPT	0.31	1.00	0.97	0.52	0.75	0.26	0.38	0.50	0.34	0.0474
ECN	0.33	1.03	1.00	0.87	1.53	0.41	0.45	0.48	0.48	0.0615
TSS	0.43	1.91	1.15	1.00	1.60	0.33	0.48	0.77	0.42	0.0707
UIA	0.28	1.34	0.65	0.63	1.00	0.23	0.25	0.29	0.30	0.0428
DOO	3.15	3.87	2.46	3.01	4.34	1.00	1.96	2.17	1.97	0.2396
TPH	1.18	2.62	2.21	2.08	4.04	0.51	1.00	1.89	1.27	0.1511
NTT	0.89	2.02	2.08	1.30	3.44	0.46	0.53	1.00	0.61	0.1048
BOD	0.90	2.98	2.07	2.36	3.36	0.79	0.79	1.64	1.00	0.1436

λ_{max} = 2.2144 CI = 0.0304 CR = 0.0209

Table 3. Random consistency index for different order of the elicitation matrix (Saaty, 2012)

n	1	2	3	4	5	6	7	8	9	10
RCI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Table 4. Evaluation of WRSM for the seventeen water resources under study

Source of water	PHH	TPT	ECN	TSS	UIA	DOO	TPH	NTT	BOD	WRSM
VICR	1.0000	0.6257	1.0000	0.2813	1.0000	1.0000	0.6780	1.0000	0.6375	0.8307
GASR	1.0000	0.5543	0.2453	1.0000	0.6988	1.0000	1.0000	1.0000	1.0000	0.9195
TOAR	0.8948	0.3114	0.1238	0.8313	1.0000	1.0000	0.9375	1.0000	1.0000	0.8775
PVAR	1.0000	0.0314	0.9115	0.9000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9415
PARR	1.0000	0.3514	0.3172	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9272
TASE	1.0000	0.0500	0.4918	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9237
VILW	0.1701	0.9371	0.0983	1.0000	1.0000	0.6236	1.0000	1.0000	1.0000	0.7364
DAIW	Nitrate limit exceeded									
FUFW	0.4075	0.9371	0.1955	1.0000	1.0000	0.0000	1.0000	0.7152	1.0000	0.5961
CDEW	Nitrate limit exceeded									
CIRW	Nitrate limit exceeded									
POBW	Nitrate limit exceeded									
DARP	Biological oxygen demand exceeded									
MARP	0.6378	0.7543	1.0000	0.5910	0.0271	0.2041	0.7695	1.0000	0.7250	0.6027
FURP	Total phosphorous limit exceed									
VIRP	0.4252	0.7371	0.4540	0.9900	1.0000	0.4082	0.7627	1.0000	0.8750	0.6780
ALRP	Biological oxygen demand exceeded									

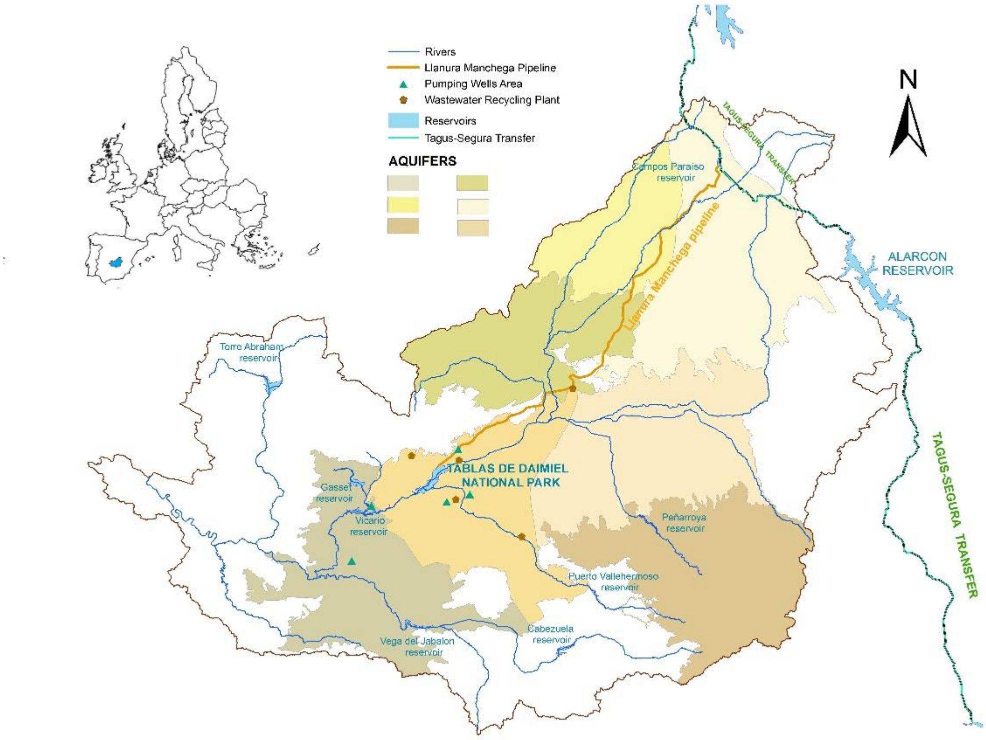

Fig. 1. Las Tablas de Daimiel National Park wetland is the core area of La Mancha Húmeda in central Spain

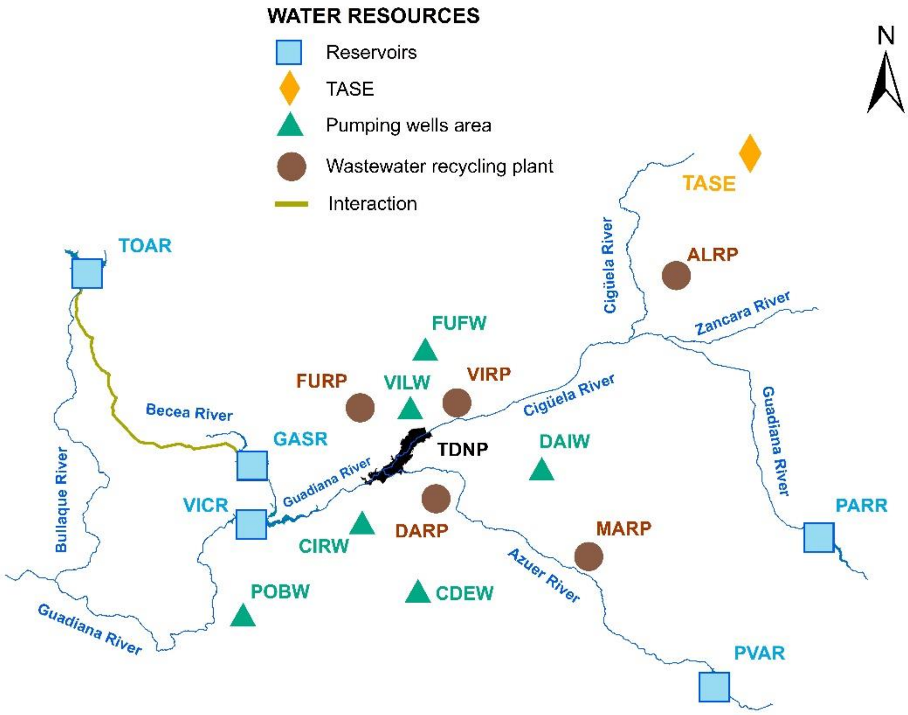

Fig. 2. The water resources assessed pertain to four different categories: reservoirs, interbasin water transfers, pumping wells and wastewater recycling plants

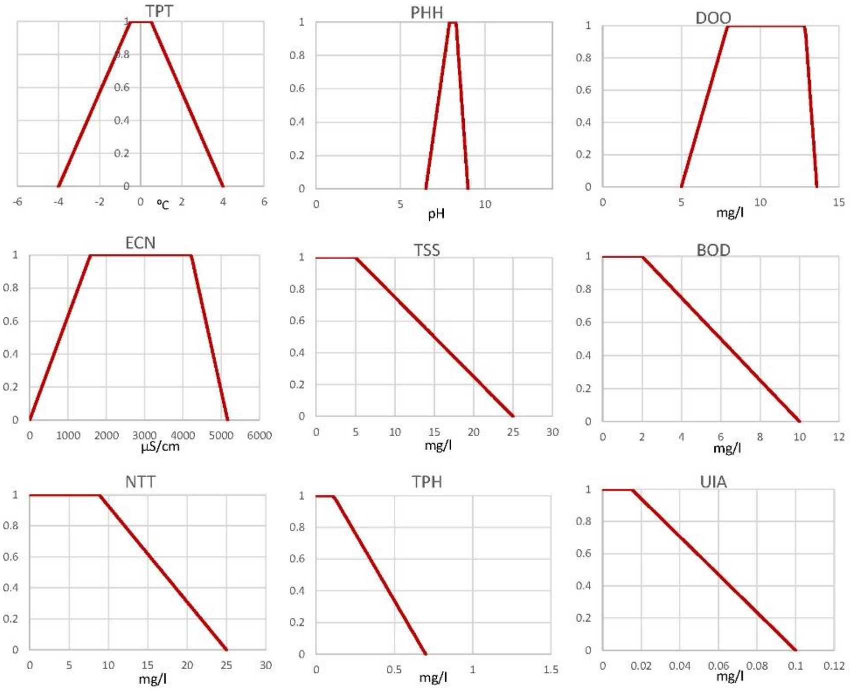

Fig. 3. Rating curves for each indicator constructed by linear functions

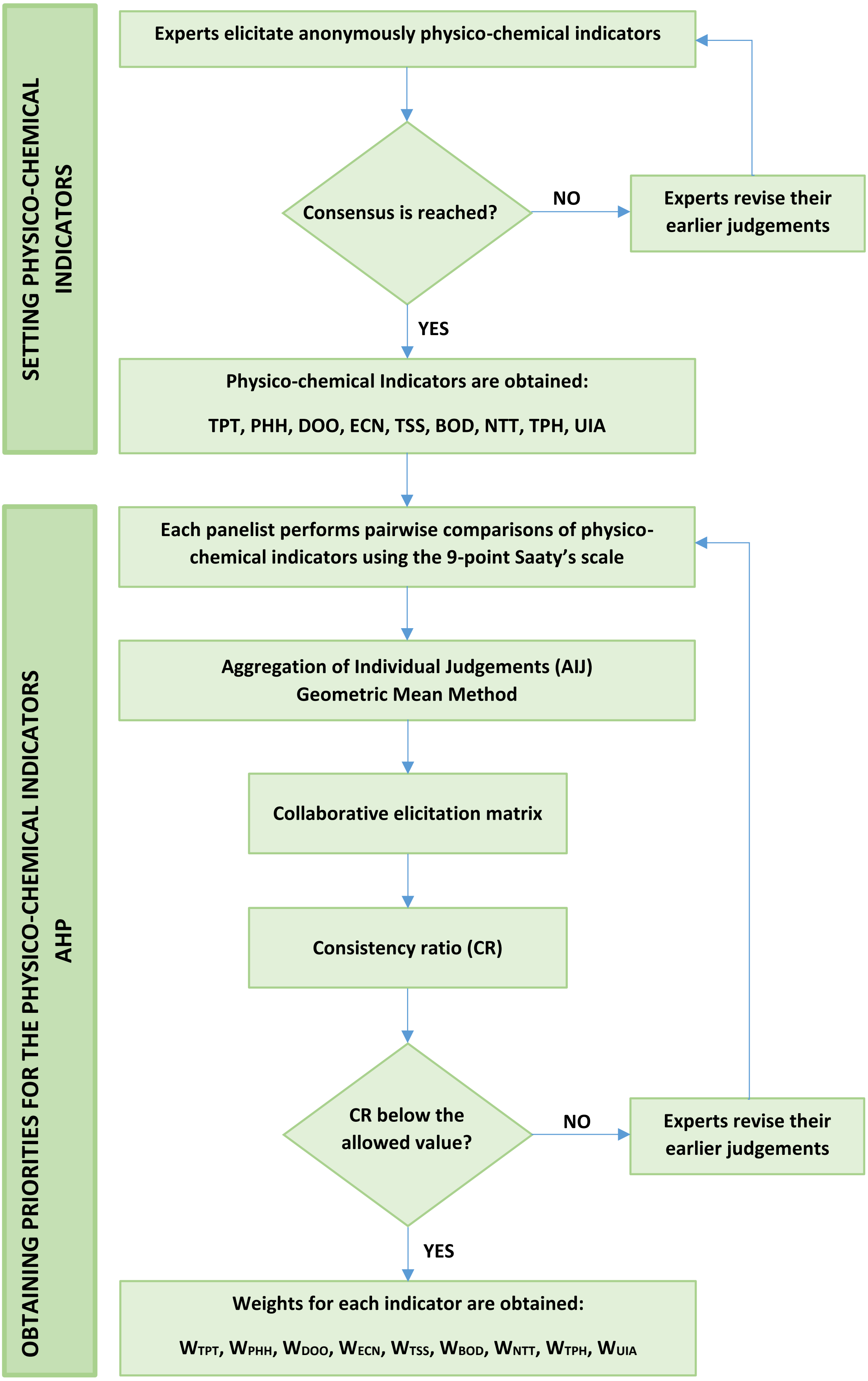

Fig. 4. Setting physico-chemical indicators and obtaining priorities using AHP

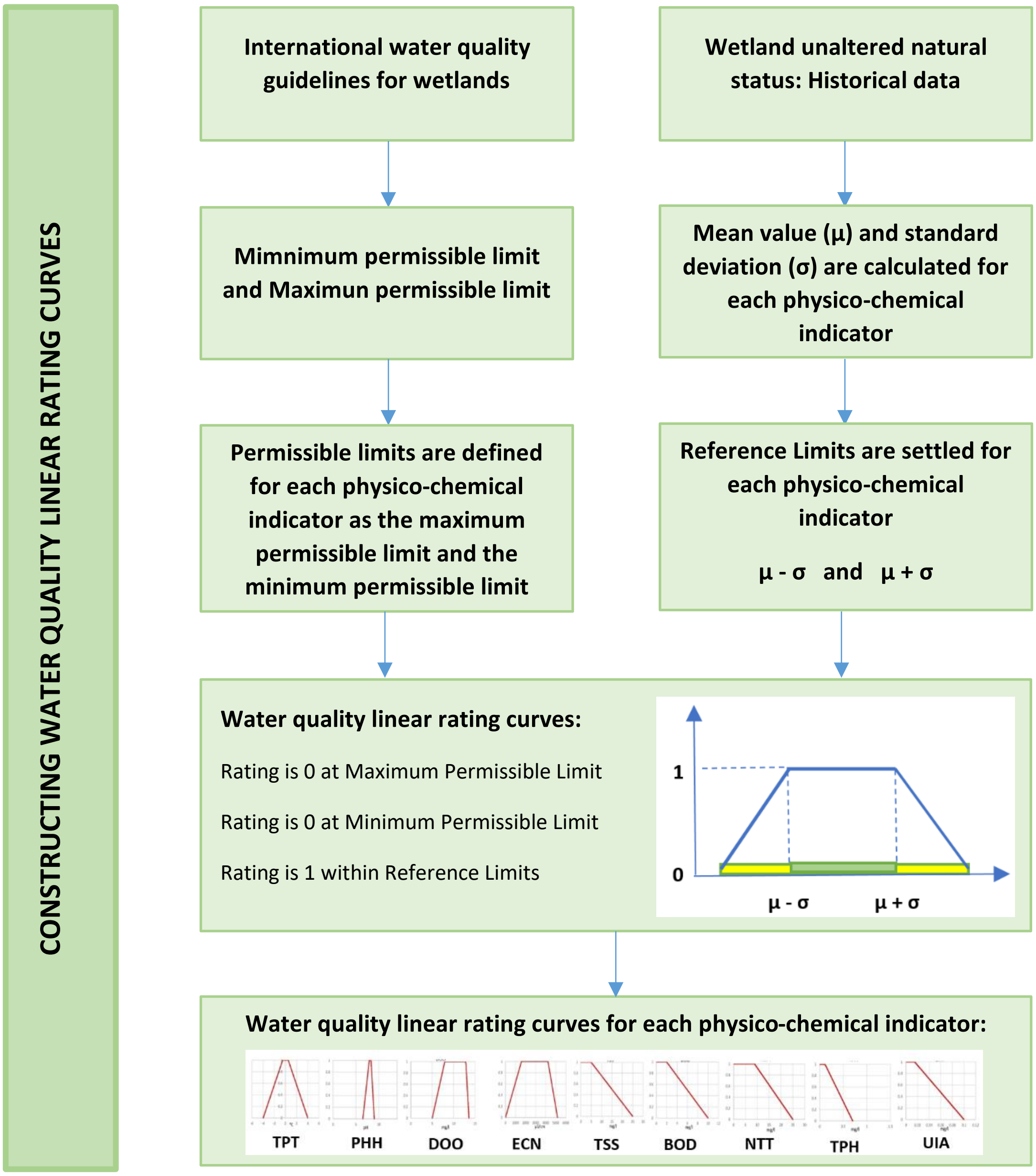

Fig. 5. Constructing water quality rating curves for each physico-chemical indicator

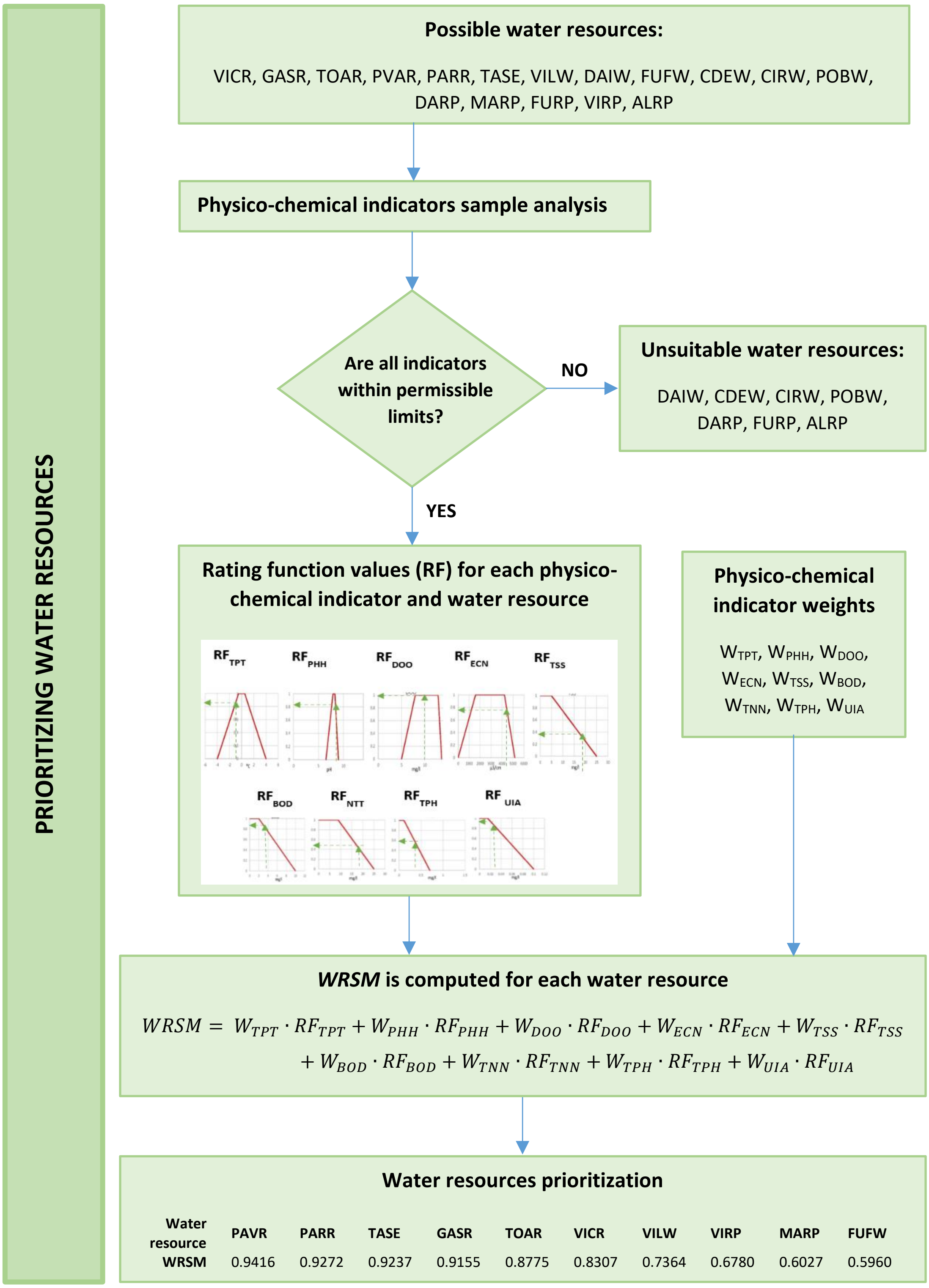

Fig. 6. Prioritizing water resources under study