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Review

Water resource management: A comparative evaluation of Brazil, Rio de Janeiro, the European Union, and Portugal

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HIGHLIGHTS

- The growing scarcity of fresh water in the world, the frequent difficulties of management and interest in contributing to change this situation were the main reasons for conducting this study.
- The study of water management in different contexts enables a greater understanding of the topic subsidizing the decision making of managers and society in general, in relation to environmental quality and ecological and human health.

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ABSTRACT

This paper presents an overview of water resource management in Brazil, in particular the state of Rio de Janeiro, and in the European Union, with an emphasis on member country Portugal. The study examines the primary laws, governing bodies and water resource plans. The paper describes the concerns and interests of the scientific community and other sectors of society with regard to water resource management. The paper also draws attention to challenges and opportunities concerning the main objective of water resource management, which is to ensure the availability of water of high quality and sustainable quantity. Additionally, it also mentions good and poor management practices. Among the concerns highlighted are integrated water resource management and water resource monitoring. The objective of this study was to contribute to water resource management processes. The primary reasons for this study are the growing scarcity of freshwater in the world, recurrent problems in managing this resource and a desire to contribute to the improvement of the current situation. The study of water management in different contexts allows for a greater understanding of the subject, thereby assisting the decision-making of managers and society in general with regard to environmental quality and ecological and human health. There is an increasing interest in efficient water resource management, which creates a demand for information on the subject. Both Brazil and the European Union are facing problems related to quantity and quality of water. Problems like scarcity of freshwater, contamination, salinization, and floods. This makes the realities of them quite close, despite the physical distance between them. In general, Brazil, Rio de Janeiro, the European Union and Portugal have similar water resource management requirements. If these regions are to supply a consistent quantity of high-quality water to present and future generations, then they need effective laws and plans, efficient managing agencies, political interest and economic resources. Investments in research and developing water resource management plans are inefficient measures if they are not implemented with special emphasis on monitoring and inspection.

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1. Introduction

Water resource management encompasses a range of information from various sources and areas of knowledge. This information includes technical, legal and institutional information that have their conceptual, ideological, and ethical aspects and new administrative models, different ways of thinking and new phenomena such as economic crises, climate change and anthropogenic activities that continuously change the environment. The following information demonstrates the scope and complexity of this subject.

UN-Water (United Nations — Water) (2010) calls attention to the fact that water stress is already high and that improved management is critical to ensure sustainable development. The organization also asserts that "water resource management affects almost all aspects of the economy, in particular health, food production and security; domestic water supply and sanitation; energy and industry; and environmental sustainability." According to UN-Water, water resource management is of such importance that if not addressed appropriately, "the progress towards poverty reduction targets and sustainable development in all its economic, social and environmental dimensions will be jeopardized."

There are many issues that are addressed by international organizations. UN-Water (2014) draws attention to the major issues regarding water: (a) climate change, (b) water and biodiversity, (c) water and disasters, (d) water and gender, (e) water quality, (f) sanitation, (g) water scarcity, (h) transboundary waters, (i) water and urbanization, and (j) water and food. Each one of these issues is discussed using statistical data regarding the current situation. On the subject of water quality, the organization notes that approximately 2 million tons of human waste per day is discharged into the world's water bodies. With regard to sanitation, 2.5 billion people worldwide live without improved sanitation. This lack of adequate sanitation results in the death of one child every 20 s. As noted by UN-Water, the world's population is expected to grow from 7 billion to 9 billion by 2050, thereby leading to a 60% increase in the amount of food needed globally and a 19% increase in agricultural water consumption. With respect to urbanization, half of the world's population currently lives in cities, among which 827,600,000 are people living in slums.

The relationship between water and energy is also a matter of great concern worldwide. The large and growing demand for water for energy production highlights the impacts generated by the production of energy on the planet (WWAP, 2014). Groenfeldt and Schmidt (2013) emphasize the importance of ethics and values in water management. The authors note how value systems reflect water policies and how these values influence the establishment of governmental priorities. They also note that water scarcity should not be treated as only an economic issue but also as a social, environmental and cultural issue. Groenfeldt and Schmidt assert that ethics has been left out of discussions of water governance.

Jha et al. (2012) state that urban flooding is due to a combination of causes: meteorological and hydrological phenomena, ruptures of dams or landfills, and other human activities such as unplanned growth.

The goal of urban planners is an organized process of urbanization. However, planning is often thwarted by legal and illegal changes that are not always in the public interest. The public interest is served by implementing projects that improve the quality of life of urban inhabitants and that preserve the environment (Araújo, 2009). The illegal exploitation of water resources is a problem that affects water quantity and quality. Hirata (2014) notes that illegal pumping of groundwater from wells hampers the development of a program of water resource management.

The issue of climate change has drawn significant attention from several sectors. Europeans have conducted major studies of this phenomenon, as it is increasingly common to observe adaptations to climate change. In 2012, the European Environmental Agency (EEA) published an important study of the impacts of climate change in Europe (EEA, 2012b). In 2013, the European Commission adopted a strategy with the goal of preparing the European Union for current and future consequences of climate change, in other words, making the EU more resistant to climate change (European Commission, 2013). In Brazil, this subject has increasingly gained attention; however, it is still far from becoming a core concern of Brazilian authorities and society. In 2008, the Brazilian government published the National Climate Change Plan (PNMC), one objective of which is to contribute to the reduction of greenhouse gases (CIM, 2008).

The balance between water quantity and quality is currently the main focus of water resource management. Therefore, given the diversity of users and interested parties, integrated management has become a paradigm. The concept of integrated water resources management (IWRM) is "a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (http://www.gwp.org/The-Challenge/What-is-IWRM). The integration of water management with land use planning should be a goal.

During the last few decades, many countries have made commitments to the environment. This is due to the continuous increase in global awareness regarding the environment and sustainability. The United Nations Environment Program (UNEP, 2012) underscored the importance of ECO 92 in Rio de Janeiro, the responsibilities assumed by many countries since the conference and environmental projects that have been implemented specifically to manage water resources.

The basis for water resource management lies in legislation containing parameters that will respond to specific policies. For member countries of the European Union such as Portugal, the benchmark for planning and water resource management is the Water Framework Directive — WFD, Directive 2000/60/EC, whereas in Brazil, the benchmark is the "Lei das Águas" (Water Law), Law No. 9.433/97.

Hering et al. (2010) conducted a critical review of the 10-year history of the European Union's Water Framework Directive and found that implementing the WFD has been a great challenge. According to the review, almost all EU member states have spent time and resources to develop tools, collect data and conceive watershed management plans, with various degrees of success.

In the case of Portugal, an EU member country, the WFD was incorporated into national law in the form of Law No. 58/2005 (Portugal, 2005). Vieira (2003) highlights the current perspective of WFD's integrated management and the importance of its implementation to the protection of surface and groundwater. The author cites as major challenges the streamlining of Portugal's legal and institutional framework and the implementation of watershed plans and the National Water Management Plan.

Veiga and Magrini (2013) analyze Brazil's water resource management policies, which were established with the approval of the Water Law of 1997. Their paper emphasizes the role of watershed committees and water management agencies. They also report that the Brazilian model, for the most part, is aligned with international trends and has undergone major improvements in certain hydrographic regions. However, the implementation of many instruments is still in its early stages and requires considerable effort.

This study focused on water management in Brazil, specifically in the state of Rio de Janeiro, and in the European Union, particularly in Portugal. Major laws, management agencies and water resource plans in Brazil, the state of Rio de Janeiro, the European Union and Portugal were analyzed.

The concerns and interests of the scientific community and other sectors of society with regard to water resource management were assessed. This paper also draws attention to challenges and opportunities concerning water, such as sustainably ensuring the availability of ample high-quality water for present and future generations, and cites examples of good and poor management practices. These aspects are important for developing an overview of the issues of water resource management. To develop an understanding of water resource management, the study also relied on events, news releases, debates, advice from experts and scientific articles. The objective of this study was to analyze water resource management in Brazil and Portugal, and thus it was necessary to research this activity in the context of the European Union and the state of Rio de Janeiro. The choice of the two objects of study was due a Covenant between two organisms for research funding from Brazil and Portugal (CAPES-FCT), and that makes them very appropriate because it is different continents, in different contexts, but with similar problems. To accomplish the objective, certain relevant and illustrative aspects of these contexts were researched. Selected geographic and demographic data of these areas are presented in Table 1. The information in the table indicates that Brazil has a lower population density than the European Union. The population density of Rio de Janeiro greatly exceeds that of Brazil, whereas the densities of the European Union and Portugal are nearly equal.

Today, water resource management is both socially and scientifically important. The scarcity of high-quality water even impedes social improvements. Additionally, water management is pertinent to water-related social and scientific issues because there is a need to continually seek ways to ensure the availability of high-quality water and to preserve and care for this resource. This study, which explores water resource management in Brazil and the European Union, Portugal in particular, was performed with the goal of providing information that will contribute to decision making and the development of policies concerning water.

2. Legislation

2.1. Brazil/State of Rio de Janeiro

Brazil is a federal republic composed of 26 states and a federal district. The country is politically organized into states, municipalities and districts. Brazil is managed by federal, state and municipal governments (IBGE, 2014).

In Brazil, the primary legislation regarding water resource management is called the Water Law, Law No. 9.433 of 1997 (Brasil, 1997), which established the National Water Resource Policy and created the National Water Resource Management System (Singreh). According to this law, the National Water Resource Policy's core principles are that water is a public good and a finite natural resource with economic value; water management should allow for multiple uses of water, be decentralized and include the participation of the government, users and communities; in the event of a water shortage, water shall be used for human and livestock consumption; and Singreh and the National Water Resource Policy have jurisdiction over watersheds. The National Water Resource Policy includes the following instruments: water resource plans; classification of water bodies based on their primary water use; granting of water use rights; charging for the use of water resources; and information systems for water resources (http://www2.ana.gov.br/Paginas/leidasaguas.aspx).

In the state of Rio de Janeiro, the State Water Resource Policy was established by State Law No. 3.239/99, which also created the State Water Resource Management System following the provisions of the federal law. The objective of this policy is to find a balance between the multiple and competitive uses of water to integrate regional efforts to protect, conserve and restore water bodies and promote the cleaning of water bodies and aquifers.

With regard to groundwater, Resolution No. 15 of the National Water Resource Council (CNRH) of January 11, 2001, establishes general guidelines for the management of groundwater; Resolution No. 396 of the National Environmental Council (CONAMA) of April 3, 2008, addresses the classification of groundwater resources and sets forth environmental guidelines for groundwater; and Resolution No. 92/08 of the National Water Resource Council (CNRH) establishes general criteria and procedures to protect and conserve groundwater in Brazil.

Certain Brazilian states created specific laws to protect and conserve groundwater. Among the many such laws, the laws of the following states are noteworthy: São Paulo (Decree No. 32.955, 1991), Pernambuco (Law No. 11.427, 1997), Pará (Law No. 6.105, 1998), Minas Gerais (Law No. 13.771, 2000), Goiás (Law No. 13.583, 2000), Rio Grande do Sul (Decree No. 42.047, 2002), Mato Grosso (Law No. 8.97, 2004),

Table 1
Statistical data.

	Brazil	Rio de Janeiro	European Union	Portugal
Area	8,515,767.049 km^2 (IBGE)	43,780.172 km^2 (IBGE)	4,385,549 km^2 [a]	92,072 km^2 [a]
Population	202,640,565 people (06/01/2014 estimate, IBGE)	16,461,106 people (06/01/2014 estimate, IBGE)	507.4 million people (Eurostat, 2014)	10.6 million people[a]
Population density	23.79 people/km^2	375.99 people/km^2	115.69 people/km^2	115.12 people/km^2

[a] http://europa.eu/about-eu/countries/member-countries/index_pt.htm.

Mato Grosso do Sul (Law No. 3.183, 2006) and the Federal District (Decree No. 22.358, 2001) (Toscano et al., 2008). In Rio de Janeiro, Decree No. 40.156 of October 17, 2006, established technical and administrative procedures to regulate surface and groundwater.

The Forest Code and its amendment, Law No. 12.651 of May 25, 2012, address the preservation of the environment surrounding water resources (Brasil, 2012). This law (Article 4) defines permanent protection areas (APPs) in rural and urban areas and specifies buffer zones. For example, water courses that are less than 10 m wide should have 30-meter-wide buffer zones, whereas water courses that are more than 600 m wide should have 500-meter-wide buffer zones. The current Forest Code, which was amended by Law No. 12.727/2012, is less restrictive than the 1965 Forest Code. In certain cases (Law No. 12.651/12, Article 61-A, Paragraph 6, I), the buffer zones of permanent protection zones may be only 5 m wide. The new Forest Code also included permanent protection areas in the calculation of the percentage of legal reserves required for a plot of land (Article 15).

2.2. European Union/Portugal

The European Union is an organization of 28 European countries that began as a purely economic union and has evolved into an organization spanning policy areas from development aid to the environment (http://europa.eu/about-eu/index_pt.htm). The aims specified in the EU treaties are achieved by several types of legal acts. A directive is a legislative act. European Union countries must meet the goals set out by the directives (http://europa.eu/eu-law/decision-making/legal-acts/index_pt.htm).

The key instrument of EU policy for water management is Directive 2000/60/EC of the European Parliament and of the Council of October 23, 2000, or, in short, the Water Framework Directive (WFD) (EC, 2000). This directive establishes a framework for community action to protect inland surface waters, transitional waters, coastal waters and groundwater. The WFD describes “good surface water status” in both ecological and chemical terms and “good groundwater status” in both quantitative and chemical terms. In Portugal, the WFD was incorporated into national law in the form of Law No. 58/2005 of December 29 (INAG, 2012).

In addition to the Water Framework Directive, the European Union established other, more-specific directives regarding water resource management. Directive 2006/118/EC of the European Parliament and of the Council aims for the protection of groundwater from pollution and deterioration. In Portugal, this directive was incorporated into national law in the form of Decree-Law No. 208/2008, which established the protection of groundwater from pollution and deterioration and regulates Article 47 of Law No. 58/2005, which addresses the assessment of the chemical status of groundwater. Commission Directive 2009/90/EC, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, specifies the chemical analysis and monitoring of water. Decree-Law No. 83/2011 establishes technical specifications for the analysis and monitoring of the chemical and physicochemical parameters of surface and underground water bodies in Portugal. Directive 2008/105/EC addresses environmental quality standards (EQS) for priority substances and other contaminants following Article 16 of the WFD. In Portugal, Decree-Law No. 103/2010 addresses this subject. Directive 2006/7/EC establishes provisions for the management of bathing water quality and strives to preserve, protect and improve the quality of the environment and to protect human health. Directive 91/676/EEC aims to protect waters from pollution caused by nitrates from agricultural sources. Directive 91/271/EEC addresses the treatment of urban wastewater.

Directive 2007/60/EC addresses the assessment and management of flood risks and aims to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. This directive refers to floods as a natural phenomenon that cannot be prevented and states that certain human activities and climate change contribute to an increase in the likelihood and adverse impacts of flood events. In Portugal, Decree-Law No. 115/2010 established a framework for the assessment and management of flood risks.

3. Management agencies

3.1. Brazil/Rio de Janeiro

In Brazil, the National Water Resource Management System consists of the following organizations: (a) On the federal level, there are policy makers, i.e., the Ministry of the Environment (MMA)/Water Resources and Urban Environment Secretariat (SRHU); water resource managers, i.e., the National Water Agency (ANA); and deliberative bodies, i.e., National Water Resources Council (CNRH). (b) On the state level, there are policy makers, i.e., the State Environment Secretariat — Rio de Janeiro (SEA); water resource managers, i.e., the State Environment Institute (INEA), headquarters and regional superintendencies; and deliberative bodies, i.e., the State Water Resources Council (CERHI). (c) On a regional level (municipalities and hydrographic regions), there are policy makers, i.e., the municipalities; water managers, i.e., the water management agencies — executive delegatory bodies; and deliberative bodies, i.e., the watershed committees (INEA (Instituto Estadual do Ambiente), 2011).

On July 17, 2000, Law No. 9.984 created the National Water Agency (ANA), a federal agency responsible for the implementation of the National Water Resource Policy and coordination of the National Water Resource Management System. ANA is structured in such a way as to strengthen the technical aspects of water management.

> Traditionally, there has been extensive political interference in water management, some of which has even influenced technical decisions. Inroads have been made into isolating water management organizations from political interference, as is evidenced by the institutional structure of Brazil's National Water Agency (ANA) (WWAP, 2012).

Rio de Janeiro's State Water Resource Council (CERHI), which is authorized and regulated by Decree No. 27.208/2000 and amended by Decrees No. 32.862/2003 and No. 41.039/2007, is a collegiate body that makes up the State Water Resource Management System, has normative, consultative and deliberative functions, and is responsible for overseeing and promoting the implementation of the guidelines of the State Water Resource Policy. CERHI includes a president, a legislative assembly, an executive secretariat and three technical boards: the boards for institutional & legal affairs (CT-IL), management instruments (CT-ISG), and groundwater (CT-AS). Additionally, CERHI includes 30 members, of which 10 are representatives of the public sector, 10 belong to civil society and watershed committees and 10 are water users (Governo do Estado do Rio de Janeiro, 2013).

State Law (RJ) No. 5.101/2007 created the State Environment Institute (INEA) with the aim of executing state environmental policies regarding water and forest resources. INEA's organizational structure was established by State Decree No. 41.628/09.

In Brazil, watershed committees are organizations created to play a meaningful role in the process of planning and managing water resources. Federal Law No. 9.433/97 (Article 37) specifies the functions of the watershed committees in regard to watersheds, subwatersheds and groups of contiguous watersheds and contiguous subwatersheds. This law also addresses the functions of the committees (Article 38). Among the functions worth noting are the promotion of debates regarding water resources, the initial arbitration of conflicts related to water resources, and the approval of watershed resource plans. The law also mandates that the State Water Resource Plan shall consider proposals of the watershed committees (Article 8, sole paragraph). The water management agencies (Article 44, X), which operate as executive secretariats of the watershed committees (Article 41), are responsible for

developing water resource plans. Resolution No. 05/2002, Article 1, Paragraph 1 of the State Water Resource Council of Rio de Janeiro (CERHI) mandates that the watershed committees have normative, deliberative and advisory functions (Rio de Janeiro (Estado), 2002).

The Baixo Paraíba do Sul Committee, which was established by State Decree — RJ No. 41.720/2009, consists of a 30-member legislative assembly, which is the committee's highest-ranking deliberative body. Of these members, 10 are public and private water users, 10 belong to civil society (professional class organizations, NGOs, public foundations, private higher educational institutions, and public universities) and 10 are representatives of the federal, state and municipal governments. The committee also consists of three technical boards: the boards for water resources and hydraulic structures, civil defense, and legal and institutional affairs. In addition to approving watershed plans and establishing water management agencies, the committee also has the authority to approve water body classes, develop methods to charge fees and allocate resources (CBH Baixo Paraíba do Sul, 2014).

The meeting minutes of the watershed committees provide a detailed record of their activities. The meeting minutes of the legislative assembly of the Baixo Paraíba do Sul Committee encompass several subjects, particularly those related to the organization and operation of the committee (http://www.cbhbaixoparaiba.org.br/reuniaoplenaria.php). The meeting minutes of the technical boards record debates regarding technical issues. The Water Resource and Hydraulic Structures Technical Board addresses such issues as drainage channel cleaning, floodgate maintenance and operation, data correction and updating, water desalinization and environmental programs.

3.2. European Union/Portugal

Regulation (EEC) No. 1210/1990 of the Council established the European Environment Agency (EEA) and the European Information and Observation Network (EIONET). The role of the EEA is to help the European Community and member countries make informed decisions (http://www.eea.europa.eu/about-us). This regulation has been amended several times, and, in 2009, it was codified by Regulation (EC) No. 401/2009.

In Portugal, the Water Law (Law No. 58/2005, Article 7) specifies that the Water Institute (INAG) is the federal administrative body with the authority to represent the state in matters pertaining to water management. However, in 2012, INAG was shut down and incorporated into the Portuguese Environmental Agency (APA) as mandated by Decree-Law No. 56/2012. APA also incorporated the regional watershed administrations, the Climate Change Committee, the Waste Management Monitoring Committee and the Environmental Emergency Planning Committee (Ficheiro Nacional de Autoridades Arquivistas, 2012).

Today, the Portuguese Environmental Agency (APA) is responsible for water management in Portugal. APA is in charge of performing the functions of the National Water Management Authority according to the provisions set forth in the Water Law. APA also sets and monitors the execution of policies, plans and coordinates water use, and manages hydrographic regions to achieve the objectives set forth by the Water Law (APA, 2013a, 2013b).

The Ministry of Environment, Spatial Planning and Energy, which includes the State Secretariats of the Environment, Energy, Spatial Planning and Nature Conservation, is in charge of water management policies in Portugal (http://www.portugal.gov.pt/pt/os-ministerios/ministerio-do-ambiente-ordenamento-do-territorio-e-energia.aspx).

In Portugal, the Water Law (Law No. 58/2005, Article 7, 2, b) states that the regional watershed councils will serve as "advisory bodies to the Regional Watershed Administrations of their respective watersheds." Ordinance No. 394/2008 of June 5 specifies the internal structure and organization of the regional watershed administrations (ARH).

4. Water resource plans

4.1. Brazil

With the approval of Federal Law No. 9.433/97, the water resource plans were configured as instruments to implement the National Water Resource Policy. According to Article 8 of this law, the water resource plans should be developed in accordance with the watershed, state and country. The water resource plans are divided into three levels: I, the national level, whose plan is the National Water Resource Plan; II, the state level, whose plans are the state water resource plans; and III, the watershed level, whose plans are the watershed water resource plans (MMA, SRHU, ANA, 2011).

On January 30, 2006, the National Water Resource Council enacted the current National Water Resource Plan (PNRH) through Law No. 9.433/97 (http://www.mma.gov.br/agua/recursos-hidricos/plano-nacional-de-recursos-hidricos). Decree No. 41.039/2007 mandates that Rio de Janeiro's State Water Resource Council (CERHI) is in charge of setting the guidelines for the watershed plans and the State Water Resource Plan (PERHI). The council is also responsible for approving and monitoring the execution of these plans.

During the development of the State Water Resource Plan, the technical boards (CTs) and the State Water Resource Council issued technical reports regarding several issues concerning water resource management in the state of Rio de Janeiro. The Technical Board on Underground Water (CT-AS, 2012) recommended that CERHI-RJ conduct studies of fractured aquifer systems, uncharted aquifers, saline intrusion into coastal groundwater, contaminated sites, and point-source and linear contamination of groundwater; support studies of underground aquifers of the Campos watershed; promote educational activities to protect and control the use of groundwater; build a comprehensive data base of wells and groundwater; and create a semi-detailed hydrogeological map of the state of Rio de Janeiro. The State Environment Institute (INEA) and Coppetec Foundation specified the requirements for the state water resource plan in Contract 33/2011, Process No. E-07/502.786/10 (Governo do Estado do Rio de Janeiro, 2013).

To better manage water resources and effectively allocate financial resources to the watershed committees, Resolution CERHI-RJ No. 107/2013 of the State Water Resource Council divided the state of Rio de Janeiro into nine hydrographic regions.

4.2. Portugal

Decree Law No. 45/94 of February 22 regulates the water resource planning process and the elaboration and approving of plans for water resources. The law also set and approved the National Water Management Plan (PNA) and 15 watershed plans (PBH) (INAG, 2002, V.1, C.1). Decree-Law No. 45/94, Article 5, mandated that the Water Institute (INAG) is responsible for developing the National Water Management Plan (PNA) and four watershed plans (PBH). The Regional Environmental and Natural Resource Directorates (DRARN) are responsible for developing the remaining watershed plans.

Decree-Law No. 112/2002 of April 17 established the National Water Management Plan. Article 2 of the law establishes the plan's validity for a maximum of 10 years and requires that it be reviewed within a maximum of 8 years. The National Water Management Plan (PNA) of 2002 was published on the National Water Institute's website. However, the National Water Management Plan of 2010 has not yet been published.

With the aim of reducing water waste and optimizing water use, on June 2012, the Portuguese government published the National Program for the Efficient Use of Water (PNUEA). This program will be implemented from 2012 to 2020 (APA, 2012).

5. General framework

Tables 2 and 3 provide an overview of the abovementioned information and compare and contrast water resource management in Brazil (BR), Rio de Janeiro (RJ), the European Union (EU) and Portugal (PT). For example, in Brazil, water bodies are classified based on the primary use of the water, whereas in the European Union, the classification method is based on the goal of achieving good water quality.

6. Concerns and interests

Today, water is of great interest to many sectors worldwide, particularly because there is an understanding that water is a limited resource in terms of quality and quantity. At present, there are many concerns and interests regarding water. The decision-making process is not always technical and is often conceptual. With that in mind, this paper highlights certain points of concern and interest regarding the current water situation.

a) Water quantity and quality for the present and future generations (key concern)

The Brundtland Report (1987) addresses water quality from a sustainability perspective. "14 (…) Sustainable development requires that the adverse impacts on the quality of air, water and other natural elements are minimized to sustain the ecosystem's overall integrity." This report also addresses pollution resulting from activities in rural areas: "19. (…) Efforts to restore water quality have been met with a mixed record of success because of pollution from outside of cities, notably nitrates and other fertilizers and pesticides (…)."

In 1995, the European Environment Agency published the "Environment in the European Union" report, which summarizes the state of the EU's environmental conditions. This document highlights the need for the EU to implement actions to protect the quality and the quantity of the water in the EU (*in*: EC, 2000). Edmunds et al. (2003) underscore the importance of preserving ecosystems because they impact the quality and quantity of groundwater.

The WFD (Directive 2000/60/EC; EC, 2000) is the result of a joint decision and policy-making process initiated by an increasing demand from citizens and environmental organizations for cleaner rivers and lakes, groundwater and coastal beaches. Currently, 70% of EU citizens consider the lack of water quality and 63% consider the shortage of or excess (such as floods) water to be serious problems in their country. The Portuguese believe that the primary threats to the water environment are chemical pollution (73.4%), water shortages (43.6%) and climate change (36.1%) (EC, 2009).

During the last two decades, Portugal has made important progress in environmental protection as a result of the incorporation of the European (EU) environmental directives into national law and financing from the EU Cohesion and Structural funds. The Portuguese economy has been badly affected by the global economic and financial crisis, and the primary short-term challenge for Portugal now is to enhance the cost-effectiveness of policies, i.e., to do more with less (OECD, 2013).

Brazil's Water Law, Law No. 9.433/1997, sets the following objective: "ensure, for both the present and future generations, an adequate water supply, whose quality is suitable for the purposes it will be used." Its general action guidelines (Article 3) state that the implementation of the National Water Resource Policy requires "the systematic management of water resources, without losing sight of its quality and quantity."

Rio de Janeiro's State Water Resource Plan (PERHI) specifies actions to reverse environmental degradation and improve the quality and quantity of water available on both the state and national levels. These actions include water resource management and planning, i.e., implementation of integrated water resource management (organizational management of SEGRHI, communication and provision of information, technical knowledge for management, a framework for identifying priority water sources, improvement of water management plans, regulation of water use); strategic subjects for water resource management, i.e., actions to protect and better use water resources, thereby ensuring the quality and quantity of water resources (sanitation, groundwater, studies of water and extreme flow, vulnerability to critical events, hydroelectric power, saline intrusion, monitoring of water quality and quantity); environmental recovery, i.e., actions intended to restore environmental quality (restoration and protection of springs, rivers and lakes; and sustainable use of water resources in rural areas) (Governo do Estado do Rio de Janeiro, 2013).

b) Climate change

The world has become increasingly more interested in major natural phenomena. Climate change has drawn considerable attention from various sectors of society, namely the technical, political, economic and social sectors. These actors have been conducting studies, setting policies, developing discussion forums, developing plans and implementing interventions regarding climate change.

Climate change is intimately connected to uncertainties and risks. UN-Water, the United Nations inter-agency coordination mechanism for all matters related to freshwater and sanitation, has developed a framework to mitigate greenhouse gas emissions and adapt water and service infrastructure (UN Water, 2012).

Climate change has become increasingly visible on the international political agenda. In recent years, the European Environment Agency has paid special attention to this issue. Both Report No. 12, "Climate

Table 2
Legislation, managing bodies, plans for water resources.

Legislation — policies and directives	BR	The Water Law, Law No. 9.433/97, established the National Water Resource Policy and created the National Water Resource Management System (Singreh).
	RJ	State Law No. 3.239/99 established the State Water Resource Policy and created the State Water Resource Management System.
	EU	Directive 2000/60/EC, the Water Framework Directive, established a framework for community action to protect inland surface waters, transitional waters, coastal waters and groundwater.
	PT	Law No. 58/2005 incorporated the WFD into national law.
Primary management agencies	BR	MMA — Ministry of the Environment; SRHU — Water Resources and Urban Environment Secretariat; ANA — National Water Management Agency; CNRH — National Water Resource Council
	RJ	SEA — State Environment Secretariat; INEA — State Environment Institute; CERH — State Water Resource Council
	EU	European Parliament: Environmental Commission; European Union Council: Environment; European Commission: Environment; European Environment Agency.
	PT	MAOTE — Ministry of the Environment, Spatial Planning and Energy APA — Portuguese Environment Agency
Water resource plans	BR	On January 30, 2006, the National Water Resource Council (CNRH) approved the National Water Resource Plan (PNRH).
	RJ	The State Environment Institute (INEA) and Coppetec Foundation set the requirements for the State Water Resource Plan in Contract 33/2011, Process No. E-07/502.786/10.
	EU	There is no specific plan. The EU monitors the implementation of the WFD.
	PT	Decree-Law No. 112/2002 of April 17 established the National Water Management Plan (PNA). The law is valid for a maximum of 10 years and must be reviewed within a maximum of 8 years. The PNA of 2010 is not yet complete. Regional watershed management plans.

Table 3
Specific legislation and directives.

Nitrate	BR	CONAMA Resolution No. 357/05, Table I, Class 1, Freshwater, Quality Standard. Nitrate: 10 mg/L N CONAMA Resolution No. 396/08 addresses groundwater classification, human water consumption and nitrate concentration (10 mg/L N)
	RJ	
	EU	Directive 91/676/EEC specifies protection of water from pollution caused by nitrates. 50 mg/L (approximately 11.3 mg/L N)
	PT	Decree-Law No. 208/2008 sets quality standards for groundwater. Nitrate: 50 mg/L (approximately 11.3 mg/L N)
Buffer Zones	BR	CONAMA Resolution 396/08, Article 20. Environmental agencies and water resource management agencies shall promote the implementation of buffer zones for aquifers and water wells to protect water quality.
	RJ	State Law RJ No. 3.239/99, Article 39, classifies buffer zones for aquifers as either class I — maximum protection buffer zone (APm); class II — restricted and controlled buffer zone (Arc); or class III — water well and other water extraction system buffer zone (APPoc). Article 10 of State Law RJ No. 1.130 of February 12, 1987, establishes class III buffer zones, i.e., for water wells: these buffer zones must extend 30 m outward from the water well.
	EU	Directive 2000/60/EC, Article 7, addresses waters used for the extraction of drinking water. 3. Member states shall ensure the necessary protection for identified water bodies with the aim of avoiding deterioration in their quality to reduce the level of purification treatment required in the production of drinking water. Member states may establish buffer zones for these water bodies.
	PT	Decree-Law No. 382/99, Article 1, establishes standards and criteria for setting buffer zones around public-supply groundwater wells. Annex — Definition of buffer zones. Type of aquifer system — inner buffer zone: Type 1 — r = 20 m; Type 2 — r = 40 m; Type 3 — r = 30 m; Type 4 — r = 60 m; Type 5 — r = 60 m; Type 6 — r = 40 m Note: The law also addresses intermediate and outer buffer zones.
Classification	BR	Federal Law No. 9.433/97, Article 5, specifies the instruments of the National Water Resource Policy. II — classifies water bodies according to their predominant water use; CONAMA Resolution No. 357, Article 2, IX — quality class: sets water quality conditions and standards necessary to meet predominant current and future uses;
	RJ	State Water Resource Council (CERHI), Resolution No. 02 of October 15, 2001, establishes technical boards. Article 2, III, technical board of management is responsible for proposing methodologies and rules to classify bodies of water.
	EU	The objective of Directive 2000/60/EC, the Water Framework Directive, is to establish a framework to protect inland surface waters, transitional waters, coastal waters and groundwater (Article 1). (26) Member states should aim to achieve the objective of at least good water quality by defining and implementing the necessary measures within integrated programs of measures, taking into account existing EU requirements.
	PT	
Riverbank Protection	BR	Forest Code, Law No. 12.651 of 2012, addresses the protection of native vegetation. Article 4 classifies permanent protection areas into rural and urban zones: I — the banks of any perennial, intermittent and natural water course: (a) 30 (thirty) meters for water courses less than 10 (ten) meters wide; (b) 50 (fifty) meters for water courses that are between 10 (ten) and 50 (fifty) meters wide; (c) 100 (one hundred) meters for water courses that are between 50 (fifty) and 200 (two hundred) meters wide; (d) 200 (two hundred) meters for water courses that are between 200 (two hundred) and 600 (six hundred) meters wide; (e) 500 (five hundred) meters for water courses that are over 600 (six hundred) meters wide.
	RJ	
	EU	
	PT	Law No. 54/2005 establishes the rules of ownership of water resources. Article 11 defines the concept of a margin and establishes its width: 1 — The margin is the strip of land adjacent to or overlooking the line that limits the water bed. 2 — The sea and the navigable or floatable (subject to the jurisdiction of the maritime authorities) water margins have a width of 50 m. 3 — The remaining navigable or floatable water margins have a width of 30 m. 4 — The margins of nonnavigable and nonfloatable waters, including streams, ravines and streams of discontinuous flow, have a width of 10 m. Decree-Law No. 222-A/2007 — Water resource usage, Section XIII — Extraction of inert material. Article 78, 2 — the extraction of inert material from margins and water beds connected to public waters is allowed only in places that ensure (g) the integrity of the water beds and margins in addition to their licensed structures.

change, impacts and vulnerability in Europe 2012" (EEA, 2012b), and Report No. 2, "Urban Adaptation to climate change in Europe", address the issue.

In Brazil, the Water Law, Law No. 9.433/1997, Article 15, states that the right to water use may be suspended should there be a need to use water for emergency situations arising from adverse weather conditions. In 2009, Law No. 12.187 established the National Climate Change Policy (PNMC). One goal of this policy is to implement measures to assist all three levels of government in adapting to climate change (Article 4, V) and to establish the National Climate Change Plan and its instruments (Article 6).

In Portugal, the Water Law, Law No. 58/2005, Article 54, addresses the monitoring of surface water, groundwater and protected areas and authorizes the collection of climatological data and water-related biological, hydrological, physico-chemical, sedimentary, chemical and environmental data.

IPCC (2013) notes that, for more than two centuries, humans have released significant amounts of greenhouse gases into the atmosphere. Deforestation and the emission of carbon dioxide significantly affect springs and watersheds.

c) Integrated water resource management and spatial planning

The European Union's Water Framework Directive (2000/60/EC) highlights the interaction between water resource issues and spatial planning. The following activities are used to identify anthropogenic pressures on surface bodies of water: "evaluation of land use patterns, including identification of the largest urban, industrial and agricultural areas, and also, where relevant, of fishery areas and woodlands" (WFD, Annex II, 1.4). With regard to underground bodies of water, "Member States may group groundwater bodies together for the purposes of this initial characterization. This analysis may employ existing hydrological, geological, pedological, land use, discharge, abstraction and other data" (WFD, Annex II, 2.1). The directive also highlights the importance of information concerning "land use in the catchment or catchments from which the groundwater body receives its recharge, including pollutant inputs and anthropogenic alterations to the recharge characteristics such as rainwater and run-off diversion through land sealing, artificial recharge, damming or drainage" (WFD, Annex II, 2.1) (EC, 2000). A report published by Portugal's Ministry of Environment, Spatial Planning and Energy (MAOTDR, 2008) highlights the importance of analyzing the interrelations, interfaces and possible dysfunctions between water resource management and spatial planning, which complement and overlap each other at a conceptual and operational level. With regard to sustainability, the spatial context presumes territorial cohesion (that which refers to land use, functions, dynamics, and structures), whereas the environmental context presumes environmental quality (that which refers to the protection, restoration and improvement of natural resources and environmental services in ecosystems, thereby eliminating losses of biodiversity). The analysis also addresses the economic, social and institutional contexts.

The ministry's report notes the importance of the scale of intervention in the spatial context. The perspective is different from the point of view of water management or spatial planning.

(…) in regard to water resources, the relevant spatial unit is the watershed. The Water Framework Directive (WFD) and the Water Law consider the watershed as the fundamental unit in water resource management, whereas units such as rivers, watercourses, flood zones, river beds, riverbanks, lakes, ponds and reservoirs are pertinent to surface freshwater. Additionally, aquifers are the spatial units for groundwater and coastlines are the spatial units for seawater. In regard to spatial planning, there are different spatial units: the region, the district, the county, the town, the urban agglomeration, the place, the lot or parcel, for example. Therefore, the intervention units for both areas under discussion do not generally match each other.

The integration of water resource management and spatial planning encompasses a range of issues, thereby making integration difficult. Furthermore, many issues are not addressed thoroughly because there is a lack of studies regarding the interaction between these two spheres. The spatial planning cycle requires greater coordination and cohesion, greater attention to timing and more-integrated sectoral policies. It is also important to coordinate and integrate other policies in sectors that affect water, such as agriculture, forestry, energy, health and tourism (MAOTDR, 2008).

Saraiva (1999)(in: MAOTDR, 2008) stresses the importance of environmental corridors linking water systems (rivers, estuaries or coastlines) for the ecological structure of a region. These corridors are the manifestation of ecological criteria to conserve and manage water bodies. These areas are a noteworthy example of the integration of water resource management and spatial planning.

In recent years, the Tagus River, a transnational river that runs through Spain and Portugal, has been the object of water resource management and spatial planning activities. The Tagus estuary, for example, has been the target of such activities. The region's priceless landscape, which has multiple ecological functions, leisure activities, urban uses and economic activities, including a port, receives wastewater from cities and industries along its banks. The need to protect this area and manage the conflicts arising from its several functions and uses make the Tagus Estuary Spatial Plan a vital instrument. The development of the Tagus Estuary Spatial Plan is viewed as a unique opportunity to plan, organize and manage the estuary and the estuarine waterfront because this plan may yield a balance between the territory's numerous uses and functions while protecting the region's water resources, ecosystems and natural assets. It is also important that efforts be made to coordinate the interests of various key players to develop a consensus of shared responsibility in the planning and management process (APA, 2013b).

During the previous 20 years, the Tagus estuary has undergone several environmental recovery interventions. The EU has built wastewater treatment plants, eliminated and converted industrial zones and implemented fishing regulations, all of which have significantly improved the estuary's water quality. The Nations Park of Lisbon, which has been monitored for 13 years, has improved environmentally based on its marine biotic index (AMBI). In 1997, the park was classified as a region of high degradation, whereas more recently it has been classified as a region of moderate degradation. However, the estuary still receives organic waste and sediment contaminated with heavy metals. These discharges make it more difficult for member states of the European Union to achieve one of the WFD's goals, which is to protect and improve bodies of water so that they may achieve good status by 2015 (Chainho et al., 2013).

The delineation of protection perimeters around groundwater abstraction points is an activity where water resource management and spatial planning interact. In Portugal, Decree-Law No. 382/99 (Article 3, 1) states that a "source protection zone is all forbidden or conditioned activities and facilities that may pollute groundwater in the area surrounding the water abstraction point." There are three types of source protection zones: the inner zone, the intermediate zone and the outer zone. Each of these zones has different specifications. Ordinance No. 327/2013, for example, defines prohibited activities and facilities. The following are prohibited in the intermediate zone: (a) aeronautical infrastructure and (b) automobile service stations, including scrap yards. The following are prohibited in the outer zone: (a) transportation of hydrocarbons, radioactive materials or other hazardous substances; (b) deposits of radioactive materials, hydrocarbons and hazardous waste; (c) pipelines for toxic products; (d) refineries and chemical industries; and (e) dumpsters and landfills, including any types of landfills for hazardous, nonhazardous or inert waste.

In Brazil, urban policy was established in Articles 182 and 183 of the Federal Constitution of 1988 and is regulated by Law No. 10.257/01. According to Article 182 of the Federal Constitution of 1988, municipal governments are responsible for executing an urban development policy whose objective is to regulate the development of the city's social functions and ensure the well-being of its inhabitants. Additionally, the master plan serves as this policy's primary instrument. Law No. 10.257/01 (city statute) addresses the regulation and control of land use to prevent pollution and environmental degradation (Article 2, VI, g) and states that environmental zoning is an urban policy instrument for municipal planning (Article 4, III, c). Ordinance No. 231/98 of the National Department of Mineral Production regulates groundwater source protection zones.

d) Monitoring

In accordance with Article 8 of the WFD, member states are required to establish monitoring programs for the assessment of the status of surface water and groundwater to establish a coherent and comprehensive overview of water status within each river basin district. Monitoring is an essential element in ensuring the quantity and quality of water resources. However, monitoring activities face a range of difficulties.

For adequate compliance with the WFD, it is crucial to implement adequate monitoring of groundwater and surface waters for quality and quantity assessment and to install a representative monitoring network throughout an entire river basin district (Mendes, 2013). Representative monitoring and correct data interpretation can substantially increase the efficiency and the rate and extent of the success of restoration policies (Stigter et al., 2011).

In Portugal, the following difficulties in implementing the WFD have been observed: (1) the qualitative and quantitative monitoring networks generally do not display adequate spatial representativeness, and in certain cases, they do not exist; (2) the gaps in and lack of long-term monitoring data do not allow for the distinguishing of natural changes from anthropogenic changes; and (3) the definition of environmental objectives for groundwater bodies is based on the protection of groundwater-dependent ecosystems (GDEs) from significant damage, whereas the WFD presents no definition for the term "significant" and refers only to its dependence on the ecological quality of GDEs (Mendes and Ribeiro, 2014).

Brazil, according to its National Water Agency, does not have a national network of monitoring water quality. In the case of groundwater, whose domain is that of the state governments, according to the Federal Constitution of 1988, monitoring the quality of groundwater resources is performed by certain states (ANA, 2007).

In the state of Rio de Janeiro, the expansion of the qualitative and quantitative monitoring network is defined in the state water resources plan — PERHI. The purpose is to install new fluviometric stations for monitoring the pluviometry and water quality in river basins (Governo do Estado do Rio de Janeiro, 2014).

e) Virtual water and water footprint

John Anthony (Tony) Allan (1993, 1994) wrote about embedded water, "virtual water." This concept is defined as the amount of water demanded for the production and commercialization of a certain product. Each cup of coffee consumed, for example, requires 140 L of water to grow, produce, package and ship the beans. Therefore, countries such as Brazil, the USA and Argentina are major exporters of virtual water, whereas Japan, Egypt and Italy are major virtual-water importers. The United States is also a major water consumer, because each American consumes approximately 6800 L of virtual water per day — three times more than an average Chinese. Virtual water has had major impacts on global trade policy and research and has altered the discourse in water policy and management (http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/images/TonyAllanWWAPLecture.pdf).

This concept created by Allan has been adopted worldwide and has great potential for use in the compensation of virtual-water exporting countries. Spatial, environmental, economic and, particularly, social actions may be performed to compensate these exporting countries.

"Water footprint" is a term that complements the "virtual water" concept. The "virtual-water content of a product" is the same as 'the water footprint of a product', but the former refers to the water volume embodied in the product alone, whereas the latter term refers to that volume and also to the type of water being used and to when and where it is used. Thus, the water footprint is an indicator of freshwater use that captures both the direct and indirect uses of water by a consumer or producer (http://www.waterfootprint.org/?page=files/Glossary). Hoekstra (2003) introduced the concept of the water footprint as "the cumulative virtual water content of all goods and services consumed by one individual or by the individuals of one country" (in: Hoekstra, 2003).

The concept of virtual water contributes in understanding the situation of water scarcity, which in the case of Brazil is very representative because the country is a major exporter of food.

f) Surface water vs. groundwater

According to studies by the European Environment Agency, deterioration of water quality and overexploitation of reserves are the main threats to water resources, both surface water and groundwater. Between 1970 and 1985, the rate of water uptake increased by 35%, and it was predicted that there would be further increases, particularly in the agricultural sector. The overexploitation of aquifers in many European countries resulted in decreased flow of rivers, saltwater intrusion in coastal aquifers and drying of wetlands. The report by EEA (1995) highlights the threat to the use of groundwater for human consumption by the presence of pesticides and nitrates due to agriculture.

In Portugal, surface waters are the primary source of domestic water. In 2012, groundwater and surface water supplied 33.35% and 66.65% of domestic supplies, respectively (ERSAR, 2013).

Domestic water in Brazil is supplied by surface water and groundwater: "of Brazilian municipalities, 47% are exclusively supplied by surface water sources, 39% by groundwater and 14% by the two types of sources (mixed supply)." In the state of Rio de Janeiro, 85% of municipalities are supplied by surface water, which indicates the importance of the Paraíba do Sul River (ANA, 2010).

Studies of water supply and demand in Brazil indicate that 45% of municipalities have adequate supplies (until the year 2015) and that 55% may have deficient supplies (surface and/or underground). It was also observed that 46% of urban municipalities need to invest in solutions to problems in their production systems (ANA, 2010).

g) Public and/or private management

The issue of whether water resources should be publicly or privately managed is controversial because it involves political, ideological, technical and legal aspects. However, several examples from around the world provide a better understanding of the subject and help water resource managers in the decision-making process. The subject is relevant to current events.

There are many significant examples of such controversies in the European Union. Certain European countries have decided to privatize their water and sanitation services, whereas others have decided to keep these public, and still others are making the reverse decision. In Germany, municipalities and intermunicipal associations are in charge of most of the water and sanitation management services. In Berlin, the state government sold a 49.9% share of its water utility in 1999 but soon afterward renationalized it. In Spain, approximately 50% of water services have been privatized. France has major private water and sanitation companies but has renationalized certain services. Holland is a country where water and sanitation services are provided by public companies. In the United Kingdom, England and Wales are served by private water supply and sanitation services; however, in Scotland and Northern Ireland, these services are provided by public companies. In Bulgaria, privatizations are moving forward. In Hungary, the opposite process is occurring in major cities. Recently, the government of Lithuania decided that these services will only be provided by municipal companies. In Portugal, the debate is increasingly polarized. Currently, 2.3 million people use water supplied by a foreign-capital company (Marques et al., 2013).

Brazil Law 11.445 of 2007 established national guidelines for basic sanitation. In Article 8, it was declared that holders of public sanitation services may delegate the organization, regulation, supervision and the provision of those services. The provision of these public services will depend on the conclusion of contracts (Article 10).

According to the National Water Agency (ANA, 2010), 69% of Brazilian cities are provided with water services by state sanitation companies, 27% of municipalities are themselves responsible for providing these services, and 4% of municipalities have contracted with the private sector for these services.

h) Preservation vs. deforestation

Deforestation is a serious problem for the water cycle and has coexisted with mankind throughout history. The Earth's surface has lost 53% of its original vegetation, and most of this deforestation has occurred in developed nations (Nações Unidas, 2012).

The world's population has been growing at a rapid pace, thereby increasing the demand for food production. According to UNEP/FAO/IPCC/Worldwatch Institute (*in*: UNEP, 2014), "agricultural expansion is responsible for 80% of deforestation." These organizations also assert that agriculture consumes approximately 70% of freshwater worldwide.

Deforestation can impact the water cycle in many ways. Fewer trees result in less transpiration, which reduces the amount of local rainfall and increases the severity of droughts. These events eventually reduce the amount of available water and the flow of rivers. Less vegetation also creates more runoff, thereby lowering water tables and reducing the amount of water stored in the soil. Additionally, deforestation increases naturally occurring fires and alters entire watersheds, thereby affecting forests and communities across areas measuring many miles across (Fintrac, 2013).

Brazil's Forest Code of 2012, which amended the Forest Code of 1965, is still the subject of controversy. Clashes are frequent between environmentalists and farmers. The quantitative elements of the forest code have been the primary points of controversy. A study conducted by Soares-Filho et al. (2014) revealed that the Forest Code of 2012 significantly increases the amount of land subject to deforestation in Brazil.

Many rivers in the world suffer from a lack of vegetation along their banks. In Brazil, this situation is a cause for concern. There is a lack of native vegetation along the Paraíba do Sul River in the state of Rio de Janeiro. The width of the river varies in the municipalities in the northern part of the state. Certain segments of the river are more than 600 m wide, whereas others are less than 600 m wide. Fig. 1

is an image of a segment of the river located in the municipality of São João da Barra (district of Barcelos), Rio de Janeiro. According to the Forest Code, this segment requires a 500-meter-wide protection zone. However, it can be observed that the native vegetation (Atlantic forest) is nearly absent and has been replaced with farms and pastures.

Deforestation along the banks of the Paraíba do Sul River is the primary cause of siltation in the river. The vegetation along the Paraiba do Sul watershed has been drastically changed due to several forms of occupation and land use, thereby causing erosion and siltation of the river (http://www.inea.rj.gov.br/fma/bacia-rio-paraiba-sul.asp). Water scarcity in the Paraíba do Sul watershed region has caused disputes between the states of São Paulo and Rio de Janeiro. The State of São Paulo's project to build an aqueduct from the Paraíba do Sul River to greater São Paulo has been met with heavy criticism. On the one hand, São Paulo has experienced major water supply problems, which were exacerbated by the drought during the summers of 2013 and 2014; on the other hand, the state of Rio de Janeiro has essentially only one source of freshwater — the Paraíba do Sul River. Thus, water security is of fundamental importance to the region (Remégio et al., 2014).

Portugal's environmental laws define narrower water resource protection zones than do Brazilian laws (see Table 3 — Protection of Margins). However, the amount of native vegetation along the banks of the Tagus and Paraíba do Sul Rivers is similar. For comparative purposes, Fig. 2 shows an image of the Tagus River in Ribeira de Santarém, Portugal, and 500-meter distances from the river banks (the buffer zone widths of Brazilian law).

Madeira (2005) attributes the flooding along the Tagus River to the siltation of the river bed. The author asserts that the siltation of the Tagus River is a result of deforestation along its banks, inappropriate overuse of its steeper banks for farming and a convergence of other factors that produce siltation.

Forest fires are also another serious problem for the hydrological cycle. Certain chemical elements in the burned areas are released into waterways, thereby causing changes in the water quality (Meneses, 2013).

7. Challenges and opportunities

Currently, the primary challenge is finding a balance between water quality and quantity. Many other challenges stem from this primary challenge. In Brazil and the European Union, such as in Portugal, the monitoring of surface water and groundwater is a constant challenge. Reality has shown that it is not easy to achieve this goal. This situation is present for several reasons, but the lack of financial resources in this sector aggravates the situation. If there is no efficient monitoring system, then there is no monitoring and, as a result, no current information is gathered.

There are several anthropogenic and natural factors that affect the availability of high-quality water, such as the disordered use of water resources and climate change. Experts have discussed the challenges and opportunities stemming from these issues. Studies and projects addressing these issues have been conducted on a global scale. The European Environment Agency, for example, published a report on urban adaptation to climate change (EEA, 2012a, 2012b).

The European Union's Water Framework Directive sets major goals for its member nations. One noteworthy goal is the classification of the status of water bodies and the establishment of measures to restore these bodies so that they may attain good ecological status by 2015. By identifying water bodies of poor status, it becomes possible to implement environmental measures to restore the status of such bodies.

The opportunities and challenges in water resource management that are listed in Table 4 have been cited by several agents who are involved in the context of water resources sector. This information contributes to understanding the complexity of the problem but also point paths.

8. Good and poor water management practices

The efficiency of water resource management is directly related to quality of the actions of water resource managers. International organizations have expressed concern regarding good and poor water resource management practices. UNESCO, for example, published reports citing countries that have been able to effectively deal with droughts and increase their supplies of water for domestic use. However, the report also raises concerns regarding corruption in certain countries (UNESCO-WWAP, 2006).

The good and poor water resource management practices listed in Table 5 are relevant to the contexts addressed in this article but are also applicable to other contexts.

9. Discussion

The concerns and interests regarding water resource management, some of which are technical and others are more conceptual, contribute to the defining of policies and decisions with global implications.

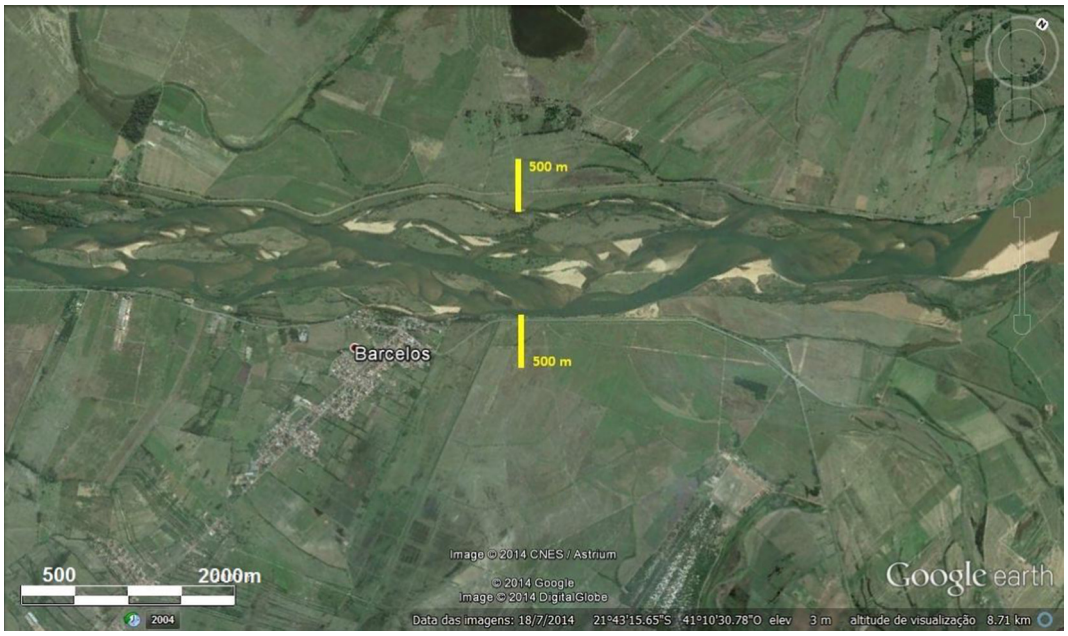
When the concept of virtual water is used to view the issue, all countries of the world may be viewed as being subject to the effects of global population growth or increased levels of global development. These factors interfere in food production and water consumption. Therefore, when there is the possibility of water stress or environmental degradation in a particular watershed, emphasis should not be placed on the jurisdiction of a river within a territory but instead on all who consume the products that are produced using this water.

If we analyze the situation in Brazil using the concepts of virtual water and the water footprint, the prognosis is not good for the availability of water resources. With a growing world population and Brazil's status as a major exporter of food and therefore virtual water, the tendency is to increase the consumption of water for agricultural production, resulting in the aggravation of water scarcity, which already affects certain regions of the country.

The challenges and opportunities regarding water resource management vary depending on whether the water resources are managed by a public or a private company. There may be ideological biases in this discussion; nevertheless, the main challenge is to effectively and efficiently manage water resources. Additionally, companies need to address other sustainability issues, particularly those regarding environmental and social aspects. Private companies see opportunities in situations where investment is lacking and there is a potential for profits, even where they need to make investments in infrastructure, for example.

An organized territory with high-quality water depends on efficient management. Therefore, it has become increasingly important to bring to the discussion various areas of expertise and a range of agents who operate in a territorial space. It is essential that different levels of government coordinate their water resource management efforts so that their activities in managing natural and urban systems do not overlap. The points of interaction between water resource management and spatial planning must be maintained through planning and effective implementation. In this light, it is essential that there be a culture that promotes the coordination and strengthening of the respective governing authorities. In Brazil, municipal governments have jurisdiction over the planning process and have the constitutional authority to enact master plans. However, this process is vulnerable due to the fragility of the municipal governmental agencies responsible for implementing the planning.

Integrating water resource management is viewed, to a certain extent, as a solution to problems in the water sector and as a great challenge. Water resource management is intimately connected to green areas and land use, and the availability of high-quality water thus depends on the preservation of green areas and orderly land use. Laws



Source: Google Earth, 2014. Adapted by the authors.

Fig. 1. Image of the Paraíba do Sul River between Campos dos Goytacazes and São João da Barra, Rio de Janeiro, Brazil.
Source: Google Earth, 2014. Adapted by the authors.

are not effective if they are not backed by effective inspection and monitoring of green areas.

The differences between the legal requirements for the areas of protection along river banks in Brazil and Portugal (Table 3) reflect differences in the respective anthropogenic contexts. However, the environmental needs are the same and independent of any natural patterns of human needs.

The Climate Summit (United Nations, 2014) in New York resulted in a goal to address the problem of deforestation: "At least halve the rate of loss of natural forests globally by 2020 and strive to end natural forest loss by 2030". The report is fairly ambitious in its goal of solving the problem of deforestation, but the same level of ambition is not applied to the subject of reforestation of the world's original vegetation. Reforestation is an even more controversial topic. Reforestation of deforested

Source: Google Earth, 2014. Adapted by the authors.

Fig. 2. Image of the Tagus River in Ribeira de Santarém, Portugal.
Source: Google Earth, 2014. Adapted by the authors.

Table 4
Challenges and opportunities regarding water resource management.

Challenges	Opportunities
Water quantity and quality; monitoring; risks and disasters; classification; environmental education; scarcity of fresh water; pollution control; salinization; security; information systems; water integration; transboundary watershed management; vegetation and soil use; adaptation to climate change; water reuse; combating deforestation and forest fire; forest restoration; environmental preservation.	New methods; new technologies; innovative techniques; public–private partnerships; research and development; new economic and social activities; quality of life.

rural areas would adversely affect the production of food. Imagine the reforestation of urbanized areas: this action would mean the demolition of entire cities.

10. Conclusions

The legal and institutional frameworks that have been established in Brazil and the European Union have enabled major advances in water resource management and, consequently, the availability of high-quality water. However, major challenges still have to be addressed for this goal to be achieved. Water resource legislation should contain guidelines for the preservation of forests and be integrated with forest legislation because forests are a key to ensuring water supplies and sustainability.

In addition to decreasing the rate of deforestation worldwide, it is also necessary to propose reforestation in various countries based on their levels of development. To develop such proposals, it is necessary to perform extensive studies to characterize and identify deforested areas around the world and then define the goals of a program of global reforestation.

Given that water scarcity is the result of inadequate water resource management, the solution must also lie in water resource management. Therefore, investments must be made in projects that protect water quality and quantities. Investments must be made for the purpose of reducing water consumption by agricultural activities because these activities represent the greatest consumption of freshwater. Investments must also be made in projects that protect springs and riparian forests and that reduce water, soil and air pollution.

In Brazil, 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.

This study makes it clear that monitoring of water resources is essential to achieving the primary goal of current water policies, which is to make high-quality water available to present and future generations. Brazil needs to deploy a national network of quantitative and qualitative monitoring of water resources. Portugal needs to expand and maintain its existing network.

Climate change has been a prominent topic of debate in online discussion forums centered on water-related topics. However, it is essential to preserve anthropogenic and natural activities in watersheds. Spatial planning often has a narrow focus on flooding, and it needs to adopt a more comprehensive approach in which studies and actions are performed throughout a watershed. The concept that the watershed is the basic unit for water resource management should be widely adopted in the spatial planning process.

There are many similarities between Brazil's and the European Union's current water resource management models, particularly with regard to their primary goal of supplying a consistent quantity of high-quality water. The differences are related to the different contexts: water availability, development levels, population growth, resource exploitation, pollution levels and environmental degradation. Brazil's various regions lack equipment and technicians, which influences the supply of data and studies of potential water sources and the quality and quantity of water resources, particularly groundwater.

Both Brazil and the European Union are facing problems related to quantity and quality of water. Problems like scarcity of freshwater, contamination, salinization, and floods. This makes the realities of them quite close, despite the physical distance between them.

Brazil's and Portugal's margins for the protection of rivers illustrate the need to establish a global model based on environmental preservation characteristics rather than anthropogenic needs. Both the Paraíba do Sul and Tagus Rivers (Figs. 1 and 2) require larger areas of vegetation along their banks. The reforestation of the banks of these rivers is fundamental to improving the quantity and quality of their waters.

In generally, both Brazil, Rio de Janeiro, the European Union and Portugal have similar water resource management requirements. If both regions are to supply a consistent quantity of high-quality water to present and future generations, then they need effective laws and plans, efficient managing agencies, political interest and economic resources. Additionally, they must implement measures regarding proper land use, availability of groundwater recharge areas, preservation of green areas, pollution control, and control of the availability and use of water resources in urban and rural areas. However, if their governments are to effectively face the various agents of environmental degradation, then they must develop and promote a global environmental culture in which water resources play an important role. Therefore, a balanced environment is intimately related to the consolidation of environmental principles. Education may significantly disseminate knowledge among the general population. It is important that the principles of water management that ensure the quality of the environment and all of its dimensions are continually promoted and defended. Investments in research and developing water resource management plans are inefficient measures if they are not implemented with special emphasis on monitoring and inspection.

The main reasons for performing this study were the growing scarcity of freshwater in the world, recurrent problems in managing this

Table 5
Good and poor water management practices.

Good water management practices	
Brazil/Rio de Janeiro	European Union/Portugal
Development and implementation of water resource policies; increase in environmental awareness.	Development of new technologies to provide an adequate quantity of high-quality water; significant investments in research and education.
Poor water management practices	
Little control over pollution and environmental degradation; disorderly occupation of urban and rural land; little control over the preservation of riparian forests; lack of environmental restoration actions; little investment in sanitation; little control over the use of surface water and groundwater.	Environmental degradation in favor of economic and technological development; little integration between water resource management initiatives and other sectors.

resource and a desire to contribute to the improvement of the current situation. The study of water management in different contexts allows for a greater understanding of the subject and thereby assists the decision-making of managers and society in general with regard to environmental quality and ecological and human health.

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