Water Policy in Brazil

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Summary

Abstract

In this document the authors describe the distribution, the availability and the contamination of the water resources in Brazil as well as the water policy needed to cope with these problems. The institutional organization of the integrated management of water in Brazil is presented, and challenges to further develop a water policy in Brazil are discussed.

These challenges range from, a better enforcement of a legal framework at watershed level, to reduce contamination and disasters which occur due to hydrological changes and watershed degradation, to the development of technologies for an adequate ecological management of water resources with regards to watershed protection, restoration, prevention and deterioration. Investments in Science, Innovation and Technology dedicated to water resources need a vigorous and long term strategy in order to sustain a permanent improvement on the water policy. Regions which require a special attention with regards to the water policy in Brazil are the Amazon and the Northeast.

Key words: Water resources; water availability; water quality; hydrological cycles, contamination, management; water policy.

1- Introduction: Water Resources in Brazil

Brazil has 12% of the Planet Earth's fresh water resources. These resources are unevenly distributed throughout its national territory, which extends from 5º north latitude to 34º south latitude, with a variety of climates and climatological influences which range from the Equatorial region, to the cold fronts originating in the Antarctic Zone. The average precipitation in Brazil (historical data 1961-2007) is of 1.765 mm, ranging from 500 mm in the semiarid regions of Northeast Brazil to 3.000 mm in the Amazon region. (fig.1)

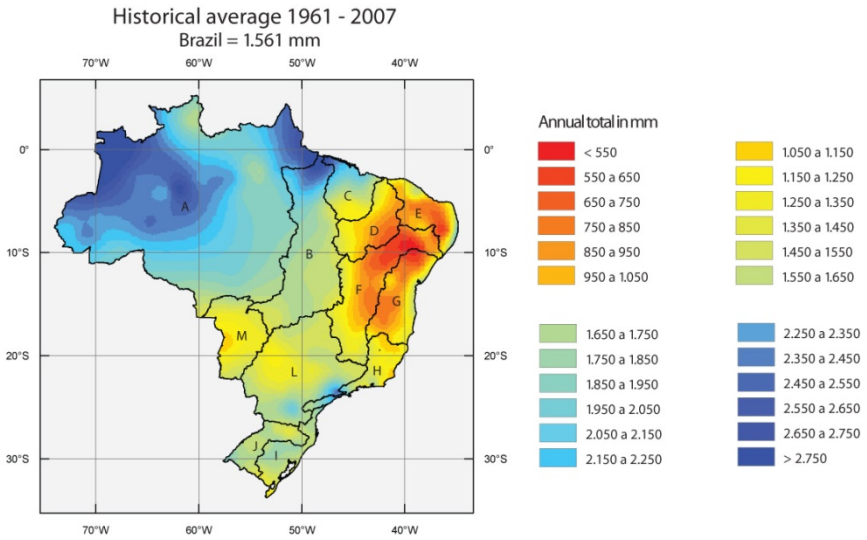


FIG. 1 – Average precipitation in Brazil (source ANA 2009)

The main watersheds of Brazil are represented by 12 hydrographic regions. The three most significant ones are: the Amazon Watershed, The Paraná Watershed and the São Francisco River Watershed. (fig. 2)



FIG 2 – The twelve hydrographic watersheds of Brazil (source ANA 2009)

In fig. 3 we see the spatial distribution of specific water discharge which ranges from less than 2 liter/second/km^2 (in semiarid region of the Northeast) to more than 30 liters/second/km^2. Currently, fluviometric stations all over Brazil are providing representative data showing specific discharge at all twelve watersheds.

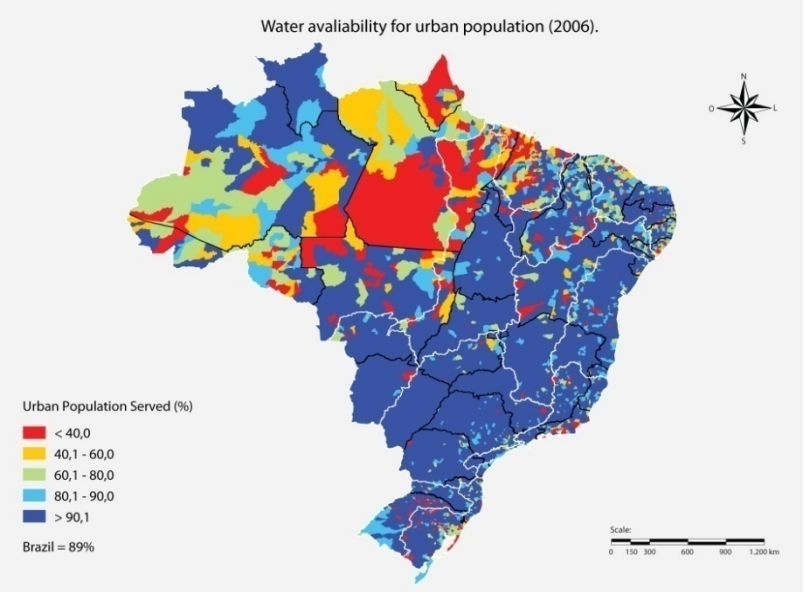


FIG 3 – Spatial distribution of specific discharge in Brazil (source ANA 2009)

The distribution of ground waters in Brazil is also inconsistent. There are regions with abundant water availability (such as The Guarani Aquifer in southern Brazil and other sedimentary aquifers) and regions with low availability (such as those of the crystalline rocks in the semiarid regions). The sedimentary aquifers occupy 48% of Brazil´s total area. Figure 4 shows the area of recharge of aquifers in relation to the twelve hydrographic basins. The number of new wells constructed for exploitation of ground water is around 10.500/year in Brazil, which shows the economic importance of this resource.

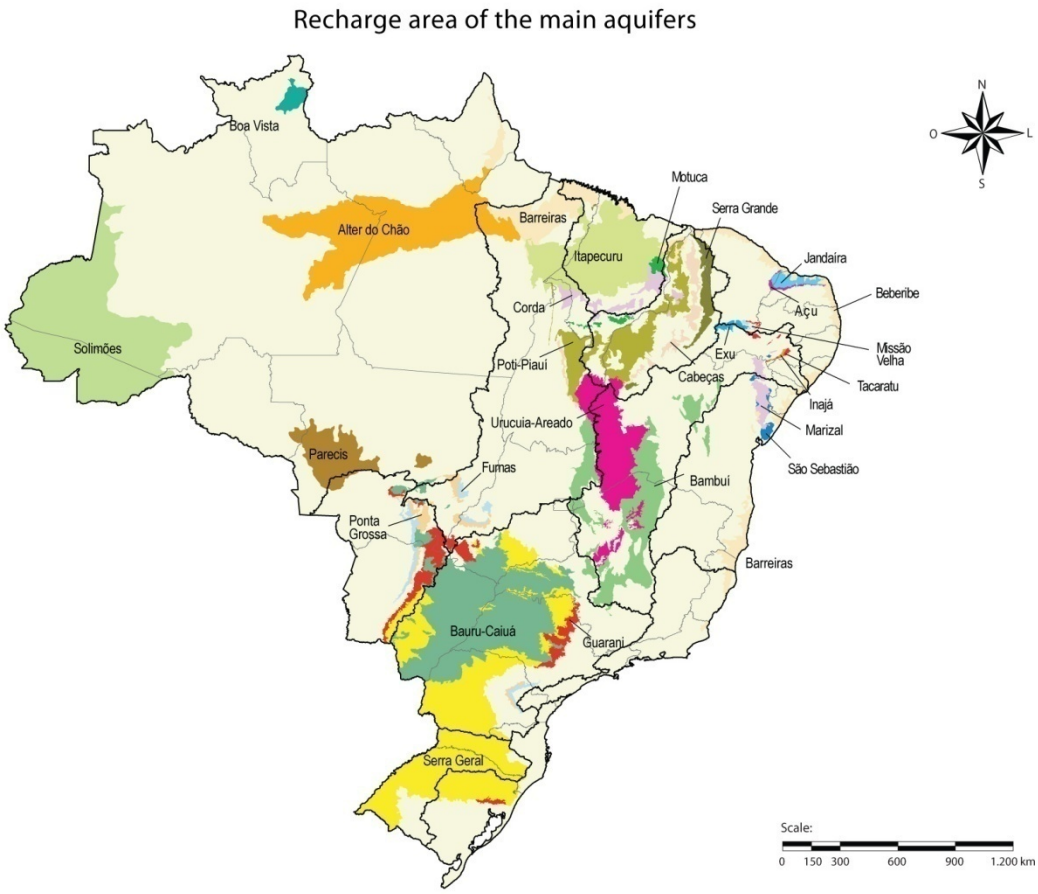


FIG 4 – Area of recharge of the main aquifers in Brazil (source ANA 2009)

2- <u>Water uses</u>

As in many other countries or regions of the world the forms of utilization of water in Brazil are diversified and their intensity is related to the economic, social and agricultural development in the 12 watersheds. Among the consumptive uses are: public supply (urban and rural), industry and irrigation. As for non consumptive uses, we can cite: hydroelectricity, fisheries, navigation, agriculture, tourism and recreation). (fig. 5)

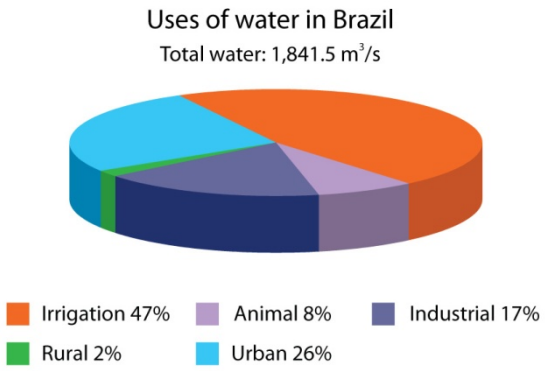


FIG 5 – Water uses in Brazil (source ANA 2009)

An important issue in Brazil is the discharge of used water into reservoirs, rivers and lakes. When this water is not treated (as is frequently the case) it becomes a problem that needs to be seriously considered, seeing that the water becomes unavailable to support any other activity which depends on clean water.

Hydroelectricity generates 68% of the total energy produced in Brazil (ANEEL 2008). The potential of hydroelectricity in the southeast of Brazil is now almost worn out, therefore a large percentage of them potential of hydropower still remains in the Amazon region (70% of all hydroelectricity potential of Brazil). This is an issue which needs to be considered for the future water policy in Brazil (Tundisi & Matsumura-Tundisi (2010a); Tundisi and Campagnoli in preparation).

3- Multiple water uses and conflicts

The multiple uses of water in Brazil, together with the economic development of the country, have generated conflicts in the following areas:

i. Water use in agriculture and the supply of water for urban areas;
ii. The public supply of water has been affected due to an increase of agribusiness production and deforestation, which have affected areas of recharge of aquifers, and water quality at their sources.
iii. Expansion of urban non treated solid waste disposal and the water quality of surface and ground water.
iv. Expansion of hydroelectricity impact in the tributaries of the Amazon River and disruption of the hydrosocial cycle.
v. Heavy contamination by toxic metals, eutrophication, excessive use of fertilizers in agriculture, discharge of non-treated domestic water and costs of water treatment.
vi. Increase in the cost of treatment of water due to the degradation of the sources, deforestation, and contamination of aquifers.
vii. Impacts of degraded water on human health, mainly in urban and metropolitan regions.

4- The Water Quality in Brazil

The present situation of water quality in Brazil is a consequence of several impacts which resulted from the following situations

i. Urbanization and discharge of non-treated waste water in rivers, lakes and reservoirs; (UNESCO, UNEP, 2008).

ii. Inadequate disposal of solid waste, which impacts the surface and the ground waters.

iii. Agricultural activities with excessive use of fertilizers, pesticides and herbicides;

iv. Industrial activities with effluents containing toxic metals; deforestation and the increase of transportation of suspended material reducing the volume of the reservoirs, changing morphometry of the rivers and the natural lakes; mining activities degrading the surface and ground waters; production of hydroelectricity and construction of reservoirs which change river flows, river biodiversity and are the cause of several impacts on major watersheds such as the Paraná, São Francisco and the Amazon River tributaries (Straskraba & Tundisi 2008; Tundisi & Matsumura-Tundisi,T. 2008).

As a consequence of the several economic activities and the multiple uses of water, the main problems of water pollution and contamination are: the increase of toxicity of the surface and ground waters; the eutrophication of rivers and reservoirs with excessive growth of toxic cyanobacteria causing organic contamination of water sources, especially near the large urban centers and metropolitan regions; siltation; and emission of greenhouse gases from eutrophic waters. (Azevedo 2005;Jorgensen et al 2005; Tucci & Mendes 2006; Straskaba and Tundisi 2008; Tundisi et al 2006; Abe et al 2009; Sidagis Galli et al 2009; ANA 2009; Bicudo, Tundisi and Cortesão S. 2010).

The Water Quality Index shows critical negative values in the upper Paraná watershed (Tietê and Iguaçu Rivers) located in the south and southeast regions. The cost of water treatment in the watersheds of the southeast and south regions is very high (more than 200 US dollars/1.000m^3). The Trophic State Index for Brazil is also high in the southeast and south regions. Eutrophic and hypereutrophic waters in these regions are a source of heavy expenses with regards to water treatment, impairing multiple uses such as recreation, tourism and fisheries (Tundisi et al 2006).

As a general trend, the surface and ground waters of watersheds of the South, Southeast and Northeast have a low Water Quality Index and a high Eutrophic Index as a result of human activities and the concentration of waste water and toxic substances and elements (fig.6 and fig.7).

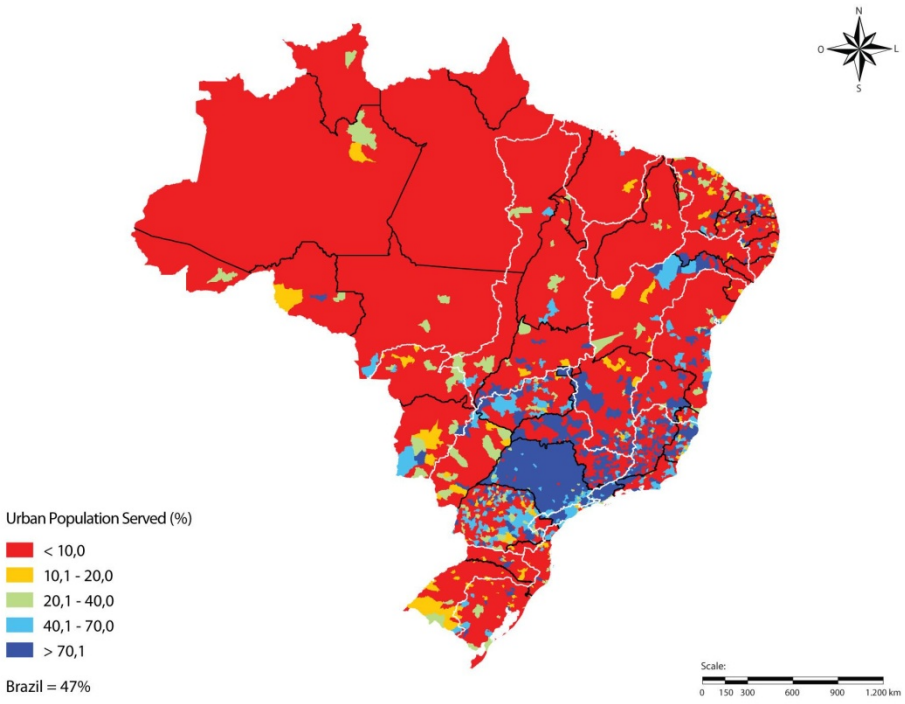


FIG 6 – Percentage of treatment of wastewater in Brazil (source ANA 2009)

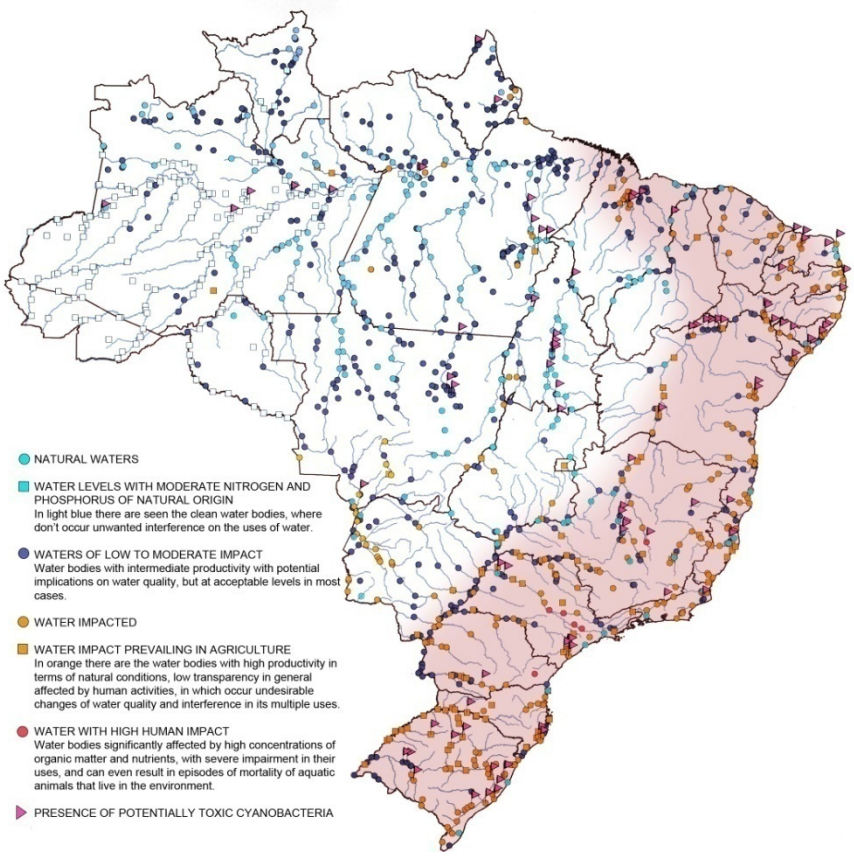


Fig. 7 – The Scenario of the water quality in Brazil 2007 (source: Moss & Moss 2005)

In certain regions of the country, such as in some reservoirs of the Paraná and São Francisco watersheds, the use of water for fisheries, recreation and to supply the population was prohibited due to the heavy degradation.

The degradation of water quality in Brazil can also be aggravated due to hydrologic extremes. For example, with heavy rains and high discharge in urban and metropolitan regions, contamination can increase three to four times its usual (Tucci & Mendes, 2006; IIEGA/PMSP 2009). During extreme events of dryness in the Northeast, eutrophication in reservoirs, used for storage of drinking water and for quenching animal thirst, can frequently be a source of water quality degradation.

A general overview and trend of the capacity of assimilation of organic discharge also shows a picture that matches the Water Quality Index and the Trophic State Index: the surface and ground waters of the watersheds located in the south and southeast region have low capacity of assimilation of organic discharge, whereas in the Amazon region

watersheds have high capacity for assimilation of organic discharge (78% of the Amazonian rivers). (ANA 2009).

5- The Institutional Development of Water Resources Management

The Brazilian water law was edited by the Federal Government in 1997 (law 9.433 of January 8th, 1997). From that year on, until 2007 all 27 Brazilian states, edited their water law. The Brazilian water law promoted several advances in the integration of management of water resources in Brazil: first an ample decentralization process was put into practice, with each state implementing their own watershed committees consolidating their plans and their watershed agencies. In addition they created a plan for the economic development of the watersheds and for the use of water, and formed state agencies responsible for controlling pollution and water contamination. The advances in the legislation were registered in regions or states where water conflicts over water uses and water availability existed ANA (2002). The process of institutionalization, therefore is more advanced in the south, southeast and northeast watersheds where initial problems already occurred. The National System of Integrated Water Management in Brazil consists of the National Council for Water Resources, the Secretary of Water Resources of the Ministry of Environment, the National Water Agency, the State Councils for Water Resources, the State Agencies and the Watershed Committees and Watershed Agencies (Braga et al 2006).

The consolidation of the institutional framework in Brazil is also due to the establishment of mechanisms to support research and development in the water sector: The implementation of the sectorial funds on water resources, which allocates 1% of the profit of private business in water to support projects on mineral research, hydroelectricity and environmental problems, was a major achievement. These sectorial funds, established in 1999, enabled scientific and technological development, which supported the work of the watershed committees and agencies. Therefore financial resources are now adequate for the expansion of water research and for technological advances.

These advances at federal and state levels were not followed by the organization of the water management at the municipal level; therefore, this is one of the major challenges needed to be addressed in the water policy in Brazil. Another relevant challenge is the need to establish adequate pricing

mechanisms. For example, agricultural use of water is heavily subsidized thus preventing better and more efficient use of water for food production.

For the interstate watersheds, plans for water resource management are in progress but show slow advances. The specification of desired standards of water quality of the rivers, lakes and reservoirs related to the multiple uses of water, is also slow, considering the economic pressure for more water withdrawals in different sectors of activities.

The licensing for water withdrawals has been in progress since the editing of the water law in 1997. This authorization is given by the National Water Agency and includes all multiple uses such as public supply of water, extraction of ground water for several purposes, hydroelectricity and food production. Currently water license for withdrawals has been given to 3.520m3/s in several of the twelve watersheds of Brazil (ANA 2009). The largest water withdrawals licenses were granted in the Paraná watershed (1.300m^3/s).

The National System of Information for water resources in Brazil is coordinated by the National Water Agency and started to be implemented in the year 2000.

This system consists of four major components: subsystem of use and regulation; subsystem of planning and management; subsystem of quality and quantity and a subsystem of "water intelligence" (geographical/territorial information and documentation on water resources)*.*

Water pricing is at present implemented in four watersheds, in Brazil, with a tendency to improve and be established in federal and state rivers.

6- Challenges for the Water policy in Brazil

6.1 Social challenges

Despite the institutional progress in the organization of the integrated water resources management in Brazil, huge problems still exist with regards to proving water and sanitation services to the entire population. The water availability is relatively good, with about 80% of the population being supplied with clean water. But the sanitation problem is enormous and complex. With only 30% of the wastewater being treated and very poor systems of solid waste disposal and removal, the contamination of surface and ground waters are high and severely impact human health (ANA 2009). As expressed in OECD (2003) "many social issues involved in water management" (pg 33. "key trends and challenges") can be analyzed in terms of "equity". This means equity among income groups. In Brazil poorer consumers can be found paying more for the

water due to an inefficient distribution system. And in the surroundings of the urban areas of all metropolis of Brazil (São Paulo, Rio de Janeiro, Salvador, Recife, Porto Alegre, Belém, Fortaleza and Manaus) around 30 million people need adequate sanitation (solid waste disposal and wastewater treatment) (Tundisi and Matsumura-Tundisi, 2010c). The current situation of urban rivers is a picture of this problem: most urban rivers in large cities or small towns are polluted and degraded and need urgent projects for restoration and recovery (Tucci and Mendes, 2006).

There is also a disparity among regions with regards to having access to water services and wastewater treatment. Rural populations are affected in many regions of Brazil with regards to having limited access to water and sanitation services. Consumption levels also show disparities among regions in Brazil (Rebouças et al 2006).

The large scale deficit in sanitation in Brazil is thus a social challenge of the highest priority, concerning reduction of vulnerability of periurban populations. Diseases generated from poor water distribution or non treatment of wastewater is high.

The changes in the hydrosocial cycle as a consequence of human activities such as the construction of reservoirs, are not yet well understood in Brazil and efforts to measure the impacts, reduce or remove them are needed especially considering the expansion of the hydroelectricity production (Tundisi and Campagnoli, in preparation).

6-2 Integrated water resources and watershed management

Efforts to implement an integrated policy for the management of water resources at watershed level in Brazil have to be enhanced through the support of the large scale decentralization program which is currently in progress. This will include attention to surface and ground water management, and the promotion of an integration of biogeophysical data, soil uses, agricultural activities and water quality of streams, large rivers, reservoirs and lakes (Braga et al 2006, Tucci 2007). The pressure to increase food production is becoming a threat to natural areas of forests, riparian vegetation and wetlands. Removal of vegetation by increasing the area of agriculture is one of the urgent problems to be solved by both the municipalities and the federal and state agencies. Changes in water quality of surface water due to the removal of riparian forests, mosaics of vegetation and wetlands were demonstrated recently (Tundisi &

Matsumura Tundisi 2010b). A modification of the forest protection law in benefit of agriculture production is in discussion in the Brazilian Congress, mobilizing society, the Brazilian Academy of Sciences and scientists in order to stop changes that will be harmful to the water availability and quality as well as to biodiversity.

On the other hand there are several initiatives to improve reforestation by promoting incentives to farmers. These initiatives at municipal level are being adopted in many regions of Brazil and will undoubtedly be countermeasures to the deforestation process and the possible changes in the federal law. In many Brazilian towns of 200.000 to 500.000 inhabitants, the proposal for the protection of areas that are important to water supply and aquifer recharge have been made, creating new opportunities for improving water management.

The improvement of the practices of river basin management, adopting the ecosystem approach, is a step that is being incorporated in water management initiatives in Brazil. Though this is still a relatively slow process, this concept is already established in several states and regions reflecting a positive trend in the necessary advances for management (IIEGA/PMSP, 2009).

6.3 Protection and restoration of surface and ground waters

The large scale of contamination and pollution in Brazil is a consequence of a long term process of watershed degradation, discharge of wastewater, excessive soil uses and toxicity impacts. The degradation of the ecological values and services of freshwater ecosystems is followed by a general increase in the vulnerability of populations (urban and rural) to toxic chemicals and pathogens. The capacity of fish production in rivers, reservoirs and lakes has been impaired by this deterioration either directly, by producing mass mortality, or indirectly, by stopping consumption of contaminated fish, crustaceans and mollusks (Tundisi et al 2006). Dealing with invasive species is another management priority. Mollusks such as *Limnoperna* fortunei (mussel) and fishes introduced from other continents or even other watersheds in Brazil are considerably changing the structure of food chains and in the organization of the ecological network in rivers, lakes, and reservoirs, with impacts on fisheries (Rocha et al 2005).

Additionally, the intensive development of aquaculture with non native species is an impact of considerable magnitude in several watersheds in Brazil. Technologies for restoration of watersheds need to be introduced at a larger

scale in Brazil (Zalewsky 2007). Ecohydrological technologies combined with ecological processes can reduce costs of restoration, prevent floods and inundations and can be a new alternative technology to be applied in many regions of Brazil (Straskaba & Tundisi, 2008). In urban and metropolitan regions ecohydrological technologies are in progress (IIEGA/PMSP 2009), though still very limited to a few experiences.

6.4 Climate change and water resources

For the last 10 years, studies on the variability of climate and climatic changes in South America and in Brazil are being developed with great intensity. Variations in rainfall and discharges in the Amazon and Northeast Brazil show interannual and decadal patterns. These variations are more important than the trends for the constant reduction of rainfall (Marengo 2006). Variability is associated to patterns of oscillation related to the El Niño (ENOS), the Pacific Decadal Oscillation – PDO, The North Atlantic Oscillation – NAO and the variability of Tropical and South Atlantic.

Impacts of the El Niño or La Niña have been observed in the north and northeast regions (dry periods) and South Brazil (dryness during La Niña and excess rainfall and floods during El Niño). With the increase of the frequency or intensity of El Niño, Brazil will be subject to more dry periods or floods or warmer spells (Marengo & Nobre 2001; NAE (2005 a,b); Marengo & Silva Dias (2004a).

The phenomena of El Niño and La Niña in the Equatorial Pacific, and the meridional gradient of the temperatures (temperature at sea surface) over the Tropical Atlantic are responsible, in great part, for the interannual variability of climate in South America. Cold fronts from Antarctica affect the climate of the south and southeast regions and the ecological and limnological functioning of lakes, rivers and reservoirs (Tundisi et al 2004, 2006, 2010). One important achievement in the studies of the water flux in Brazil was the understanding of the fundamental role the Amazon region plays on the water balance and hydrological cycle of central and southeast areas of Brazil. Marengo et al (2004 a) have proposed a conceptual model, with jetts of moisture being transported from the Amazon to the Southeast and la Plata basin. (fig. 8)

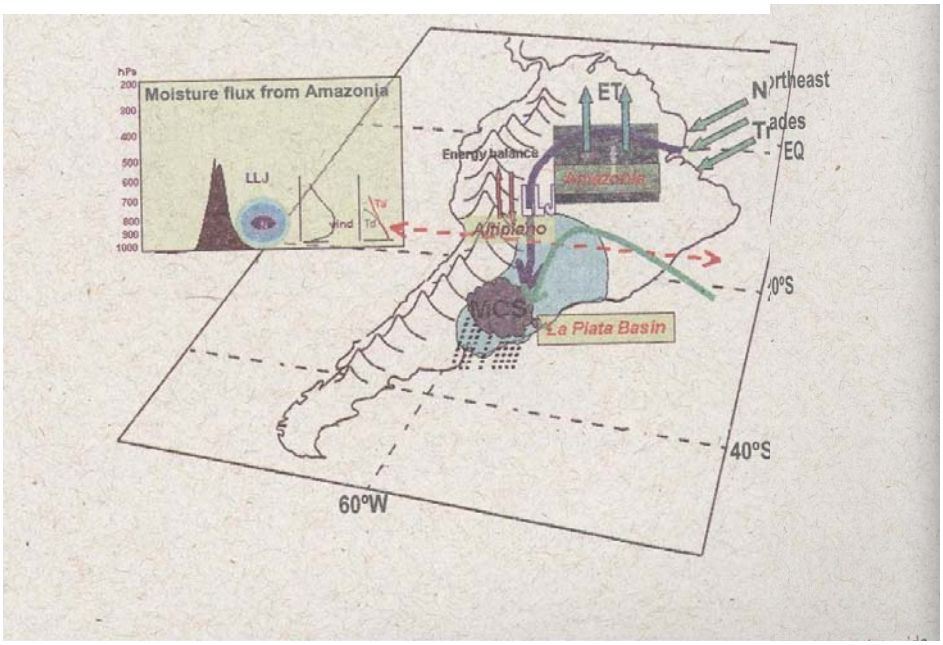


Fig.8 – The moisture flux from Amazonia to the Southeast accordingly to the conceptual model of Marengo el al (2004 a)

The climate changes in Brazil and the impacts on the hydrological cycle, water distribution, floods and dry periods, have to be understood against a large scale of land use, deforestation and increased and inadequate solid waste disposal. For example, a synergy between untreated wastewater and the warming of surface temperature in lakes and reservoirs, could result in heavy blooms of cyanobacteria and increase in the frequency of toxic blooms as discussed by Tundisi et al (2010).

The "savanization" of the Amazon could result in 30% less water for the south and southeast regions of Brazil, with enormous social and economic impacts. Changes in discharge of rivers of the Pantanal (largest wetland in the world 200.000 km^2) were already observed by Tucci (2003), Tucci & Braga (2003). The impacts of climatic changes can affect human health, also, due to the increase in the number of temporary ponds and the growth of vectors of water borne diseases (NAE 2005 a,b).

The water policy in Brazil is addressing some of the problems related to possible climatic changes and their impacts in the water quantity and water distribution. The *Nucleo de Assuntos Estratégicos da Presidência da República* – the Nuclei for Strategic Studies of the Presidency of Brazil has developed studies, scenarios and trend analysis in order to promote policies for adaptation and mitigation of the impacts of climatic changes such as large floods in urban

areas or long dry periods in certain regions (Tucci and Mendes 2006, Tucci 2007).

Seminars on climatic changes and possible impacts on the water resources led to discussions and proposals for the intensification on modeling efforts in order to develop more accurate scenarios of consequences of climatic changes in the hydrological cycle and on the economy (Tundisi, 2010, in press).

6.5 The Hydrological extremes and impacts in Brazil

In the last five years hydrological extremes combined with inadequate use of land and watershed deterioration have caused many disasters in Brazil with loss of lives and properties. In January 2011 landslides due to heavy precipitation, well above the average for Southeast Brazil, claimed 1.000 lives and economic losses of U$ 500 million. (Fig. 9)



Source: http://satelite.cptec.inpe.br/acervo/loop/?idFonte=14. January, 13th 2011.

Fig. 9 shows the extension of the cold front in Southeast Brazil that resulted in disasters on January 13th 2011. This was a result of cold fronts from the Antarctic with a contribution of excess moisture from the Amazon resulting in heavy rains and excess drainage. The prevention of these disasters, by removing people from potential areas of impact, by educating decision makers to apply correct public policies, by creating artificial wetlands and areas of water retention, is an urgent need (Tucci and Braga 2003, Tucci 2007). The potential population in Brazil subject to these disasters and living in areas of risk is 20 million people. The prevention of these disasters should be a priority in the water policy in Brazil, articulated with territorial and regional studies and water management.

6.6 Contamination of coastal waters

The concentration of the human population in urban and metropolitan areas resulted, as shown, in the contamination of rivers, lakes and reservoirs in an unprecedented scale. Since most of the Brazilian population is also concentrated near or in the coastal areas, contamination of estuaries, bays and coastal waters is also increasing. Lacerda et al (2008) have shown that nitrogen and phosphorus from anthropogenic sources are producing an over enrichment of the estuaries along the Ceará, state coast in Northeast Brazil. This is mainly due to urban runoff and solid waste disposal affecting surface waters. Evidence of contribution of non point emissions of Cd and Zn contamination in Sepetiba Bay (Southeast Brazil), confirm the quantitative importance of these sources (Lacerda and Molisari 2006). Recovery of estuaries, impacted by point and non point sources of contaminants and nutrients originated in urban regions near coastal areas, is urgently needed.

6.7 Improvement of drinking water quality, risk control and vulnerability reduction

Contamination of drinking water due to poor infrastructure occurs in Brazil in large and small towns. The most common cause is the contamination of the distribution systems. Corrosion of pipes, damages to pipes due to construction or repairs, low pressure on pipes, all lead to outbreaks of waterborne diseases. Inadequate control of chemical substances and inadequate filtration are other causes.

There is a need to improve the technical quality of the distribution and water treatment systems. Monitoring of water quality at the catchment (introduced in the year 2000), was a significant policy implemented for the control of water contamination in Brazil, assisting in the determination of adequate treatment for drinking purposes. This is a compulsory law enforced in all of Brazil (Tundisi and Matsumura-Tundisi, 2010c).

The control of water quality for drinking purposes also needs the implementation and introduction of advanced technology in order to establish limit standards to the presence of persistent organic pollutants (POPs). Increased risk and vulnerability of human population to dissolved organics and viruses have to be considered in the development of new molecular techniques.

6.8 Strategic studies

6.8.1 Hydroelectricity

Strategic studies on the use of hydroelectricity should address the Amazon region that could potentially supply, in the future, 70% of the hydroelectricity of Brazil. This must be considered regarding biodiversity loss, greenhouse gas emissions, and change in the hydrosocial cycle in the river morphology and flow. As the aquatic fauna of rivers is severely impacted by reservoirs, the large catfish living in the tributaries of the Amazon can be affected running the risk of depletion of stocks and even extinction. Therefore the location, engineering, retention time, volume and inundated areas of reservoirs should be strategically studied in order to preserve important areas of mega biodiversity and the hydrosocial cycle (Tundisi and Campagnoli, in preparation).

6.8.2 Water and economy

The relevance of the national water resources in the economic development of Brazil is well known. Water is fundamental for food production, hydroelectricity, navigation, recreation and fisheries. Studies on the relationship between the limits of economic growth and the surface and ground water availability are required. The use of economic instruments to manage water resources (such as the water polluter pays or the water consumer pays principles) requires further strategic studies (Canepa et al 2006, Hartman 2010).

6.8.3 The social and economic impact of hydrological changes and extreme conditions

As referred by Tucci (2007), the management of risks related to natural disasters has social and economic implications that need to be analyzed. Between 1994 and 2003 losses due to natural disasters amount to 6.8 billion U$ dollars in all countries. The recent trend in the growth of natural disasters is due to the increase of the population in areas of risk, increase of urban growth and variability of the hidrological cycle associated to climatic changes. In Brazil with 80% of the human population located in metropolitan regions or urban areas, infrastructure and soil use are deteriorated especially in the periurban areas of midsize (< 1.000.000 inhabitants) or larger metropolis (> 5.000.000 inhabitants). Areas of risk are extensive and the population considered vulnerable amounts to about 20 million inhabitants. The fragmentation of the watersheds due to urbanization is a reality, generating consequences on the water cycle, floods and the deterioration of water quality. Strategic studies on these impacts, development of alarm systems, and removal of populations are urgent actions needed to improve the National water policy.

6.9 Water and Human Health

In Brazil many water borne diseases still persist despite national government efforts or regional actions. Schistosomiasis, Leptospirosis intoxication by toxins of cyanobacteria, and dengue fever are diseases that affect millions of people all over Brazil, especially in periurban areas and rural villages (700.000 cases of dengue fever in 2008 and 8.000.000 infected with Schistosomiasis all over the country (Confalonieri et al 2010). One relevant development in the area of water resources and human health is the management of contamination and the adoption of targets to reduce morbidity and mortality due to lack of sanitation. Children of one up to five years of age are affected by water borne disease causing high infant mortality. The development of an index of water/human health/environment could be very helpful in the setting up of targets based on concrete actions and measures (Confalonieri et al, 2010).

6.10 The Amazon and northeast regions of Brazil

An integrated management of water resources in the Amazon region is a priority. The characteristics of this region consisting of high rainfall, abundant discharge of rivers (Amazon River: 225.000 m^3/s), interactions of rivers and forests and high biodiversity are relevant natural assets of Brazil. Investment in Science and Technology in the Amazon and the further development of

ecological studies articulated with economic evaluations of the “natural capital” and ecosystem services, and a better knowledge of the hydrosocial cycle - such as the Homo sapiens interaction with the water and ecosystems - is a priority. Efforts in capacitating technical staff of scientists and water managers are essential (Val et al 2010).

An equally relevant challenge is the semiarid region of Northeast Brazil. This is the home of 30 million people that suffer from water scarcity on a daily basis. The São Francisco River, which is the most important water source for the Northeast, is now suffering a process of water depletion, contamination by heavy metals and toxic substances, and water discharge. The waters of the São Francisco River are now being transferred to the eastern and western parts of the northeast region, through a series of artificial channels (26 m^3/s). This could change the economy and the life quality of millions of people. Notwithstanding, the success of this process depends on close evaluation of the development programs and human capacity building.

6.11 International watersheds

Brazil and 4 other countries (Argentina, Bolívia, Paraguay, Uruguay) share the La Plata Basin with, 3.000.000 km^2 and 120 million inhabitants. The Amazon Basin shared by Ecuador, Peru, Colombia, Venezuela, French Guiana, British Guiana and Suriname, has 5.000.000 km^2, scarce population and abundant water supply.

In the water policy of Brazil, the integration with these countries in the sharing of water resources is essential for future economic development and future multiple uses.

6.12 Research needs

There is a need to include Science, Technology and Innovation in the planning and implementation of integrated water resources management. Research, technology and innovation are essential components of the integrated management process. Improving technology for eutrophication and contamination abatement, development of new desalination technologies and water reuse, and implementation of data banks of national and regional levels constitute major challenges. Integration of ecologists, engineers and limnologists is needed for these advances (Hespanhol, 2010, Tundisi and Matsumura-Tundisi 2010a). Research to support technical criteria for adoption

of measures for protection and vulnerability of aquifers is also needed (Hirata et al 2010). Additionally, the development of guidelines of contamination based on bioindicators, ecological and limnological studies at different watersheds are needed (Bere and Tundisi 2010, Tundisi et al 2010a).

7. Summary and conclusions

The water policy in Brazil considering present and future perspectives was discussed in this document. Brazil is a country with abundant water resources unevenly distributed in relation to the distribution of population and economic activities. Water uses in Brazil are diversified with approximately 70% used in agriculture and 30% in water supply for human uses, industries, fisheries, recreation, tourism, navigation and hydroelectricity. The Brazilian water law was established in 1997 and the implementation of integrated water resources management has evolved since then. In 10 years, the 27 states in Brazil have established councils for water management and systems of water management throughout the watershed committees. In 2001 the National Water Agency was founded with the objective to coordinate actions at federal level, and help implement the integrated water management process at each region with federal rivers and each state of the Brazilian federation. Despite considerable advances at institutional level and a continuous search for efficiency and decentralization, problems remain.

Brazil water policy challenges:

- Further efforts to implement integrated watershed management at the watersheds (state and national watersheds);
- Adopt water quality targets, sanitation targets (domestic wastewater treatment and solid waste disposal and treatment), in order to reduce risk and vulnerability especially of periurban and rural populations;
- Promote heavy investments at federal, state and municipal levels to reduce water contamination by fertilizers, pesticides and toxic metals;
- Develop strategies for solving conflicts over multiple water uses: hydroelectricity in areas of high biodiversity (as the Amazon region), regional impacts on the hydrosocial cycle, growth of agriculture and deforestation, with impacts on water sources for public supply;

- Develop and stimulate strategic studies in water resources, economic development and the use of economic instruments for integrated water resources management (the polluter pays and the consumer pays principles).
- Promote integrated watershed management, with an ecosystem concept introducing new and less costly technologies such as ecohydrology and ecotechnologies. These management practices can be articulated with ecological studies and the introduction of technologies for recovery of streams, urban rivers, large rivers, and protection of aquifers.
- Promote studies for the economic evaluation of freshwater ecosystem services such as the role of wetlands and riparian forests in the maintenance of water quality and water quantity and maintaining biodiversity.
- Develop strategies, study groups and implement actions for the reduction of the impact of disasters of hydrological origin due to climatic changes and inadequate land use. This includes risk analysis of critical areas.
- Improve research on biological indicators, on modeling of aquatic ecosystems and the studies and strategic evaluations of the future of water resources, quality and quantity and water reuse.
- Promote and implement adaptive management strategies to cope with the impacts of climate change on the hydrological cycle, water availability and water supply.
- Provide support to improve capacity building of managers and technology transfer to all regions of the country and develop actions for mobilizing public participation at watersheds level, promoting education on water resources issues for all the Brazilian population.
- The Amazon and northeast regions of Brazil should have special attention considering the peculiar characteristics of their hydrosocial cycles, the extreme dependence on water for local and regional development and the need for a national capacity building effort in these regions.
- Promote studies, evaluating the impact of the use of ground water. Promote the monitoring of the quality of ground water and manage over exploitation in certain regions.
- Develop water resources management at internationally shared watersheds, as part of the water policy of Brazil.

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References

Abe S., D.; Sidagis-Galli, C.; Matsumura-Tundisi, T.; Tundisi, J.E.M.; Grimberg, D.E.; Medeiros, G. R.; Teixeira-Silva, V.; Tundisi, J.G. 2009. The effect of euthrophication on greenhouse gas emissions in three reservoirs of the Middle Tietê River, Southeast Brazil. Verh.Internat.Verein.Limnol.vol 30, Part 6, p. 822-825.

Agência Nacional das Águas (ANA). 2009. Conjuntura. Recursos Hídricos no Brasil.Brasília, D.F. 203 pp.

Agência Nacional das Águas. 2002. A evolução da gestão de recursos hídricos no Brasil/The evolution of the Water Resources Management in Brazil. Brasília. 64 pp.

Azevedo, S.M.F.O.2005. South America: toxic cyanobacteria. In.: Codd,G.A., Azevedo, S.M.F.O., Bagchi, S.N, Burch, M.D., Carmichael, W.W., Harding, W.R., Kaya, K. & Utkilen, H.C. (eds). Cyanonet: a global network for cyanobacterial bloom and toxin risk management, IHP-Unesco, Paris, p. 115-126.

Bere, T. and Tundisi, J.G. 2011. Influence of ionic strength and conductivity on benthic diatom communities in tropical river (Monjolinho), S.Carlos, SP. Brazil. Hydrobiologia vol. 661 pp. 261-276.

Bicudo, C.E.M.; Tundisi, J.G.; Cortesão S., Marcos (Editors) 2010. Águas do Brasil: analyses estratégicas. Academia Brasileira de Ciências. Secr. Meio Ambiente Estado de São Paulo, 222 pp.

Braga, B.; Flecha, R; Pena, S.D.; Felman, J. 2006. A reforma institucional do setor de recursos hídricos. In: Rebouças, A.;Braga,B.; Tundisi, J.G (Editores). Águas doces no Brasil: capital ecológico, uso e conservação. Escrituras Editora, São Paulo. Pp; 639-673 (3ª edição).

Braga, B.; Porto, M. & Tucci, C. 2006. Monitoramento da quantidade e qualidade das águas. In: Rebouças, A.;Braga,B.; Tundisi, J.G (Editores). Águas doces no Brasil: capital ecológico, uso e conservação. Escrituras Editora, São Paulo. pp. 146-160 (3ª edição).

Cánepa, E.M; Pereira, S.J.; Lana, E.L. 2010. Água e Economia. Pp. 43-54. In: Bicudo, C.E.M; Tundisi, J.G.; Cortesão S.,M. (orgs). Águas do Brasil: Análises estratégicas. Academia Brasileira de Ciências; Secretaria Meio Ambiente, Estado de São Paulo. 222 pp.

Confalonieri, U.; Heller, Azevedo, S. 2010. Água e saúde:aspectos globais e nacionais. pp.27-38. In Bicudo, C.E.M; Tundisi, J.G.; Cortesão S.,M. (orgs). Águas do Brasil: Análises estratégicas. Academia Brasileira de Ciências; Secretaria Meio Ambiente, Estado de São Paulo. 222 pp.

Hartman, P. 2010. A Cobrança pelo uso da Água como instrumento economico da Política Ambiental. Aeba. 497 pp.

Hespanhol, I. 2010. Conservação e reuso como instrumentos de gestão para atenuar os custos de cobrança pelo uso da água no setor industrial. Pp. 59-76. In Bicudo, C.E.M; Tundisi, J.G.; Cortesão S.,M. (orgs). Águas do Brasil: Análises estratégicas. Academia Brasileira de Ciências; Secretaria Meio Ambiente, Estado de São Paulo. 222 pp.

Hirata, R.; Gomes Zoby, J.L.; Oliveira de, F.R. 2010. Água subterranean: reserva estratégica ou emergencial. Pp. 149-161. In Bicudo, C.E.M; Tundisi, J.G.; Cortesão S.,M. (orgs). Águas do Brasil: Análises estratégicas. Academia Brasileira de Ciências; Secretaria Meio Ambiente, Estado de São Paulo. 222 pp.

IIEGA/PMSP.2009. Manual de gerenciamento de bacias hidrográficas. 134 pp. São Carlos/São Paulo.

Instituto de Estudos Avançados. 2008. Dossiê Água. Universidade de São Paulo. 336 pp.

Jorgensen, J.E; Lofler, H.; Rart, W.; Straskraba, M. 2005. Lake and reservoir management. Elsevier. Amsterdam. 502 pp.

Lacerda, L.D; Molisani, M.M.; Sera,D; Maria, P.L. 2008. Estimating the importance of natural and antropogenic sources on N and P emission to estuaries along the Ceará State Coast. N.E of Brazil. Environ. Mon.t.Ass. vol. 141 pp. 149-164.

Lacerda, L.D. and Molisani, M.M. 2006. Three decades of Cd and Zn contamination in Sepetiba Bay SE Brazil: evidence from the mangrove oyster Crassoscrea rhizophorae. Mar.Poll. Bull. Vol. 52 pp. 969-987.

Marengo, J.A. 2008. Água e Mudanças climáticas. Pp. 83-96. In: Dossiê Água. Inst. Estudos Avançados, U.S.P. 336 pp.

Marengo,J.A.2006. Mudanças climáticas globais e seus efeitos sobre a biodiversidade. IBAMA 212 pp.

Marengo,J.A.; Silva Dias, P. 2006.: Mudanças climáticas e globais e seus impactos nos recursos hídricos. Capítulo 3 em Águas Doces do Brasil: Capital Ecológico, uso e Conservação, pp. 62-109. Eds. A. Rebouças, B. Braga, J. Tundisi. Editora Escrituras, SP.

Marengo, J.A; Soares, W.R; Saulo, C.; Nicolini, M. 2004a: Climatology of the Low-Level Jet East of the Andes as derived from the NCEP-NCAR reanalysis. Journal of Climate, 17, 2261-2280.

Marengo, J.A e Soares, W.R. 2003. Cap. 6. Impacto das mudanças climáticas no Brasil e possíveis futures cenários limáticos: síntese do terceiro relatório do IPCC. pp. 209-242. In: Tucci, E.M.C e Braga, B. (Organizadores). 2003. Clima e Recursos Hídricos no Brasil. ABRH.ANA. Forum Brasileiro de Mudanças Climáticas. 348 pp.

Marengo,J.A.; Nobre, C.A. 2001. The Hydroclimatological framework in Amazonia. In Biogeochemestry of Amazônia, Richey., McClaine, M., Victoria, R., Eds., pp. 17-42.

Moss, G. e Moss,M. (Editors) 2005. Brasil das Águas. Revelando o Azul do Verde e Amarelo. Petrobrás. 153 pp.

NAE 2005a: Mudança de Clima, Vol.I: Negociações internacionaos sobre a mudança de clima; vulnerabilidade, impactos e adaptação à mudança de clima. Cadernos NAE, Núcleo de Assuntos Estratégicos da presidência da República. NAE-SECOM 2005. Brasília, 250 pp.

NAE 2005a: Mudança de Clima, Vol.II: Mercados de Carbono. Cadernos NAE, Núcleo de Assuntos Estratégicos da presidência da República. NAE-SECOM 2005. Brasília, 500 pp.

OECD. 2003. Improving water management: recent OECD. Experience. IWA Publishing. 128 pp.

Rebouças, A; Braga,B.;Tundisi, J.G. 2006. Águas doces no Brasil: Capital ecológico, usos e conservação. Escrituras Editora, S. Paulo: 732 pp. (3ª edição).

Rocha, O.; Espíndola,E.; Fenerich-Verani,N.; Verani, J.R.;Rietzler, A.C. 2005. Espécies invaspras de água doce: estudos de caso e propostas de manejo. EDUFSCAR. 416 pp.

Sidagis-Galli, C.; Abe S., D.; Teixeira-Silva, V.; Medeiros, G.R; Brum, P.R.; Cimbleris, A.C.P. 2009. Greenhouse gas concentration and diffusive flux at the sediment-water interface from two reservoirs in Brazil. Verh.Internat.Verein.Limnol.vol 30, Part 6, p. 830-833.

Straskraba, M; Tundisi, J.G. 2008. Diretrizes para o gerenciamento de lagos. Vol. 9. Gerenciamento da qualidade da água de represas. 2ª Edição. ILEC/IIE. 300pp.

Tucci, C.E.M. 2010. Urbanização e Recursos Hídricos. Pp-113-128. In: Bicudo, C.E.M.;Tundisi,J.G; Cortesão S,Marcos (editors) Águas do Brasil. Análises Estratégicas. Academia Brasileira de Ciências;Secretaria do Meio Ambiente. Estado de São Paulo. 222 pp.

Tucci, C.E.M.2007. Inundações urbanas. ABRH;RHAMA. 389 pp. (1ª edição).

Tucci,C. & Mendes, A.G. 2006. Avaliação Ambiental integrada de bacias hidrográficas. MMA.PNUD. 311 pp.

Tucci, E.M.C e Braga, B. (Organizadores). 2003. Clima e Recursos Hídricos no Brasil. ABRH.ANA. Forum Brasileiro de Mudanças Climáticas. 348 pp.

Tucci, E.M.C. 2003. Recursos hidrológicos e os impactos do uso do solo. Pp. 31-76. In: Tucci, C.E.M, Braga, B. (Organizadores). Clima e Recursos Hídricos no Brasil. ABRH;ANA; GWP. Forum Brasileiro de Mudanças Climáticas. 348 pp.

Tundisi, J.G. and Campagnoli, F. 2011. How many more dams in The Amazon? (in preparation).

Tundisi, J.G. e Matsumura-Tundisi,T. 2010a. Ciência, Tecnologia, Inovação e Recursos Hídricos: oportunidades para o futuro. Pp. 179-197. In: Bicudo, C.E.M.;Tundisi,J.G; Cortesão S,Marcos (editors) Águas do Brasil. Análises Estratégicas. Academia Brasileira de Ciências;Secretaria do Meio Ambiente. Estado de São Paulo. 222 pp.

Tundisi, J.G and Matsumura-Tundisi, T. 2010b. Potential impacts of changes in the forest law in relation to water resources. Biota Neotropica. Vol. 10 nº 4, (in press)

Tundisi, J.G and Matsumura-Tundisi. 2010c. Recursos Hídricos no século 21. Oficina de Textos (in press).new edition.

Tundisi, J.G.;Matsumura-Tundisi,T.; Pereira, K.C; Luzia, A.P, Passerini, M.D.;Chiba, W.A.C; Morais, M.A; Sebastien, N.Y. 2010. Cold fronts and reservoir limnology: an integrated approach towards the ecological dynamics of freshwater ecosystems. Braz. J. Biol. vol.70 no.3 supl.0 São Carlos Oct. 2010.

Tundisi, J.G. and Matsumura-Tundisi,T. 2008 Limnologia. Oficina de Textos, SP. 632 pp.

Tundisi, J.G.; Sebastien, N.Y; Matsumura-Tundisi, T.; Tundisi, J.E.M and Manzini, N.F. 2006. The responses of reservoir of Southern Brazil to the passage of cold fronts as

reflected by physical, chemical and biological variables. Verhandlugen Internacionale Vereinigung Limnologie, vol. 29, p. 2124-2128.

Tundisi, J.G.; Matsumura-Tundisi,T.; Galli, C.S. 2006 (editors) b) Eutrofização na América do Sul: causas, conseqüências e tecnologias para gerenciamento de controle. São Carlos: Instituto Internacional de Ecologia, Associação Instituto Internacional de Ecologia e Gerenciamento Ambiental, Eutrosul. 531 pp.

Tundisi, J.G. 2005. Águas futuras: o futuro dos recursos hídricos no Brasil. Pp. 148-153. In: Moss, G. e Moss, M (Editors). Brasil das Águas. Revelando o Azul Verde e Amarelo. Petrobrás. 153 pp.

Tundisi, J.G; Matsumura-Tundisi, T.; Arantes Junior,J.D.; Tundisi, J.E.M.; Manzini, N.F. and Ducrot, R. 2004. The response of Carlos Botelho (Lobo/Broa) reservoir to the passage of cold fronts as reflected by physical, chemical and biological variables. Brazilian Journal of Biology, vol. 64, nº 1, p. 177-189.

UNESCO/IHP. 2004. Integrated watershed management.Ecohydrology & Phytotechnology Manual. UNEP/IETC. 246 pp.

UNESCO, UNEP.2008. Water Quality for Ecosystem and Human Health. IAP, ERCE, GEMS, Water. 120 pp.

Val L.; A. et al. 2010. Amazônia: recursos hídricos e sustentabilidade. Pp. 95-112. In: Bicudo, C.E.M.; Tundisi, J.G; Cortesão S.,M. (Esditores): Águas no Brasil: análises estratégicas. Academia Brasileira de Ciências, Secretaria do Meio Ambiente Estado de São Paulo. 222 pp.

Zalewski, M. 2007. Ecohydrology in the face of anthropocene. Vol. 7 nº 2, pp. 99-100.