Transition to Global Sustainability:

The contribution of Brazilian Science

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Water for sustainable development: the Brazilian perspective

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I – Introduction

The availability of water is fundamental for the maintenance of the functioning of the natural ecosystems, as well as to sustain human activities such as food and energy production. Water has been and will be always a limiting factor for sustainable development. To maintain an adequate level of development it is necessary an investment in the preservation and recovery of water resources and of the quantity as well the quality of the water. Human activities produce considerable changes in the quality and quantity of water and water resources and economy are always inter-related. These is also a direct relationship between water quality and human health; poor water quality and bad sanitation contribute with a great deal to infant mortality and to lower life expectancy in general.

The quality and quantity of water of a given hydrographic basin, in natural conditions, is dependent on climate and the physical and biological characteristics of the aquatic and terrestrial, ecosystems. The seasonal fluctuations and the availability of water, are dependent upon these natural conditions which have cycles that can be changed by episodic events, periodic or not.

Superimposed to these natural conditions, there is a number of human activities which, vary in amplitude and in temporal and spatial scales.

The availability and water budget should be considered at national, regional and local levels.

In this paper the authors describe and discuss the availability of water in Brazil, its water budget, the main problems with water conservation and the impact of human activities. The recent developments in water management and legislation with perspectives for sustainable development based on water resources are discussed .

II – The water resources and water balance of Brazil

Brazil is a federal republic of 8.5 million km2, located between the Equator and the tropic of Capricorn. Its extension, from both north to south and east to west is approximately 4.400 km. Eleven hydrographic zones have been established for water resources monitoring and management which corresponds to the major watersheds of the country (Fig. 1 and Fig. 2). Brazil has 16% of the available fresh water of the planet. (Rebouças et al, 1999) A balance of these watersheds is presented in Table 1.

A demand/supply balance including demands for domestic, industrial and irrigation uses is presented in Table 2. (Braga et al, 1998) From these tables, it is possible to identify four major regions of Brazil which have interest for sustainable development:

a – Amazonia

b – The northeast of Brazil

c – The center west of Brazil

d – The degraded urban and rural watersheds in the south and southeast.

TABLE 1: WATER BALANCE FOR THE MAJOR BRAZILIAN WATERSHEDS

Basin		Area (km2)	Average Rainfall (m3/s)	Average Discharge (m3/s)	Evapotrans-piration (m3/s)	Disch/ rainf. (%)
(1)	Amazon	6112000	493191	202000	291491	41
(2)	Tocantins	757000	42387	11300	31087	27
(3A)	Atlantic North	242000	16388	6000	10388	37
(3B)	Atlantic Northeast	787000	27981	3130	24851	11
(4)	S. Francisco	634000	19829	3040	16789	15
(5A)	Atlantic East	242000	7784	670	7114	9
(5 B)	Atlantic East	303000	11791	3710	8081	31
(6 A)	Paraná	877000	39935	11200	28735	28
(6B)	Paraguai	368000	16326	1340	14986	8
(7)	Uruguay	178000	9589	4040	5549	42
(8)	Atlantic South	224000	10515	4570	5949	43
	Brasil including Amazon Basin	10724000	696020	251000	445020	36

From Braga et al (1998)

FIGURE 1: MAJOR HYDROGRAPHIC BASINS OF LATIN AMERICA. FROM TUNDISI (1994)

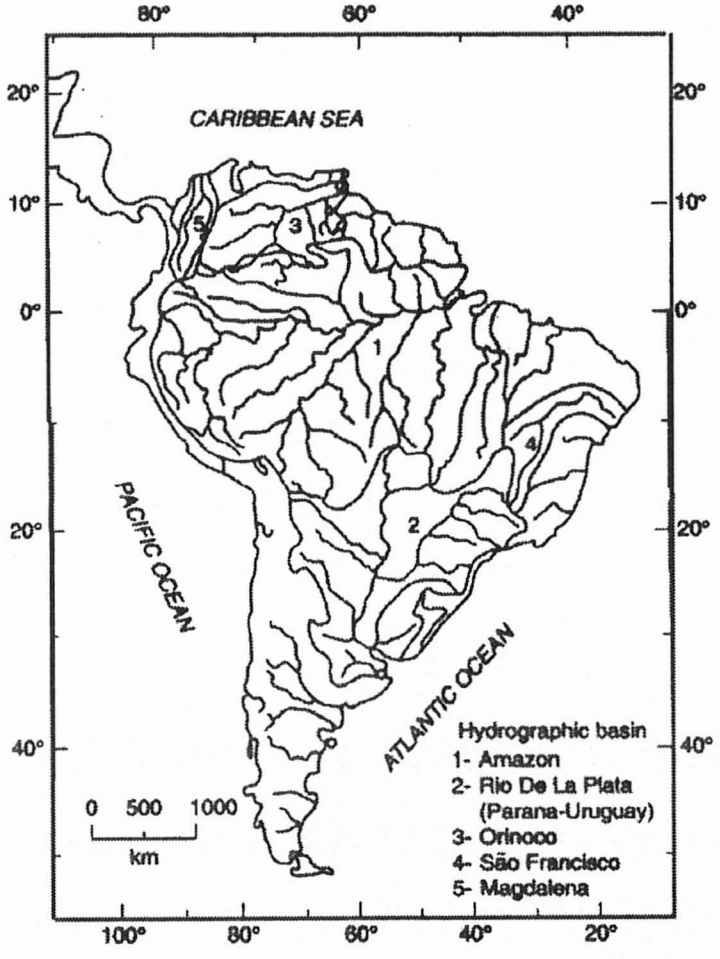

TABLE 2: SUPPLY/DEMAND WATER BALANCE FOR BRAZIL

STATE /REGION	TOTAL DISCHARGE (KM3/Y)	URBAN DISCHARGE (KM3/Y)	IRRIG. (KM3/Y)	INDUST. DISCHARGE (KM3/Y)	DEMAND/ AVAIL. (%)	URB. IND. AVAIL.-IRRIG. (%)
Rondônia	150.2	0.03	0.00	0.01	0.03	0.03
Acre	154.0	0.02	0.00	0.00	0.00	0.01
Amazonas	1848.3	0.10	0.01	0.03	0.00	0.01
Roraima	372.3	0.01	0.00	0.00	0.00	0.00
Pará	1124.7	0.19	0.05	0.06	0.00	0.02
Amapá	196.0	0.01	0.00	0.00	0.01	0.01
North Region	3845.5	0.36	0.06	0.10	0.00	0.01
Maranhão	84.7	0.22	0.01	0.02	0.20	0.28
Piauí	24.8	0.12	0.09	0.01	0.89	0.53
Ceará	15.5	0.29	0.96	0.09	8.65	2.61
R.G. Norte	4.3	0.14	0.23	0.05	9.77	4.67
Paraíba	4.6	0.15	0.27	0.04	10.00	4.39
Pernambuco	9.4	0.45	0.98	0.16	16.91	7.24
Alagoas	4.4	0.11	0.18	0.04	7.50	3.55
Sergipe	2.6	0.06	0.12	0.02	7.69	3.23
Bahia	35.9	0.52	1.07	0.12	4.76	1.84
North-east region	186.2	2.06	3.91	0.55	3.50	1.43
M. Gerais	193.9	1.22	1.63	0.59	1.77	0.94
E. Santo	18.8	0.18	0.22	0.08	2.55	1.40
R. Janeiro	29.6	1.03	0.63	0.73	8.07	6.08
S. Paulo	91.9	2.74	1.81	4.16	9.48	7.66
South-east region	334.2	5.17	4.29	5.56	4.49	3.25
Paraná	113.4	0.70	0.28	0.35	1.17	0.93
S. Catarina	62.0	0.33	0.65	0.40	2.23	1.19
R.G.Sul	190.0	0.71	6.32	0.70	4.07	0.77
South region	365.4	1.74	7.25	1.45	2.86	0.89
M.G. Sul	69.7	0.10	0.13	0.03	0.37	0.19
M.Grosso	522.3	0.08	0.03	0.02	0.02	0.02
Goiás	283.9	0.28	0.25	0.06	0.21	0.12
D. Federal	2.8	0.13	0.04	0.03	7.14	5.80
W. Central region	878.7	0.59	0.45	0.14	0.13	0.08
Brasil	5610.0	9.92	15.96	7.80	0.60	0.32

From Braga et al (1998)

FIGURE 2: POLITICAL DIVISION AND MAJOR WATERSHEDS OF BRAZIL. FROM BRAGA ET AL (1998)

III – MULTIPLE USES OF WATER RESOURCES AND ITS IMPACTS ON BRAZIL'S FRESHWATERS

The general uses of water are:

- Function of support: creating conditions for life and productive activities such as water as a natural habitat, water in soil, water for transportation or water for food production;
- Function of regulation: when it cleans, dilutes, dissolves or neutralizes residues; self-depuration capacity;
- Function of production: for human consumption and production: water for irrigation for animal use;
- Function of information: when water is used as indicator of a environmental state for example the state of conservation or degradation of watershed.

(Lanna, 1999)

All the human activities and multiple uses fall within these four categories.

The multiple uses of water in Brazil can be summarized as:

- Water supply for general public use (human consumption and all human activities);
- Irrigation;
- Industrial use;

- Navigation;
- Recreation;
- Tourism;
- Hydroelectricity;
- Fisheries;
- Aquaculture.

The number of multiple activities varies accordingly to the population in the watersheds and the economic and social organization of the regional system related to density and distribution of population, intensity of economic development.

All these activities generate impacts and deterioration of water quality as well as interfere with the available quantity of water. The deterioration of water quality and quantity starts with the watershed uses and the impacts of human activities on the soil, vegetation and other components of the watershed.

The impacts on the water resources of Brazil are several, vary in the watersheds and within the watersheds, and can be summarized as follows:

- **Deforestation: As the defore**station progress the impact on the aquatic systems increases. Loss of habitats, of animal diversity, of buffer capacity is associated with this deforestation;
- **Mining: All mi**ning operations (sand, gold, precious stones) produce general impacts on rivers and wetlands;
- **Road Construction**
- **Waste discharge: solid waste dispo**sal or non treated sewage increase the impacts. Industrial activities also increase impacts on the rivers, lakes or reservoirs.
- **Introduction of exotic species: This is now at a dangerous lev**el. Accidental introductions of exotic species or bad management practices, produce disruption of the food chains in natural lakes and rivers;
- **Removal of critical species: Many species, critical to t**he freshwater ecosystem function are removed producing another type of disruption of the diversity in the freshwater ecosystems;
- **Reservoir construction: Many reservoirs have b**een built in Brazil. Reservoir construction have negative and positive impacts. Loss of biodiversity can be expected by reservoir construction, at least in the initial stages of the functioning of the system. (Tundisi, 1999).

As a consequence of these impacts, eutrophication, toxicity of freshwaters due to algal blooms, increasing of suspended material, loss of buffer capacity, hydrological alterations, geographic expansion of water borne diseases are common in many freshwater ecosystems, specially near or in the urban regions.

Therefore as well as conservation, restoration of the freshwater ecosystems in Brazil is one of the key problems to be addressed in the next century.

It is necessary also to consider the interrelation of water quality with human health.

The contamination of the water resources is one of the most important factors for the deterioration of human health, specially in regions of poor sanitation and inadequate water supply. (Biswas, 1996)

In large urban areas of Brazil and also in some rural areas inadequate and inefficient water supply are causes of high infant mortality due to water borne diseases.

IV – New developments in management and legislation

The increasing need for an effective management of water resources in Brazil its quality and quantity – and the urgency to develop new technologies and mechanisms of control has lead to the implementation of new regulatory and institutional mechanisms.

The most effective and important development is the watershed approach to management, with the watershed committees, and the organization of funds to support the research, monitoring and management at watershed level.

This is leading to a integrated planning and management approach and stimulating a shared vision of the water problem with increasing community participation. It is clear now that the basis for sustainable development is the watershed approach with community participation, the integration of planning, management and operation and new local legislation.

The principle of the polluter – payer at watershed level and the large scale decentralization process which is under way will stimulate new and creative ideas for management and for financing the watershed and its conservation and recovery. This change in legislation and institutional framework will be the most important achievement of the brazilian society and certainly will provide a sound template for future improvements. Another fundamental change is the multisectoral and interative approach and the realization that non point source of pollution and degradation is the most important problem to be addressed in the next century and for that education al all levels is necessary.

V – Perspectives for sustainable development: Brazil's water resources and the challenges ahed

Brazil is a country endowed with many natural resources distributed in a wide range of latitudes and with several special ecological characteristics that make them unique in the planet. Such is the case of the Amazon watershed, the Pantanal wetlands where the integration of terrestrial and aquatic ecosystems is intense and extremely important for the conservation of ecological processes and the biodiversity.

Therefore this is an important asset from the ecological, economic and ecological point of view.

When considering the challenges for sustainable development and the role of water resources, the following problems are to be taken into consideration:

- The most effective and economical management of aquatic ecosystems results in a understanding of the complexity and the mechanisms that govern the hydrology, chemistry and biology of these ecosystems. Therefore from the research point of view it is necessary to stimulate an integration of studies on the climatological, hydrological, physical chemical and biological problems. This is already in progress throughout the watershed approach which is in operation in several regions of Brazil, but it is necessary to promote it more intensively. This applies to all major watersheds.

- The integration of research and management is another important topic for the future. Integrated management will have a strong research component and the training of managers and scientists in pilot programs seems to be a major challenge, for effective management.

- The conservation of aquatic ecosystems, their ecological processes and their biodiversity is another challenge that will integrate the economic and social problems with the functioning of the natural ecosystems. The conservation of the Amazon, forests and floodplain lakes is fundamental for Brazil but it has also of planetary importance due to the influence of the Amazon Rain Forest and its major processes in the climate of the planet. The aquatic biodiversity of this region and that of the Pantanal wetlands are of extremely qualitative and quantitative importance. For example for the Amazon River only, the large catfishes use most of the rivers, the lowland areas and the estuary during their life cycle (Barthem & Goulding, 1997). This area is 2.500.000 km2. These large predators, have an important role in the ecology of the Amazon river and its tributaries. Another recent study (Araujo Lima & Goulding, 1997) approached ecology, conservation and aquaculture holistically and described the life cycle the biology, the distribution, the fisheries and the fish farming of the tambaqui – Colossoma macropomum (Luvier, 1818). This study shows how this species is important for the maintenance of the ecological processes in the inundated forest. The Pantanal biodiversity of fishes is also very high but other species of animals such as capybara are very important for the functioning of the systems and for the local economy. Therefore conservation of aquatic biodiversity is of fundamental importance for the future of sustainable development.

- If conservation is fundamental for the natural areas, recovery of freshwater ecosystems in many regions, specially the southeast is of prime importance: several rivers and reservoirs have suffered very high impacts resulting in eutrophication, pollution and contamination with toxic substances.
  It is necessary the development of new and relatively cheap technologies (ecotechnologies) to recover these ecosystems. Most of there ecosystems are located in urban regions, where the need for adequate water supply is urgent and where the aquatic biodiversity has suffered heavy losses; the costs of treatment of water for public use are increasing considerably due to the effects of contamination and pollution. Eutrophication is another major problem and it will be probably the main handicap for sustainable development in the next century. Eutrophication of water bodies has reached dangerous levels in Brazil as well as in many other large countries and regions such as China, India, Southeast Asia and Eastern Europe. In Brazil most of the urban reservoirs and rivers are eutrophic producing algal blooms, massive fish kills, unsuitability of water for human use and in extreme cases human deaths resulting from inadequate consumption of eutrophic water. (Tundisi, 1999, in press).

The economic aspects of the eutrophication problem have to be considered in this integrated picture. Eutrophication management, its prevention and control can provide new job opportunities, and new tools for economic development. (Murdrock, 1999, in press)

Good water quality can improve and maintain the economy with the development of many activities such as commercial and recreation fisheries, touristic activities and the implementation of tourism and recreation facilities that will enhance the local economy.

- Improving management capacity

  The reduction of pollution and contamination as well as the conservation of freshwater ecosystems, all carry significant economic and social costs. Priorities towards sustainable development will have to face cost-benefit, cost effectiveness calculations. Ecological restoration, maintenance of biodiversity and integrated management all are related to sustaining the socioeconomy and environmental integrity. (Tundisi et al, 1999 a, b)

  The public participation in this process is fundamental. Community participation and public awareness will be more critical in the future since sustainable development can be achieved only with continuity and the public provide the necessary support for this continuity.

  The use of all forms of education, mass communication programs, acceptance by the general public of a system of value (ethics) and increasing the sensitivity to environmental problems, will be enhanced with the organization of the society and the implementation of partnerships between private and public sectors the strong participation of the Universities that will produce the conceptual framework, necessary to stimulate new and creative ideas and projects. (Tundisi and Straskraba, 1995)

- Institutional organization

  To improve management capacity and to stimulate and integrate the community participation in this management the institutional regulation at national, regional and local levels is a powerful tool. The water resources administration has, as a new challenge and perspective to a sustainable and rational utilization, to incorporate new legal mechanisms and structures. The watershed approach to management, the participation of the community, thoughout the watershed committees and the principle of the polluter-payer are new developments in this institutional framework that will improve management, conservation and recovery.

- The economy of water-Hydroeconomy

  To maintain an adequate level of sustainability for water resources and to provide tools for integrated management it is necessary to take into consideration the relationship between water quality conservation, water treatment for public use, costs of recovery of freshwater ecosystems and the costs of degradation. Community management with the participation of users, stakeholders should be the best possibility for management (Lanna, 1999). The principle of the polluter-payer for use of water is a fundamental and important step forward. It is necessary to understand the economic relationship existing between water uses the degradation of water resources and the multiple economic activities that can be developed in freshwater ecosystems with good water quality.

  The economic evaluation of water resources is another important quantitative estimate. The economic value of rivers, reservoirs, wetlands, underground waters, is fundamental for future development activities. This can generate a new series of

academic studies that will be extremely useful for application and for integrated management. (Straskraba and Tundisi, 1999; Tundisi and Straskraba, 1999)

VI - Conclusions

In the 21st century the "water business" will be an important component of the economy in urban and rural areas. The treatment of water in the rural areas will be developed with great intensity and will be an effective tool for improving quality of life in these regions. On the other hand the privatization of the water treatment, water services distribution and the solid waste treatment, will open new opportunities for employment, services and specialized work in the urban areas. The technological development for dealing with water supply, and water quality will probably enhance new investments in research and the innovation in this field.

The monitoring of water resources and the technologies for remote control coupled with the new management perspectives and approaches will be a powerful tool to control and follow up the impacts of human activities in the water resources. The urgent need for an effective management of rivers, reservoirs, wetlands, will stimulate a series of regulatory processes at the institutional level, federal, state and municipal levels. The watershed committees will have a important role in the monitoring, regulation and control of the water quality. The organization of society to manage these problems is vital for the integrated management of water resources.

In the next decades the hydrographic basin will be a major unit for research, management and monitoring .

To all these problems it must be added that preparation of qualified human resources is of prime importance in this sustainable development. Scientists and managers should be adequately prepared for this new approaches and initiatives and this implies in a revitalization of training with an inclusion of ecosystems perspective and interdisciplinary instruction.

Education of the general public in water problems will play a fundamental role in sustainable development.

All the problems discussed above have been considered in the process of sustainable development of Brazil. New programs, new training activities, monitoring, public participation, and education, the watershed as a unit for management, research and education have been discussed at several levels of national, state and municipal decision making. Many universities are discussing programs of training at undergraduate or graduate levels. The main challenge is the articulation of all these projects and ideas, and for that local, state and federal levels have to be integrated. It seems that the most successful projects for sustainable development are obtained at local (municipal or watershed) levels and this may be one of the important developments for the 21st century. The large diversity and latitudinal distribution of Brazil's water resources call for a regional and local approach to management and sustainable development and the research and search for integration of all management approaches is also a challenge for public and private organizations.

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VII-References

Araujo Lima, C. and Goulding, M., 1997. So Fruitful a fish. Ecology, Conservation and Aquaculture of Amazon's Tambaqui. Columbia University. Press New York, 191pp.

Biswas, A., 1996. Agua para el mundo en desarollo en el siglo XXI: temas e implicaciones. Ingineria Hidraulica en México. Vol. XI, Num. 3, pp. 5-11.

Braga, B., Rocha, O. and Tundisi, J. G., 1998. Dams and the environment. The brazilian experience. Water resources development, vol. 14, no 2, pp. 127-140.

Burthem, R. and Goulding, M., 1997. The catfish connection. Ecology, Migration and Conservation of Amazon Predators. Columbia Univ. Press. New York, 144pp.

Lanna, A., 1999. Hidroeconomia. pp. 533-563. In: Rebouças, A.; Braga, B. and Tundisi, J. G.. Águas doces no Brasil. Capital ecológico, uso e conservação. Academia Brasileira de Ciências. Inst. Estudos Avançados (USP), 717pp.

Rebouças, A.; Braga, B. e Tundisi, J. G., 1999. Águas doces no Brasil. Capital ecológico, uso e conservação. Academia Brasileira de Ciências, Institutode Estudos Avançados, 717pp.

Straskraba, M. and Tundisi, J. G., 1999. Reservoir water quality management. ILEC Guideline series, number 9, 129pp.

Tundisi, J. G., 1994. Tropical South America. Present and Perspectives. In: Margalef, R. (Editor). Limnology now a paradigm of planetary problems. Elsevier Science, B. Y. Amsterdam, 353-424 pp.

Tundisi, J. G., 1999. Synthesis. In: Murdroch, A. (Editor). Planning and management of lakes and reservoirs. UNEP (in press)

Tundisi, J. G., Matusmura-Tundisi, T. and Rocha, O., 1999. Theoretical basis for reservoir management. In: Tundisi, J. G. and Straskraba, M.. Theoretical reservoir ecology and its applications. Int. Inst. of Ecology, Brazilian Academy of Sciences, Backhyys Publishers. 597 pp. (in press)