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A comparison between the European and the Brazilian models for management and diagnosis of river basins

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Abstract

Water management is assuming more and more importance as freshwater resources are becoming scarce, both in quality and in quantity, across many developed and developing countries. This trend can be attributed to population growth, industrialization, growing agricultural demand, poor water management practices and climate change. In attempting to deal with the intensification of water quality- and quantity-related problems in recent decades, many countries have revised their water resource management policies and legislation, introducing new institutional frameworks and management instruments. Considering regional geographic and cultural distinctions, the present article aims at comparing the models of water resource management in the European Union (EU) and in Brazil. Institutional and legal arrangements currently in place, water planning and management instruments currently in use, assessments of water body status and watershed diagnoses were analysed. Main strengths and weaknesses of each water management system are pointed out in the conclusion. Main challenges for the water sector, and highlights of the converging and diverging points concerning water resource management systems, in each region, are discussed.

Keywords: Brazil; European Union; River basin; Water Framework Directive; Water management; Water quality

Highlights

- Management of tropical and temperate water resources are distinct.
- Management differences are due to cultural and geographic characteristics of basins.

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- Drainage basins were shown to be the efficient management units in both regions.
- More efficient management tools are developed with comprehensive basin monitoring.
- Regardless of the region, management targets are difficult to be attained.

Graphical Abstract

Introduction

In the European Union (EU) and in Brazil alike, water resource management is complex, owing to the diverse geographical, cultural, climatic, socioeconomic and political realities that exist across member states and federal states. In the EU, water is generally abundant in much of the region, but it is also unevenly distributed in both time and space, with large areas experiencing increasing levels of water scarcity and drought (EEA, 2012). In Brazil, while 80% of water resources are concentrated in the Amazon, which occupies 46% of the Brazilian territory, 13% of the country's area is covered by semi-arid regions, with intermittently flowing rivers and long periods of drought (ANA – Brazilian Agency of Waters, 2019b).

Approaches for dealing with those extreme situations that entail the integration of public policy instruments, the articulation between governmental policies, and the enhancement of mechanisms that foster social participation in decision making (Brannstrom *et al.*, 2004; Abers, 2007) are desirable. This articulation promotes a more effective deployment of management actions, in supervision and enforcement, and in continuous monitoring and evaluation efforts (OECD, 2019). Furthermore, water rights evolved similarly in both regions with traditional models converging towards permit-based systems (Hodgson, 2007). Environmental concerns were the primary drivers behind both the European Community's (Akinsete *et al.*, 2019) and Brazil's (Mercure *et al.*, 2019) water policies and legislative reforms, as their governments recognized that formally and clearly allocating water rights and accountability introduces the necessity of incentives for resource conservation by rights holders (Jimenez *et al*., 2018).

The importance of water resources for a growing population has led to legislative reforms in the EU and Brazil, which progressed towards multi-layered and complex governance systems, and which, although increasingly decentralized (Jimenez *et al*., 2018), present fundamental differences in terms of settings – environmental, socioeconomic and political distinctions across and between their respective geographies. In this context, public perception is influenced by new arrangements in the governance system itself. It then follows that the comparison between the EU's and Brazil's regulatory frameworks for watershed management can be expected to provide an understanding of how each system responds to particular challenges, hopefully differentiating between stronger and weaker strategies, and building consensus regarding watershed management procedures.

The present article aims at comparing models of water resource management and policies in the European Union (EU) (with a surface area of 4,476,000 km^2 and a population of 447.7 million) and in Brazil (with a surface area of 8,516,000 km^2 and a population of 212.6 million) to identify what are the best outputs. The approach considered the legislation framework, the management procedures and the evaluation procedures, including the instruments allowing changes in the use of water for a sustainable use of the resource.

In both regions, water legislation developed within the traditional Civil Law[1] setting, established from Roman Law, in which water was regarded as a public resource, its use requiring top-down regulation by the state to prevent over-exploitation and degradation (Hodgson, 2007). Private ownership of water bodies was not permitted, water rights were connected to land tenure or ownership, and were subject to various servitudes and restrictions (Ioris, 2009). The approach employed in the present article considers the different water management systems of the two regions, aimed at answering the following questions: Which water planning instruments are used and how have they been implemented? Which institutions are involved and how are water quality and quantity assessed as the bases for watershed management? Finally, the strengths and weaknesses of each region are identified, and converging and diverging water management trends are highlighted in the conclusions.

Methodology

The starting point for this water management regional comparison was the authors' previous experience in watershed assessment, planning and management, in the European Union and in Brazil, and the discussions that these different experiences enabled. The authors carried out a brief presentation of the water management systems, practices and review the approaches applied in both regions to identify main similarities and differences. An in-depth survey was carried out via websites of entities linked to water resource management, such as the European Commission, the National Water Agency of Brazil, OECD, UNESCO and others. Due to the complexity of the subject, the bibliographic research focused on the identification of key constituents allowing the examination of similarities and deviations between the regional approaches.

[1] The great majority of EU member states use the Civil Law legal system, although some, such as England and Wales, use Common Law, and others use a combination of the two.

Overview of water management systems

European Union

Legal framework. The introduction of the Water Framework Directive 2000/60/EC (WFD) in the year 2000 aimed to bring in a new paradigm for European water management (Teodosiu *et al*., 2003), with the inclusion of inland surface waters, transitional waters, coastal waters and groundwater. The Directive established its water management objectives through an integrated and ecosystemic approach with the development and implementation of integrated water resource plans in all its member states (Soares, 2016). Environmental objectives were then sought through the implementation of programmes specified in the River Basin Management Plans (RBMPs), which decentralized policies, and standardized objectives, classification and assessment criteria. The RBMP system promotes a new water culture that requires close cooperation among public institutions, private enterprises and civil society, grounded in scientific knowledge and information, public consultation and active civic participation (Schmidt & Ferreira, 2014). Following an integrated approach, the EU directed the aims regarding the protection of its waters towards the improvement of the status across member states' water bodies (Howarth, 2005). These efforts were implemented and followed through 6-year cycles that began in 2009, and established 2015 as the original timeframe for meeting WFD environmental objectives. Member states that have availed themselves of an extension beyond 2015 are required to achieve all environmental objectives by the end of the second and third management cycles, which extend from 2015 to 2021 and 2021 to 2027, respectively (Voulvoulis *et al*., 2017).

The WFD introduced an experimentalist approach to water governance, offering more flexibility than previous directives (Liefferink *et al*., 2011). Therefore, the WFD is not a target-based piece of legislation, apart from its explicit obligation that no water bodies are to experience deterioration in status (Donauhanse & Tina Vienna Urban Technologies and Strategies, 2013). One of the important innovations of the WFD was the introduction of water pricing services applying the polluter-pays principle (Correljé *et al*., 2007; Berbel & Expósito, 2020). However, the application of the polluter-pays concept for diffuse sources, as agriculture is inappropriate and should be replaced. Albiac *et al*. (2020) suggest the integration of valuation instruments for water pricing as an improvement of WFD that would improve water quality.

Water management systems. The implementation of the WFD is achieved through a river basin-targeted planning process, which requires an RBMP for each River Basin District (RBD) (EEA, 2018). The WFD leaves to member states the ensuing development and operationalization of sub-basin plans, which include the appropriate administrative arrangements and the identification of local competent authorities.

The choice of authorities responsible for the implementation of the WFD varies significantly across member states. For half of the member states, national bodies and environmental agencies have some degree of responsibility. In some other member states, specific authorities assume most of the tasks, while assigned tasks such as monitoring are assumed by *ad hoc* agencies. Small member states, such as Cyprus, have appointed authorities only at the national level; in the United Kingdom, three regional units (England and Wales, Northern Ireland and Scotland) have the main responsibilities. Even though the overall technical and political profiles of competent authorities in Europe improved in some member states during the second management cycle, some are still recognized as needing strengthening (European Commission, 2019).

Although the progress of WFD operationalization is considered a positive example of the implementation of a policy at the European level, some problems remain. For example:

1. Sometimes, non-uniform monitoring practices and criteria are applied to evaluate environmental conditions. Lemm *et al*. (2019) point out that many of the biological assessment metrics used in WFD, especially regarding benthic invertebrates, respond to general degradation from multiple pressures and therefore do not provide causal inference in multiple-stressor situations. In this case, the choice of appropriate management measures becomes difficult.
2. Instead of following the WFD process to ensure the implementation of appropriate measures, EU member states often continued with traditional water management practices, focusing on regulating only individual monitored pollutants: an approach that tends to neglect the complexity of a catchment. Unfortunately, this is a global tendency, because it is easier to compare concentrations with limits of the legislation than to make complex analyses of iterative data.
3. Even the extended timeframes of the WFD European Commission (2019) may not be long enough to achieve its objectives (Table 1). It is possible that if more realistic targets were chosen, achievement of aims should be attained more frequently.
4. The application of the 'one-out, all-out' principle may induce a water body to be incorrectly classified as not having good conditions, inducing unnecessary restoration costs. This concept was tested by Sandin (2005) in three Swedish streams, with different ecological status indices and observed discrepancies in their classification.

Assessment and diagnosis of watersheds. The WFD adopted the Drivers-Pressures-State-Impacts-Responses (DPSIR) framework (European Communities, 2003; Oliveira *et al*., 2005) which aims to provide a systematic understanding of the relationship between environmental effects, their causes and measures (Nõges *et al*., 2002). The approach requires a programme of measures to manage anthropogenic pressures in order to improve ecosystem health (European Commission, 2000). This procedure was described in Article 5 of the WFD, stating that the characterization of each RBD should include:

1. an analysis of its characteristics;
2. a review of the impacts of human activities on the surface waters and groundwater; and
3. an economic analysis of water use.

Throughout the EU, more than 111,000 surface water bodies have been defined in the second RBMPs (European Commission, 2019). Approximately 80% are rivers, 16% are lakes and the remaining 4% are coastal and transitional waters.

The assessment of the overall status of natural surface waters includes the assessments of the ecological status[2] and the chemical status[3]. Surface water bodies within protected areas are subject to a

[2] Ecological status, according to the WFD, assesses ecosystem health as expressed by biological quality elements – phytoplankton, macrophytes, phytobenthos, benthic invertebrate fauna and fish – supported by hydromorphological and physico-chemical parameters: nutrients, dissolved oxygen, temperature, transparency, salinity and river basin-specific pollutants (RBSPs). The Directive specifies which elements are to be assessed for each water category and requires that biological and supporting quality elements achieve at least 'good' status.

[3] Good surface water chemical status means that the concentrations of all priority substances do not exceed those permitted by the environmental quality standards (EQS) established in the Environmental Quality Standards Directive 2008/105/EC.

Table 1. Status values (ecological, chemical and quantitative) expected to achieve 'good' (or 'better') status by 2015, and proportion expected to achieve good status by 2021, by 2027 and beyond.

	Ecological status/ potential of surface water bodies (%)	Chemical status of surface water bodies (%)	Chemical status of groundwater bodies (%)	Quantitative status of groundwater bodies (%)
Expected to achieve good (or better) status by the end of 2015	43	51	74%	90
Less stringent objectives already achieved	1	21	2	1%
Expected to achieve good (or better) status by the end of 2021	21	2	3	4
Expected to achieve good (or better) status by the end of 2027	31	24	17	4
Expected to achieve good (or better) status beyond 2027	1	1	4	1
Achievement unknown	2	1	1	1

All surface water bodies weighted by count and groundwater bodies weighted by area. *Source*: European Commission (2019).

complementary assessment carried out according to specific criteria. The assessment of the global status of groundwater includes the assessments of the quantitative status[4] and the chemical status[5] (Figure 1).

Of the different water bodies recognized across Europe by the WFD, groundwaters generally have the best status. Good chemical status has been achieved by 74% (achieved expectations) of the groundwater area; while 89% of the area achieved good quantitative status (almost achieved expectations). Around 40% of surface waters (rivers, lakes, and transitional and coastal waters) are in good ecological status or potential (almost achieved expectations), and only 38% (quite far from achievement) are in good chemical status (EEA, 2018).

The main significant pressures on surface water bodies are hydromorphological (affecting 40% of water bodies), diffuse source pollution (38%), particularly from agriculture, and atmospheric deposition (38%), particularly of mercury, followed by point source pollution (18%) and water extraction (7%). The main impacts on surface water bodies are nutrient enrichment, chemical pollution and altered habitats due to morphological changes (EEA, 2018).

[4] Good groundwater quantitative status is achieved by ensuring that the available groundwater resource amount is not exceeded by the long-term annual average rate of extraction. Accordingly, the level of groundwater should not lead to any reduction in the ecological status of connected surface waters or in groundwater-dependent terrestrial ecosystems. Furthermore, reversals in the direction of flow should not result in saline (or other) intrusions.

[5] Good groundwater chemical status is achieved when concentrations of specified substances do not exceed those permitted by adopted standards and when concentrations do not prevent associated surface water bodies from achieving 'good' status, or cause significant damage to terrestrial ecosystems that depend directly on this groundwater.

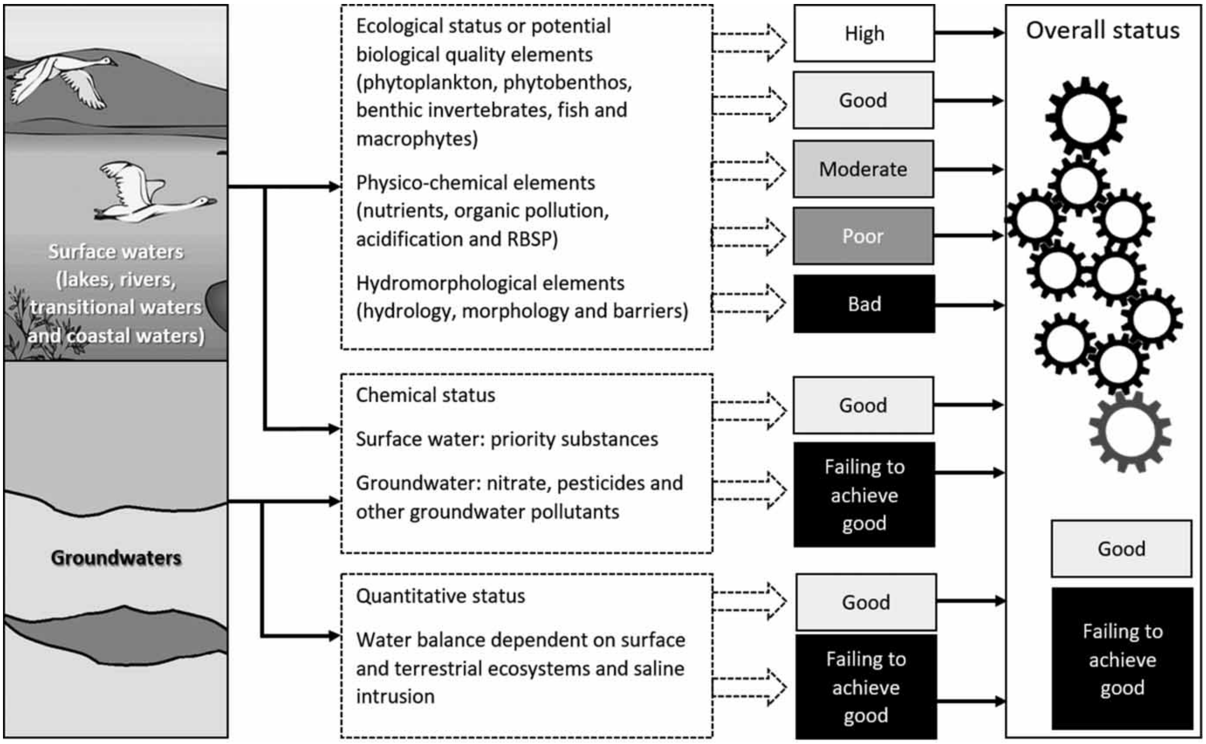

Fig. 1. Assessment of status of surface waters and groundwater according to the WFD. *Source*: Adapted from EEA (2018).

Gaps in monitoring the chemical status of surface waters are still significant but have dropped considerably since 2012, when the status of over 40% of water bodies was unknown and it was impossible to establish a baseline (EEA, 2018).

Brazil

Legal framework. Brazilian legislation is based on the Federal Law # 9433/1997, which established the National Water Resources Policy and created the National Water Resources Management System (Brasil, 2015). Institutions established in these framework are endowed with different legal statuses and specific functions, which are participative (Water Resource Councils and River Basin Committees, RBCs) or operational (Management Entities and Water Agencies) (ANA – Brazilian Agency of Waters, 2018). At the heart of this policy is the idea that water governance should be decentralized, participatory and integrated. The legislation recognizes water as a public good with economic value and as a scarce natural resource (van den Brandeler *et al.*, 2014), and introduces economic instruments, such as water use charges (implying a definition of water costs). Inspired by the French water resource management model (Laigneau *et al.*, 2018), the Law represented a paradigm shift in the country, creating the RBCs with a central role in the process. The three main stakeholders participating in the RBCs – public authorities, users and communities – seek integrated solutions to improve the quality and quantity of water in their respective river basins (Brasil, 2015). The structural aspects of the Law are the National Water

Resources Management System, the river basin as a planning and management unit, the multiple uses of water and the participative character of management (Brasil, 2015).

The National Water Resources Policy's (PNRH) objectives are threefold: the attainment of qualitative and quantitative water availability for present and future generations; rational and integrated water resource management for sustainable development; and prevention of critical hydrological events. To attain these objectives, the Law defines five management instruments (Figure 2):

1. The River Basin Plans (RBPs), at the national, state and drainage levels (depending on the extension of the basin), which define management actions, programmes, projects and investments that are prioritized for each basin;
2. A system for classification of water bodies according to their preponderant uses;
3. Water rights (water permits);
4. Water usage charges, which should be invested back into the basin; and
5. The Water Resources Information System (Elabras Veiga & Magrini, 2013).

Law # 9433/1997 (Brasil, 1997) is a policy and established only general principles and norms on priorities for use, granting and charging for the use of water resources, as well as general guidelines for the National Water Resources Management System. The regulation maintaining a broad degree of freedom for the Union and the States to organize the management of the waters under their jurisdiction (Cedraz, 2006; Brasil, 2015). Therefore, certain Brazilian States created specific laws to protect and conserve groundwater, as specified by Araújo *et al.* (2015).

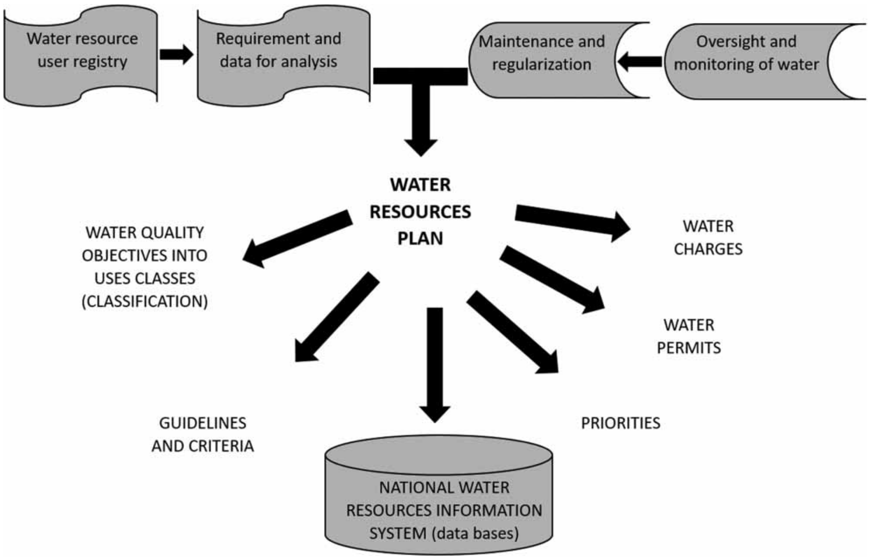

Fig. 2. National Water Resources Policy Tools. *Source*: Modified from ANA – Brazilian Agency of Waters (2018).

Water management systems. Because Brazilian drainage basins are extensive (e.g., the Amazon or São Francisco rivers), their management is complex and needs a hierarchical structure. Water planning in Brazil is, therefore, carried out through:

1. The National Water Resource Plan;
2. State-level Water Resources Plans; and
3. Water Resources Plans elaborated by hydrographic basins (RBPs).

The last National Water Resource Plan was published in 2017 and defined actions and programmes to be implemented through 2020. There are currently eight Interstate Basin Plans (ANA – Brazilian Agency of Waters, 2018). All 26 states and the Federal District have already developed State-level Water Resources Plans, which are currently in the process of revision, conclusion or procurement (ANA – Brazilian Agency of Waters, 2019b). As of the end of 2017, 158 Water Basin Resource Plans were already developed in 16 Federal States and 32 Plans were in development in 10 Federal States (Acre, Bahia, Espírito Santo, Minas Gerais, Mato Grosso, Pernambuco, Paraná, Rio Grande do Sul, Santa Catarina and São Paulo) (ANA – Brazilian Agency of Waters, 2018).

Araújo *et al.* (2015) list the National Water Resource Management System organizations on the federal, state and regional levels. In short, water management is handled by 28 different institutions – the ANA (National Water Agency) at the Federal level and 27 (including the Federal District) state water management entities (ANA – Brazilian Agency of Waters, 2018). Among the regional entities, RBCs are participative forums, responsible for approval of the RBPs. As of 2018, there were 226 of these at the state level. In addition, there were five delegatory entities functioning in interstate river basins, which function under management agreements signed with ANA, stipulating targets and indicators for programmes (ANA – Brazilian Agency of Waters, 2018).

Assessment and diagnosis of watersheds. The Resolution of the National Council of Water Resources 145/2012 established that the RBPs should be based on diagnostic, prognostic and action plans, establishing short-, medium- and long-term goals, and actions to reach those goals. They are also required to establish the aspects that the diagnoses of the water resources must include. Among these aspects is the quantitative and qualitative assessment of surface and groundwater and the balance between availability and water demand.

The Brazilian Agency of Waters (ANA) classified water bodies according to their natural or artificial origin. As of 2018, 172,837 artificial water bodies had been identified, against 67,006 natural ones (ANA – Brazilian Agency of Waters, 2018). Water bodies are also classified according to their preponderant uses, as shown in Figure 3 (National Council of Environment – CONAMA 91/2008) and water-quality criteria were established by CONAMA Resolutions # 357 of 2005 and # 396 of 2008 (ANA – Brazilian Agency of Waters, 2018). Classes in Resolution CONAMA # 357 of 2005 are defined as special, applied to protection units; class 1 applied for water uses that demand better standards; class 2 applied in water for uses that demand average standards; class 3 applied in water for uses that demand less than average standards and class 4 applied in water for uses that do not require high water quality. For each class, water quality criteria are established in a sequence of more restrictive (for class special) to less restrictive (for class 4). The column on the left in Figure 3 describes different uses.

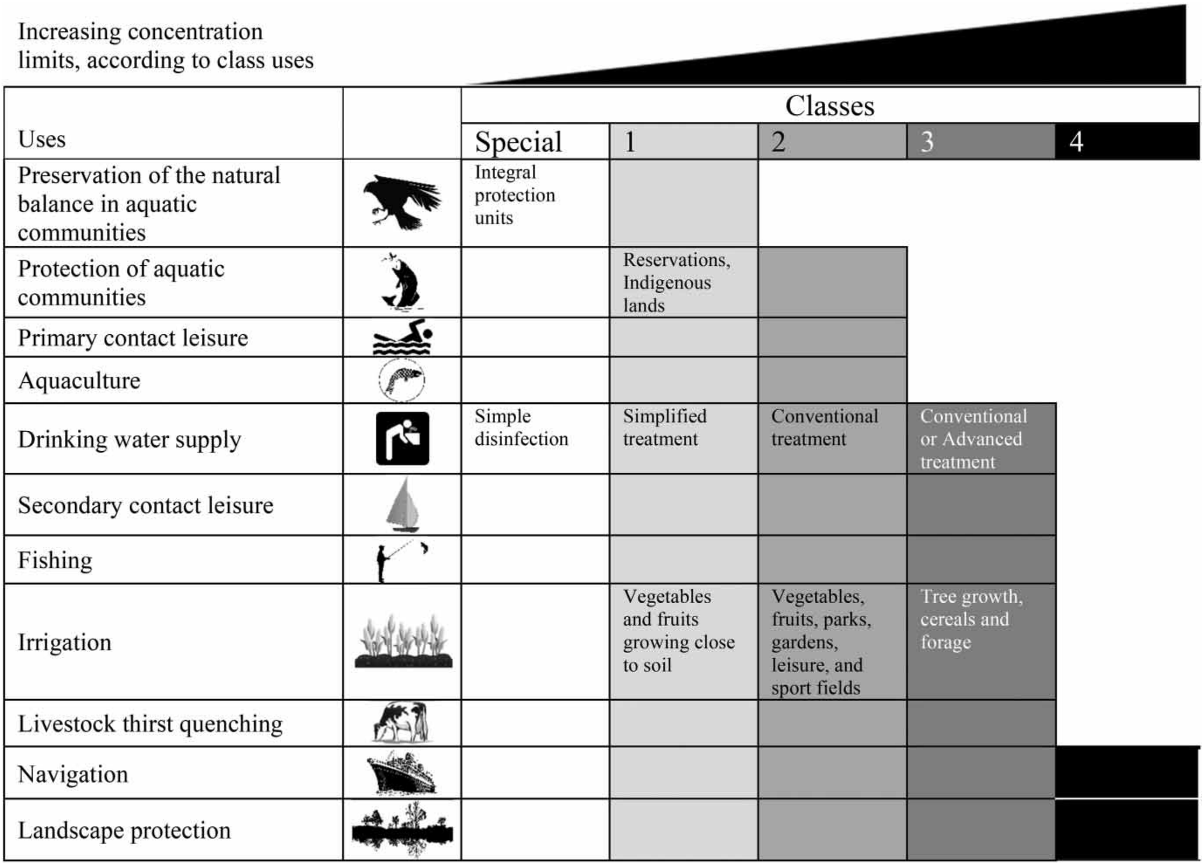

Fig. 3. Categories for the classification of water quality objectives for freshwater bodies. Classes are special (in protection units): 1 (uses that demand better standards), 2 (uses that demand average standards), 3 (uses that demand less than average standards) and 4 (uses that do not demand high water quality). *Source*: Modified from ANA – Brazilian Agency of Waters (2018).

A modelling exercise of the water quality for the Atlas Esgotos (Sewage Atlas; ANA – Brazilian Agency of Waters (2019a)) estimated that about 4.5% (83,450 km) of Brazilian river courses' extension presents concentrations of organic matter equivalent to the established limits for the class '4', restricting considerably the possible uses for those water bodies (ANA – Brazilian Agency of Waters, 2019b). These high concentrations can be attributed to poor sanitation, which has led to conflicts over the use of water resources. Greater conflicts have been caused by the irrigation sector, which has extracted water in regions where it is already a naturally scarce resource (Rigotto *et al*., 2016).

Water demand in Brazil is rising, with an estimate of 80% growth in the total volume extracted in the last couple of decades (ANA – Brazilian Agency of Waters, 2018). The main water use currently, in terms of quantity, is irrigation (at 52%), followed by human consumption (23.8%) and industry (9.1%). The rise of water demand contributes to further water stress. Critical regions include the Hydrographic Region of the Northeast Oriental Atlantic, a great portion of which is located in the Brazilian semi-arid area, and the Hydrographic Region of the South Atlantic, where water extraction for irrigation is significant. Problems have been detected in several basins where there are multiple water uses, and most of these areas lack appropriate intervention strategies for conflict resolution at the local scale (ANA – Brazilian Agency of Waters, 2018).

Comparison and discussion

There are similarities but also dissimilarities, between Brazil's and the European Union's current water resource management models. In both regions, the hydrographic basin is the geographical unit of water resource management, and management plans are the main planning instrument.

In Europe and in Brazil, legislation defines the contents for the characterization and diagnosis of water bodies, as well as the types of management measures to be employed. The use of economic and participatory incentives constitutes a commonality between the two frameworks. However, the systems for water body classification are distinct, as are monitoring requirements, which are clearly defined in the European WFD, but not in the Brazilian legislation. Furthermore, in Brazil, the geographic discrepancy between the foundations of the National Policy of Water resources (drainage basins) and the political-administrative organization of the Brazilian Federation (states and municipalities) creates conflicts of responsibilities.

In both systems, water legislation is flexible, leaving decisions to member states (EU) or federation states (Brazil), who regulate the management instruments for decentralization, transparency and participation. Furthermore, both systems establish that water resource management must not treat quantity and quality separately, considering geographical, social and economic diversity. However, in Brazil, the Water Law (Federal law 9433/1997; Brasil (1997)), as understood according to its fundamentals, objectives and guidelines, has a primarily utilitarian purpose, and water resources are managed from the perspective of their economic use. In the Brazilian Legislation, there is no specific reference to environmental care, such as the maintenance of environmental or ecological flows (Brasil, 2015). The European Union, by contrast, adopts an ecosystem approach with the aim of reaching a state of minimum degradation of the water bodies. Consequently, in Brazilian legislation, there is no clear definition of the environmental flow, but common uses are only permitted when they do not compromise more than 1% of the water availability (a vague concept). For rivers under the European Union jurisdiction, the adopted reference flow is Q_{95}: that is, the minimum flow value that must be guaranteed 95% of the time.

The duration of basins' planning cycles (from 10 to 20 years), as opposed to a globally set cycle, reflects the application of a long-term strategy in Brazil. In the European Union, cycles follow a 6-year schedule, which determines deadlines for set targets. Shorter planning cycles, clear monitoring requirements and periodic reporting also support the RBMPs' implementation, coupled with non-compliance sanctions such as fines and the negative perception of the non-compliant state by other member states. The longer planning cycles in Brazil may, in fact, hinder the effective management of water resources in the context of climatic uncertainty, important information gaps, rapid urbanization, changes in land use, leading to increased environmental deterioration. Shorter cycles confer adaptability on the planning process, since integrated water resource management is an iterative process whereby planning is followed by implementation, including monitoring and collection of information, which feeds back into the adaptation of management strategies.

The target-based cyclic system implies that monitoring is a key management tool in the implementation of the European WFD. The data from the monitoring network are used in the establishment of reference typologies and are necessary both for following the state of the water bodies and for developing restoration measures. Indeed, a consistent monitoring of water bodies sustains stronger RBMPs, as observed in the second cycle of RBMPs across the EU. Surface waters and groundwater have been monitored at more than 130,000 monitoring sites over the past 6 years (EEA, 2018). However, the European Commission (2019) still reported significant gaps in the biological and hydromorphological elements. Additionally, not all groundwater bodies that were identified as at risk of failing good chemical status are subject to operational monitoring, and not all substances capable of causing risk are fully covered. In Brazil, the National Hydrometeorological network presented, in 2017, over 21,000 stations under the responsibility of several different institutions (ANA – Brazilian Agency of Waters, 2018). Still, some states have not yet implemented their water quality monitoring networks, and in some cases, even the existing monitoring presents problems in terms of spatial and temporal representativeness. Moreover, monitoring of groundwater is still scant. At the national level, striking differences are observed between Units of Federations regarding operational capacity and the dissemination of monitoring data (ANA – Brazilian Agency of Waters, 2018). An example is presented by Wasserman *et al.* (2019), who analysed water quality in the extensive Amazon Basin, where they found only 52 water-quality monitoring stations.

Both regions show difficulties in implementing the measures foreseen as necessary, either for the lack of financing or for the lack of commitment of the responsible entities. For instance, funding was insufficient for water infrastructure that could help improve sanitation and water supply, as well as expand monitoring efforts and other instruments at the federal level (ANA – Brazilian Agency of Waters, 2019b). Some of the challenges were identified in the scope of the Projeto Legado (Project Legacy) (ANA – Brazilian Agency of Waters, 2017), which also included the proposal of management actions for their resolution.

Strengths and weaknesses in the European Union strategies

The following strengths can be highlighted in the European Union's water resource management strategy:

1. There is a common legislative framework among the EU member states, and the WFD allows an increased sharing of knowledge and a comparison of the current state and evolution of water resources across the whole community.
2. The EU's WFD sets clear timeframes (by 2027) to meet targets, and outlines periodic reporting deadlines for progress assessment.
3. Economic principles are incorporated into water management systems; these include the polluter-pays principle, as well as other economic approaches such as water pricing (Yang & Griffiths, 2010; Berbel & Expósito, 2020).
4. In several member states, water pricing and metering, together with water-saving measures, have been highly effective in changing consumer behaviour (EEA, 2018; Berbel & Expósito, 2020).
5. Stakeholder and general public consultation are widely implemented; member states use a variety of different outreach methods to ensure the appropriate participation of populations; stakeholders are invited to contribute actively to the process and, thus, play a major role in advising competent authorities (European Commission, 2019). Recently, the participation has been criticized, because, on the

one hand, it did not produce improvements in water quality, and it does not count with the real public, but with representatives of various interests (Rimmert *et al*., 2020).
6. The WFD clearly positions ecosystem health at the centre of its purposes and objectives.
7. Common monitoring and assessment programmes are developed and implemented across member states.

The following weaknesses were identified in the EU's water resource management strategy:

1. In most member states, reference conditions have not been established for all water body types and for all quality elements (European Commission, 2019).
2. There are still gaps in the reference values for some of the elements and substances required to be monitored (European Commission, 2019).
3. The improvement of ecological quality has been slower than originally envisaged (Carvalho *et al*., 2019).
4. A significant number of exemptions from the WFD objectives is still applied in the second RBMPs (European Commission, 2019).
5. Although pricing has improved water quality in many situations and is a strength in WFD, methodologies used to calculate were shown inappropriate for diffuse sources, such as agriculture (Albiac *et al*., 2020; Bouleau *et al*., 2020).
6. There are insufficient financial resources for the implementation of water management measures, including tasks such as ensuring appropriate monitoring (Verheeke *et al*., 2017); 27 RBDs in five member states reported that financing had not been secured for these measures, in any sector (European Commission, 2019; Zingraff-Hamed *et al*., 2020).

European Commission (2015, 2019) made several recommendations to member states in order to improve the implementation of WFD. EEA (2018) highlights three areas offering substantial opportunities to improve the implementation of these recommendations, and support for the achievement of WFD objectives: (a) protection of Europe's aquatic ecosystems and their services; (b) restoring degraded water ecosystems and (c) integration of water aspects into sector policies.

Strengths and weaknesses in the Brazilian strategies

Regarding Brazil, the following strengths can be highlighted for its water resource management strategy:

1. The strategic nature of water management policies for water allocation (regarding collection and granting of the rights to use water) stimulates the rational use of water in the country, as a measure to mitigate the risks of scarcity (Silva *et al*., 2017).
2. There is a National Pact for Water Management, supported by a financial incentive programme for state systems, that aims at strengthening institutional arrangements for water resource management.
3. Consultation of the public and interested parties in the water planning process and on-going involvement of stakeholders throughout management are in place.

The following weaknesses were identified in the Brazilian strategies:

1. Even though a great part of the territory is covered by water resource management plans, these do not actually have a regulatory action and do not guide the funding process of the National System for the Management of Water Resources (SINGREH) institutions (ANA – Brazilian Agency of Waters, 2017).
2. There is insufficient integration between water resource plans and other sector-specific policies, especially those regarding sanitation, the environment and water infrastructure (ANA – Brazilian Agency of Waters, 2018).
3. The institutions associated with water management have displayed limitations in effectively responding to situations of severe water crisis or federal conflict (ANA – Brazilian Agency of Waters, 2017).
4. The RBCs are generally unable to respond to stumbling blocks hampering integrated actions involving ANA and state water resource management entities (ANA – Brazilian Agency of Waters, 2018).
5. The resources available for financing institutions that have functions delegated by ANA have continuously fallen short (ANA – Brazilian Agency of Waters, 2017).
6. Often, federation states lack staff, funding, participation and political commitment to cope with water-related issues (Abers & Keck, 2009; OECD, 2015).
7. Where they exist, water charges are insufficient (OECD, 2015).
8. There are limitations in the monitoring network (ANA – Brazilian Agency of Waters, 2018).
9. The classification of water bodies has not been extensively applied (ANA – Brazilian Agency of Waters, 2018), and where the classification of water bodies is not undertaken, those already in good condition are not appropriately protected (ANA – Brazilian Agency of Waters, 2017).
10. Groundwater should be treated more strategically and deserves greater attention with regard to legislation and the quantitative and qualitative characterization and monitoring of this resource (Araújo *et al.*, 2015).

There is room for improvement in the integration of water resource plans with other sectorial policies – in particular those of water infrastructure, environment and sanitation; the sustainability and financial viability to ensure the complete functioning of the system; the conservation and preservation of strategic water bodies; payment for ecosystem services; and management of the demand, by way of promoting a more rational use of water (ANA – Brazilian Agency of Waters, 2018). The Projeto Legado (ANA – Brazilian Agency of Waters, 2017) proposed a set of measures for the improvement of water resource management in Brazil.

Converging and diverging points

Some *converging points* emerge concerning water resource management in the European Union and in Brazil, namely:

1. Definition of the river basin as the territorial unit for water resource management and planning;
2. The adoption of RBMPs and the employment of command and control instruments associated with economic instruments;
3. Difficulties, to a greater or lesser extent, in ensuring an effective, coordinated and integrated approach for water resource management;

4. Insufficient integration between water and other existing policies outside the environmental sphere;
5. The difficulty of channelling resources towards the implementation of measures specified in RBPs and complementary sectoral plans, which interfere with the quality of water resources.

On the other hand, *diverging points* are:

1. Water jurisdiction and assignment of responsibilities among authorities. While in Europe, responsibilities are attributed to member states, in Brazil, the responsibilities are hierarchical (Municipalities, States and Federal).
2. Classification of water quality follows different criteria, based on either the ecosystemic approach – EU – or on water uses – Brazil.
3. Data availability and quality concerning water resources' conditions. Although in Brazil, the centralized database is an advantage, quality and density of data have to considerably improve to reach the EU levels.
4. Level of specification of water laws (and thus, level of flexibility left to planning authorities). Although both regions developed flexible policies, because EU attributes responsibilities to member states with different cultures and habits Laws had to be adaptable. In Brazil, a more centralized system induces more rigid regulations.

Conclusions

Table 2 summarizes the findings of this article, by comparing the Brazilian and European water management situation. The differences highlighted in the table can be attributed to the historical experiences of both regions and their different hydrologies. In Brazil, although drainage basins vary in size significantly, the Amazon being the largest, their characteristics are not so variable and management procedures do not differ significantly. On the other hand, in the European Union, drainage basins are more heterogeneous, including in terms of nival and glacial regimes, leading to more flexible and complex management procedures. The smaller availability of water in the European Union also imposes more extensive monitoring programmes and comprehensive knowledge of groundwaters.

The effective implementation of the WFD is marked by member states' national contexts, including their participatory culture and the flexibility of their public administrations to respond to new challenges. The progress of WFD operationalization, although presenting some gaps and different speeds across member states, is considered a positive example of the implementation of a policy at the European level. The existence of a common legal base, the adoption of the same criteria and methodologies, the adoption of a common schedule and common evaluation time frames have incentivized the implementation of the WFDs. However, there is a need to follow up on the postponing of deadlines for achieving 'good status' of water bodies, and to manage effectively those that are not going to reach the desired status by 2027.

Brazil has made remarkable progress in water resource management, but the water policy system is still 'under construction', particularly in the least developed regions of the country, because of the varied characteristics of Brazilian basins, in terms of social, economic, hydrological and environmental development. Political, institutional and legal factors also influence management performance, either fostering or hampering its progress in specific basins.

Table 2. Characterization of the management systems in Brazil and in the European Union considering different elements of comparison.

Element of comparison	Brazil	European Union
Geographical distinctions	Very large drainages in a tropical and semi-tropical environment. Inertial rivers	Large drainage basins, temperate environment and nival and glacial regimes in mountainous environments. Less inertial rivers, responding faster to climate
Regulation	Federal Law # 9433/1997; National Water Resources Policy	Water Framework Directive 2000/60/EC (WFD)
Management units	National, State and River Basin	River Basin (Member states)
Management instruments	River Basin Plans; Classification of water bodies; Water permits; Water charges; Database	River Basin Management Plans with specifically defined targets that improve with time. Based on the principle of continuous improvements.
Planning deadlines	10–20 years. Smaller flexibility in the long term, regarding climate changes	6 years higher: shorter deadlines implies larger flexibility, regarding climate changes
Institutional framework	Based on decentralization, transparency and participation: Water Resource Councils and River Basin Committees; Management Entities and Water Agencies	Based on decentralization, transparency and participation: *Ad hoc* official institutions constituted by local authorities. Civil participation is carried out through these institutions
Assessment	Water quality and availability	Drivers-Pressure-State-Impacts-Responses (DPSIR) determining integrated indicators (lead to the status of aquatic ecosystems)
Cost of water price	Defined within the River Basin Committees, based on a participative debate	Polluter-pays principle
Monitoring	Conformity or not. Nonconformities lead to remediation actions (not quite proactive). Insufficient monitoring network, with few parameters	Set for the definition of the Ecological Status/ chemical status that should lead to targets (rather proactive). Large monitoring network, with a broader range of parameters
Water quality criteria	Determined as a function of uses of the water in each drainage basin	Established according to an ecological and chemical status (defined as a function of targets). Undefined in many member states.
Water quantity criteria	Set limitations for the uses as a function of availability. For instance, in many regions, irrigation of cultures is not allowed.	Besides setting limitations for uses, the WFD indicates the need for identification of alternative sources of water. For instance, groundwater.
Sources of financial support	Undefined, most of the time	Insufficient
Groundwater	Disregarded	Fully included in the water management framework. However, needs improvements

The present article has identified several areas where experts have recognized gaps and opportunities for improvement of water resource management in the EU and in Brazil. Despite not going into detail on the different reported issues, it is clear that analysing different examples of management approaches and water issues is key to the refinement of water resource management strategies for each region. In the context of more frequent water crisis scenarios, the utilitarian perspective will likely prevail. Decentralizing to state and local authorities for the definitions of short-, medium- and long-term water quality goals for preponderant uses is strategic in a setting of high variability and heightened water crisis; however, leaving out key functional components of water bodies (such as biological elements) from their assessment, mostly from quality objectives, may speed up overall deterioration. In Brazil, a redirection of water resources communication towards environmental, ecosystems-based discourses may be called for.

Data availability statement

All relevant data are included in the paper or its Supplementary Information.

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