CONFLICT RISK INDICATORS AROUND THE GUARANI AQUIFER SYSTEM

Mohamed Redha MENANI[1]
Harrysson Luiz da Silva[2]
Ivana Lucia Franco Cei[3]
Luciana Ribeiro Lepri[4]

[1] - Earth Sciences Dept – Batna University – Algeria - Menani-redha@lycos.com
[2] - Departamento de Geociencias Universidade Federal de Santa Catarina – UFSC – Brazil
[3] - Ministério Público do Estado *do* Amapá - Brazil
[4] - Ministério Público do Estado do Paraná - Brazil

Abstract

Among achievements related to the environmental protection and sustainable development of the Guarani aquifer system (GAS) project (World Bank, 2009), it was developed a framework for analyzing and classifying causes of critical issues and possible mitigation measures in a transboundary diagnostic analysis. The classified causes recognised are: natural (caused by climate change for example), primary or technical (related inter alia to low level sanitation coverage), secondary or economic management (uncontrolled use of the GAS…), tertiary or political (lack of legal norms or absence of managing institutions) and fundamental or socio-cultural (lack of public participation…).

Some of these causes of critical issues resemble to the indicators or sub-indicators proposed in the evaluation method of the conflict risk's index around the transboundary water resources (Menani, 2009); method which will be tested here on the GAS's case.

In August 2010, the four countries signed the Guarani Aquifer System Agreement under the framework of MERCOSUR. Through this action, it is expected a better coordination and a joint management of this strategic shared aquifer.

The current GAS data, rather reassuring, don't mean that there isn't or that there wouldn't be a risk of conflict about this cross-border aquifer. The problem deserves to be considered through several parameters which have an impact on the risk of conflict.

Keywords: Guarani Aquifer, transboundary, conflict

Introduction

The Guarani aquifer system (GAS) is this vast aquifer of approximately 1.2 million km² of surface shared by 4 countries of Latin America (Argentina, Brazil, Paraguay and Uruguay) whose water is exploited unequally and for various uses by the bordering countries.

For these close countries, groundwater, especially of deep aquifers, constitute a strategic reserve for water supply in the future face notably to pollution of surface water sources and the covetousness of this water for a commercial practice; the region is not concerned actually by scarcity.

The lack of knowledge of the aquifer from the points of view of extension, geology, hydrogeology, hydrogeochemistry, hydrodynamics.... made that the widespread belief was that of an overexploitation of the GAS, like its pollution, in particular in the cross-border zones between the 4 countries and that could lead to conflicts (Amore, 2003). A recent study of the World Bank (2009) through a detailed program (WB, 2002 and 2006) which targeted in particular pilot areas, allowed a clearer vision notably concerning:

- The hydrogeologic aspect of the GAS, whose limits and the hydrodynamic behavior were very badly known;
- The Delimitation of the zones at risk of groundwater pollution;
- The Inventory of wells catching this aquifer and location of the overexploited zones;
- The thermal water

In addition to the aquifer characterization, IWRM tools were proposed (OAS, 2005) (Project General Secretariat, 2003).

The evaluation method of the conflict risk around transboundary water resources (Menani, 2009) made it possible to measure the degree of risk in the case of the shared water resources of the GAS.

The result obtained seems in adequacy with the situation which currently prevails in the GAS's zone. By comparison with the Jordan basin (case treated by this method), the level of risk is very low.

1- Overview on the GIR method (global Index of conflict Risk around the transboundary water resources):

This method proposes a numerical indexation of the conflict risk around the transboundary water resources by considering the most representative indicators having weights proportional to their relative importance.

However, each indicator varies in a rating field according to well defined criteria which take different values according to local conditions, thus providing a partial index of risk (weight x rate) and the sum of these partial indices provides the global risk index of conflict for a given region.

This approach allows a standardized assessment of the conflict around the transboundary water resources, based on indicators having fixed weights according to their relative importance (table 1).

Table 1. Risk Indicators and their respective weights

Indicators	Weights
Dependence degree to the transboundary water resources	5
Satisfaction degree of the water needs	4
Geopolitical context of the conflict zone	3
Geographical position in relation to the water resources	2
Water governance and achievements in water resources field	2

These indicators take different values in rating intervals which depend of the local conditions (example of the rating intervals for the first indicator in table 2).

Table 2. Rating intervals of the dependence degree to the transboundary water resources (Weight: 5)

Variation intervals	Rate
Total dependence	10
Partial dependence with difficulties of satisfaction of the needs by other resources (natural and technical difficulties)	8
Partial with possibilities of supplying by other resources but with a high capital cost	6
Partial with possibilities of supplying by other resources with an advantageous capital cost	4
Partial to weak with an effective supply by other resources	2

The combination between the fixed weight and the reached rate by each indicator in a given region leads to a partial index of the risk concerning this indicator and the sum of the partial indices provides the global conflict risk index around the transboundary water resources.

The rating intervals are based on criteria and standards which take into account results of research works carried out through actions at world scale (international organisations and individual authors) which have not only integrated the quantitative and qualitative aspects of the resources, but also the economical, sociological, educational and political aspects.

According to the local conditions, risk indicators take values between 1 and 10; the greatest dimensions indicate a high risk of tension and conversely.

It's clear that these ratings must be established for each country concerned by the transboundary water resources. The interest of this method is its flexibility, i.e. the user can insert intermediate and specific steps which are not considered here and affect to them dimensions proportional to their relative importance by comparison with the proposed ratings.

The partial risk index is obtained by multiplying the fixed weight of an indicator by the rate reached by this indicator according to the local conditions ($IPR = I_{iw} . I_{ic}$)

IPR: partial index of risk

Iiw: indicator fixed weight

Iic: indicator rate (variable)

The total index of risk is the sum of the partial indexes:

$$GIR = \sum PIR = \sum I_{iw} * I_{ic}$$

With GIR: global index of risk of conflict around the transboundary water resources

One note generally that two countries or more involved in a transboundary water conflict do not present the same global index of risk because conditions which prevail in each one of these countries are different. According to this procedure, the minimum conflict risk index is 25, whereas the maximum index is 158.

Details of the method can be consulted in Menani (2009).

2. Case of the Guarani Aquifer System (GAS)

21. GAS Geographical extension

The geographic coverage of the GAS (figure 1) was determined to be 1 084 063.9 km² (or 92% of original estimate 1.2 millions km (World Bank, 2009).

Table 3. Total surface area of Guarani by country

Country	Area (km²)	% of total GAS	% of country surface area
Argentina	228 255	20.98	8.1
Brazil	735 918	61.65	8.7
Paraguay	87 536	8.05	21.5
Uruguay	36 170	3.32	19.5
Total	1 087 879	100	

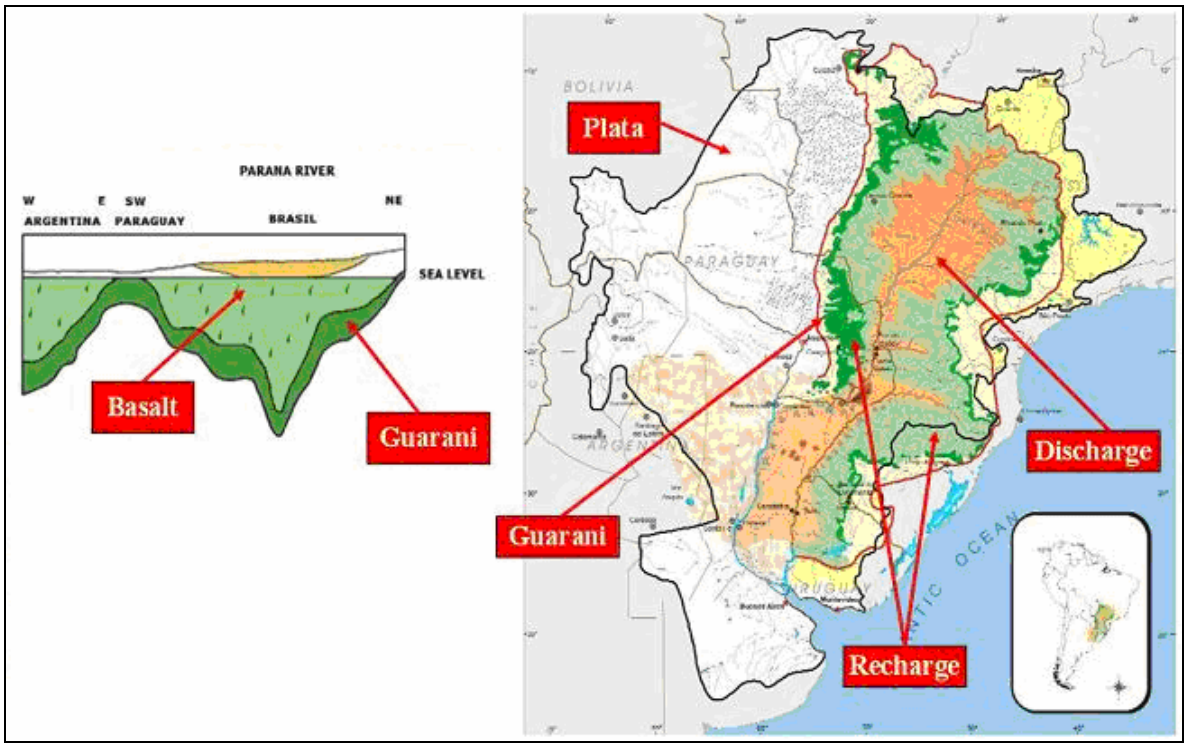


Figure 1. Geographical situation of the Guarani Aquifer System
(GAS - Project General Secretariat, 2003)

22. Principal geological and hydrogeological characteristics

The geological formations that comprise the aquifer are Mesozoic sandstones covered by thick layers of basalt that confined them (Araujo et al., 1999).

The recharge zones are principally situated in Brazil in the North and in the East and in Paraguay in the West whereas the discharge zones are situated in the South, in Argentina and Uruguay (Campos, 2000; Vives and al, 2006).

23. Current exploitation of the GAS

Currently, the GAS is predominantly utilized to supply water for domestic and industrial/commercial use (nearly 90% of the extraction). Of this, 66% is used for public water supply, 5% for rural water supply, 16% for industrial use and 13% for recreation (thermal tourism). The most diversified use of the Guarani aquifer is observed in Brazil, while the least diversification occurs in Argentina where the existing wells are used almost exclusively for recreation/thermal purposes principally in the province of Entre Rios (table 4) (World Bank, 2009).

Table 4 . Schema of the GAS water resources uses per country

Uses	Argentina	Brazil	Paraguay	Uruguay
Public water supply		44 %	96 % (in urban areas)	93% (in urban areas)
domestic use from private wells		25 %		
Industrial		22 %		
Rural		7 %		
Recreation	95-98%	2 %		6 %

The Guarani aquifer is and will remain probably destined principally to domestic and industrial/commercial uses because it was found to be economical as a source of public water supply, but generally not economical for irrigation for which exist other alternatives (abundant surface water).

The annual water extraction is nearly of 1.04 billion m^3/year, this corresponds to 0.003% of the estimated 30 trillion m3 stored in the aquifer. The recharge of the Guarani aquifer is estimated at 5 billion m^3/year. The GAS doesn't show signs of overdraft except in localized areas (World Bank, 2009).

The major user of the GAS's water is Brazil with an annual extraction of about 684 million m^3/year.

The major use is concentrated in the Guarani outcropping areas where sustainable utilization of the resource is possible, due to a large amount of natural recharge. The confined areas of the GAS are characterized by a very high storage and low recharge due to its geological nature. According to the World bank report (World Bank, 2009), the water in these confined areas could last for hundreds or even thousands of years but with a true sustainable management.

3. Numerical indexation of the risk of conflict around the GAS

31. Dependence degree to the GAS

From a general point of view, the situation by country can be illustrated by the figure 2 which expresses the population's evolution per country and the total renewable water resources per capita, according to FAO-Aquastat database (2009). For the 4 countries, the TRWR (total renewable water resources) evolves with the fall but it remains well with the top of the allowed threshold of 1000 m3/capita/year, often used as an indicator of water scarcity (Falkenmark and Widstrand, 1992).

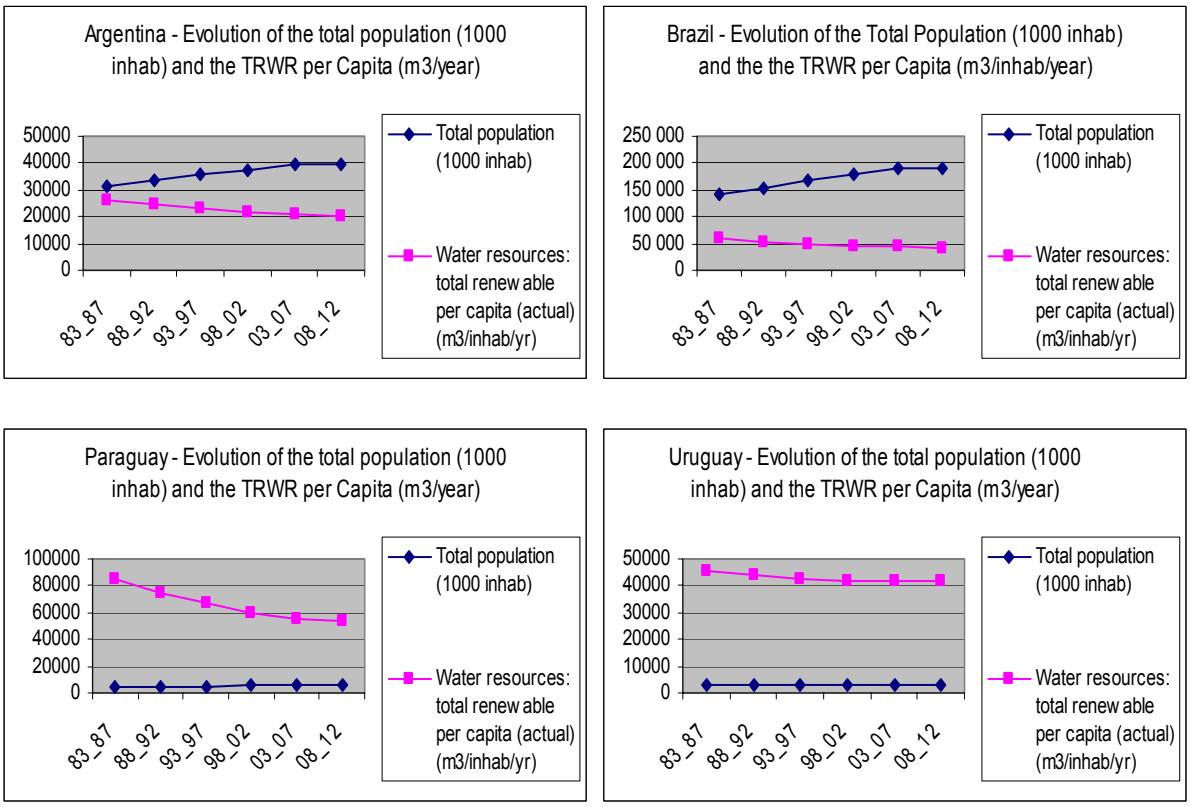


Figure 2. Evolution of the total population (1000 inhab) and the TRWR per Capita (m^3/year)

The dependence degree to the GAS's water resources must be evaluated by considering for each country, the percentage of population living in the GAS's zone and the percentage of surface occupied. These are two principal criteria in relation with the different water needs (notably domestic) and with the principle of sovereignty (territorial principle).

The large extension of the Guarani aquifer is in Brazil (68% of the total area of the aquifer) covering 8 states with more than 500 municipalities. Thus, Brazil identified the aquifer and its management as important for the country in terms of water supply for domestic and industrial uses.

In terms of strategic needs depending of the GAS, those of the other countries are apparently much less significant. For example, Argentina exploits currently only thermal waters of the GAS at recreative ends and mentions serious water quality problems due to aquifer's mineralisation and vertical contamination.

Table 5. Total Population living in the GAS region and its distribution per countries (World Bank, 2009)

Country	Population in GAS	% of Population of the country	% of population of the GAS zone	% population of the GAS zone / % of surface GAS
Argentina	7 947 667	20.59	8.64	0.41
Brazil	80 141 415	42.99	87.04	**1.41**
Paraguay	3 263 318	55.91	3.54	0.44
Uruguay	724 768	21.92	0.78	0.23
Total	92 077 168	46.67	100	

On a total of 92 million people living in the GAS zone, 87% are concentrated in Brazil. The percentage of countries' populations living in the GAS's zone per the percentage of surface occupied by each country in the GAS's zone, show clearly that Brazil occupies the first position in term of dependence to the GAS's water resources.

For Brazil, the uses differ even if the domestic use is dominant whereas for Paraguay and Uruguay withdrawals are practically all destined to the public water supply (table 4) because of the good quality of the water and its relative low cost of exploitation.

The situation can be summarized by the table 6 below.

Table 6. Partial risk index related to the dependence degree to the GAS (Weight: 5)

Variation intervals	Rate		PIR = Weight * Rate
Total dependence	10	Brazil	50
Partial dependence with difficulties of satisfaction of the needs by other resources (natural and technical difficulties)	8		
Partial with possibilities of supply by other resources but with a high cost	6	Paraguay Uruguay	30
Partial with possibilities of supply by other resources with an advantageous cost	4		
Partial to weak with an effective supply by other resources	2	Argentina	10

32. Satisfaction degree of the water needs:

As mentioned above, nearly 90% of the extraction is destined to supplying the domestic and industrial/commercial uses.

Even if the actual uses differ considerably between the close countries (see table 4), the future uses and their respective proportions will certainly differ of the current state. Thus, it is important to identify the satisfaction degree of the water needs of the 4 countries. We should note here that data expressed below concern the consumption average by country and not only the GAS extension area. Indeed, the high respective populations living in the GAS zone and the possibilities of hydraulic transfer outside the GAS zone are arguments in favour of this option.

321. Satisfaction degree of the domestic needs:

Argentina: According to WHO/Unicef (2006, 2010 update), the rate of consumption is one the highest in South America and in the world (slightly higher than 400 l/c/d with an average of 411 l/c/d) with a supply mostly continuous. Access to water by connections is characterized by relatively low tariffs, mostly reasonable service quality, low levels of metering and high levels of consumption for those with access to services.

Brazil: Average water use in Brazil for users served by utilities fell from 150 l/c/d over the past years (-34%). Water use in Brazil thus is lower than the excessively high water use found in many other Latin American countries. Increased metering and a higher share of low-income users with low per capita water use probably played a role in the reduced average water use (WHO/Unicef, 2008).

Paraguay: Average water use in Paraguay is not well known. For users served by utilities, it would exceed slightly 200 l/c/d. This level is explained by relative low tariffs compared to close countries (WHO/Unicef, 2006).

Uruguay: The average urban use of water is approximately 200 l/c/d. Per capita, water production is high at 411 l/c/d. The consumption is higher than in many European countries. However, water use is much lower than in neighbouring Argentina, where metering is not widespread, while in Uruguay 96% of water connections were metered in 2004 (WHO/Unicef, 2006).

Table 7. Rating intervals of the domestic need's satisfaction degree - Partial risk index (Consumption in l/c/d) (Weght:4)

Consumption	< 50	50<x<100	100<x<150	150<x<200	200<x<250	250<x
Rate	10	8	6	4	2	1
			Brazil		Paraguay Uruguay	Argentina
PIR			24		8	4

Partial index of minimum risk (PIR_{min}) = 4. 1 = 4 - Partial index of maximum risk (PIR_{max}) = 4. 10 = 40

An equitable tariffing and a widespread metering are at the base of any economy in water in the domestic use.

322. Agricultural needs:

Compared with GAS's water withdrawals for the other uses, those destined to irrigation can be considered as being very weak. Indeed, the surface water fills generally these needs, except in localised areas. As example of use of surface water, one can evoke the case of the Merin Lake which is shared by Uruguay and Brazil. It covers a surface of nearly 5000 km² inside its basin which extends on approximately 63.000 km². On the Brazilian side, 97% of the annual withdrawals are used for the irrigation. The situation is rather similar on the Uruguayan basin side, where more than 1.000 km² of rice plantations produce 70% of the annual Uruguay product. According to MVOTMA (2004), the current water balance of the Merin Lake basin is already stressed in relation with an increased demand of water vis a vis supply, which is fortunately far from compromising the Uruguay's water resources availability.

It is obvious that GAS's water withdrawals for the agricultural uses will increase in the future (no statistical data available). The rates of the various uses will differ generally compared to the requests but also in relation with the GAS water balance which can be modified by the climatic change's impacts. In the current state of knowledge, it is difficult to predict precisely the consequences of the climatic changes on the GAS, but what is sure it's that its water balance will be affected.

The land uses changes are another problem which can affect the management of the GAS water resources in the future. According to the World Bank report (2009), a study concerning this problem by using satellite images of three periods (1980, 1990, and 2007), "showed that during this 34 year period the area used for agriculture increased from 22% in 1980 to 47% in 2007; the land allocated to silvopasture increased from 11% to 23% during the same period; dense forest decreased from 9% to 2%; and areas not cultivated decreased from 23% to 18%".

Considering that the GAS's water withdrawals destined to the agricultural use are actually very weak by comparison to those destined to other uses, the partial conflict risk index (PIR) for this use isn't considered in this note but it should be in the future if this use becomes significant.

The following table of the PIR variation intervals for the agricultural use is given as indication.

Table 8. Rating intervals of the satisfaction degree of the agricultural needs (in relation with the percentage of irrigated surface)

	< 10 %	10<x<20	20<x<30	30<x<40	40<x<50	> 50 %
Rate	10	8	6	3	2	1

Partial index of minimum risk (PIR_{min}) = 4 - Partial index of maximum risk (PIR_{max}) = 40

323. Industrial and energetic needs

The surface water potentialities of the close countries can easily cover the possible deficits for the industrial and the energetic uses. In spite of that, one notes that the recourse to the GAS for this use is about 16% of the total extraction. The production cost of water starting from the GAS is very competitive because most of wells catch it with a rate of 300 m^3/day whereas a catchment is considered advantageous from the cost point of view starting from a rate of 75 m3/day.

In the case of these 4 countries, the industrial use is largely satisfied by the recourse not only to the GAS but to other water sources too.

Table 9. Rating intervals of the satisfaction degree of the industrial needs (in percentage of the needs) – Partial Risk index

	< 50%	50<x<60	60<x<80	80<x<90	> 90 %
Rate	10	7	5	3	1
					Argentina, Brazil, Paraguay and Uruguay
PIR					4

Partial risk index of minimum risk (PIR_{min}) = 4 - Partial index of maximum risk (PIR_{max}) = 40

324. The partial risk index related to the satisfaction degree of the total needs

The diversity of situations which can occur made that it is preferable to assign initially the same weight to the impact of each one of these uses, i.e. 4. The partial index for this indicator (the satisfaction degree of the different uses) is obtained by dividing by 3 the sum of the indices relating to the three uses. However, in regions where a particular use is not concerned, like the agricultural use in this case (generally satisfied by the surface waters), the weight of this factor is removed. The partial index is then obtained by dividing by 2 the indices related to the two concerned uses (Industrial and domestic).

PIR agricultural = 0

PIR = PIR domestic + PIR industrial /2

Partial index of minimum risk (PIR_{min}) = (2.4)/2 = 4 - Partial index of maximum risk (PIR_{max}) = (2.40)/2 = 40

Table 10. Partial risk index related to the satisfaction degree of the global needs

	Argentina	Brazil	Paraguay	Uruguay
PIR calculated	4+4/2=4	24+4/2=14	8+4/2=6	8+4/2=6

In the case of Brazil and Uruguay, it's the policy of tariffs and the metering adopted by these states which is responsible of the average of consumption per capita and not the availability of water (see the diagram 4). The applied tariffs and the metering coverage are taken in account by their respective cotes in the water governance indicator (table 19 and 20).

The water production per capita and per country is nevertheless in favour of the Uruguay with an estimation of 946.5 l/c/y, while Argentina presents the first municipal water withdrawal per capita (FAO-Aquastat, 2009)

Table 11. Water resources withdrawals per capita (FAO-Aquastat, 2009).

	Argentina	Brazil	Paraguay	Uruguay
Total renewable water resources per capita (actual) (m^3/c/y)	20410	42886	53863	41505
Total water withdrawals per capita (m^3/c/y) (1998-2002)	774,8	331,1	87,96	946,5
Municipal water withdrawals per capita (total population) (m^3/c/y) (1998-2002)	130,3	67,1	17,95	24,04

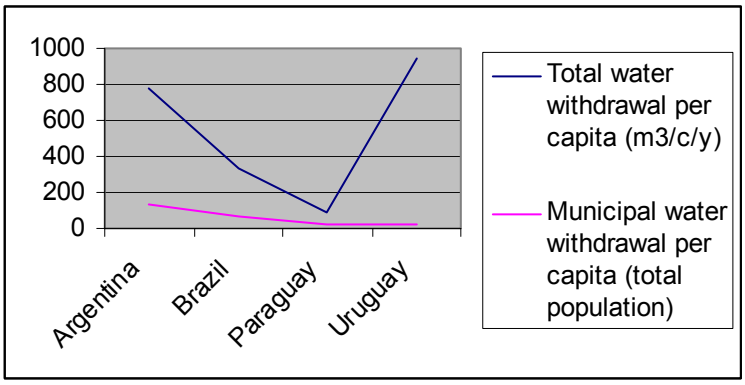


Figure 3. Water resources withdrawals per capita.

33. The geopolitical context

The close countries belong to Mercosur which was born in Mars 26, 1991 with the signature of the treaty of Asunción by Brazil, Argentina, Paraguay and Uruguay. It's the third market integrated into the world after the European Union and NAFTA (North American Free Trade Agreement). Even if progress could be noted in the development of the exchanges and the motivation of a development of the democracy, the cooperation always suffers from the relative poverty of the zone (even if it remains less low than in the remainder of the Latin America) and especially of the economic competition and policy between Brazil and Argentina. This "competition" is in fact factitious because in period of real crises, the 2 countries showed their mutual support like that was the case during the Falklands conflict having opposed Argentina to the United Kingdom. Brazil took then clearly position with Argentina; that for the global policy.

Concerning the Guarani water resources, the four countries agreed on a strategic action program and more recently, in August 2010 they signed an agreement within the framework of Mercosur (Biason, 2011). This action supposes a better coordination and a sustainable management of these shared water resources. However, this action seems to not satisfy all parties. Indeed, according to Biason (2011), the director of the International Water Law Project, Gabriel Eckstein (Biason, 2011) has shown its scepticism, arguing this by

the fact that it attaches more importance to the individual states' right than to the obligations of cooperation and concerted management.

Amore (2009), by evoking the need for evolving toward the stage of the water governance, had underlined institutional difficulties to start a new phase supported by the close countries in spite of the catalytic cooperation founded during the implementation of the World Bank project.

Concerning other conflicts related to water resources which imply separately some of the GAS' zone countries, one can cite a problem which was treated on the level of the international court of justice of The Hague about factories of pulp mill in Botnia (Uruguay).

The Uruguay River is protected by a treaty which requires both parties to inform the other of any project that might affect the river. Argentina's claims in relation to breaches by Uruguay of its substantive obligations and to the dismantling of the Orion (Botnia) mill have been rejected by judgement of the Hague court in April 20, 2010 (ICJ, 2010).

This situation which is regulated today, is however a precedent of conflict which can re-appear another time. The incidence on the joint management of the GAS's water resources remains however very weak.

It seems that Mercosur is the ideal regional framework inside whose these kind of conflict must be solved, even if its first vocation is economic, this to avoid on the one hand, the long annoyances of justice near the international court of the Hague whose judgements can take several years and on the other hand to make assume their responsibilities to Mercosur member States

On another side, it should be noted that cases of cooperation on a concerted management of the water resources exist also in the region. La Plata basin, which includes the major part of the territorial spaces of these countries, is the framework of many bi- or multilateral agreements (Pochat, 2010).

It is the case of the Itaipu dam which is the largest hydroelectric power station of the world (achieved in 2006). It is located on the Paraná River and produces 25 % of the electric power consumed by Brazil and 90 % of that consumed by Paraguay. In October 1979, a tripartite agreement (Brazil-Paraguay and Argentina) was signed between the three countries in order to lay down rules concerning the level of the river to be respected as well as the thresholds of discharges because an augmentation of the level of water in the Plata River could even drown the town of Buenos Aires.

Table 12. Rating intervals of the geopolitical context (Weight:3) and risk partial index

Variation intervals	Rate		PIR
Zone of armed conflict	10		
Zone of diplomatic tension	8		
Zone of ethnic tension	6		
Normal relations between states	4		
Zone belonging to a communitarian space	2		
Existence of treaties, commissions of basins	1	Argentina$_1$, Brazil, Paraguay and Uruguay$_1$	3

Partial index of minimum risk (PIR_{min}) = 3 - Partial Index of maximum risk (PIR_{max}) = 30

$_1$: Actually, one cannot evoke a real diplomatic tension but one cannot also be unaware of the problem arising between the 2 countries concerning the pulp mills.

34. Geographical position in relation with the water resources

In this case, this indicator is in relation with the water pollution by the fact that a water pollution caused in a country situated in the upstream part of the GAS can be propagated in a riparian country located in the direction of the groundwater flows or of surface. This indicator concerns also the GAS over exploited zones compared to the natural recharge zones. The impact of the transboundary floods propagation can also be considered by this indicator in the case where the interest is focused on the surface waters (Menani, 2009).

Concerning the groundwater pollution and according to the World Bank (2009), in general, GAS faces a limited risk of contamination, 90% of the aquifer is covered by thick basalt which limits exposure to pollution. It seems that protection measures have been introduced in vulnerable areas concerned by a lack of adequate waste water and solid waste management. The World Bank report (2009) concludes that in its present state, the Guarani aquifer water quality is essentially without contamination from human activities, except in some sectors where the life mode of the populations is the consequence.

Argentina being the country of discharge of the GAS is in fact in an unfavourable geographical position. This situation is illustrated by the last conflict with Uruguay about the mills pulp waste waters, suspected of contaminating the Uruguay River downstream on the Argentinean territory (Alvarado and Reboratti, 2006). On another side, high salinities (sometimes very high over 3 times the concentration of ocean water) were found in some parts of the aquifer in Argentina (Entre Rios province), in relation with deep thermal groundwater (Tujchneider and al., 2006).

Table 13. Rating intervals of the geographical context (Weight: 2) and the risk partial index

Variation intervals	Rate		PIR
Under a dominant position natural	3	Argentina	6
Under a dominant position provoked	7		
In dominant position natural	0	Brazil – Paraguay - Uruguay	0

Partial index of minimum risk (PIR_{min}) = 6 - Partial index of maximum risk (PIR_{max}) = 14 + 6 = 20

35. Water governance by parts in conflict

It's the indicator the more difficult to evaluate because the data available are fragmentary. The cover rates as regards to access to improved water sources (houses connection) and to improved sanitation facilities are among the elements taken into account for the evaluation of this indicator by country (Soares and al, 2002; WHO/Unicef, 2006)

It seems that this indicator represents rather well the efforts made by each country. The achievements concerning house connections in improved water sources and improved sanitation facilities are based inevitably on a governmental policy which translates partly
the results of the governance in this sector. According to these data, Uruguay appears like the country which accomplished the most efforts concerning these 2 criteria by reaching a rate of 100 % in term of house connections to improved water sources and in term of improved sanitation, as well in urban area as in rural. The most unfavourable situation is that of Paraguay, notably in terms of sanitation. In Argentina and Brazil, situations develop positively by the constant improvement of the 2 criteria in urban and rural environments, even if in rural areas, the dispersion of the populations slows down considerably their connection with safe water supply system.

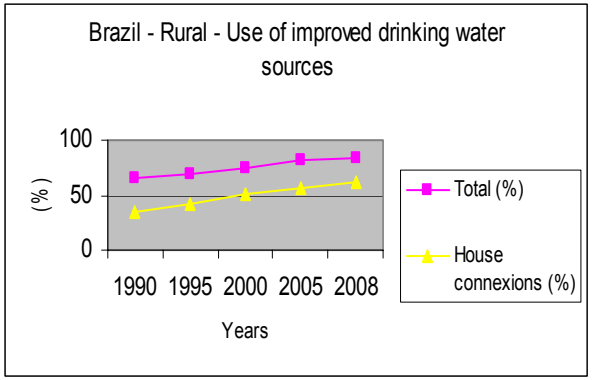
The other sub-indicators relating to the water governance (according with the GWP approach, 2003) in each country was estimated according to the available data (Table 14 - 15 and figure 4).

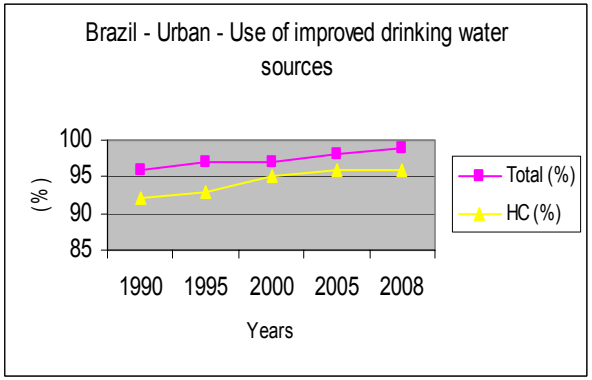
Table 14. Rating intervals of the water governance (weight: 2)

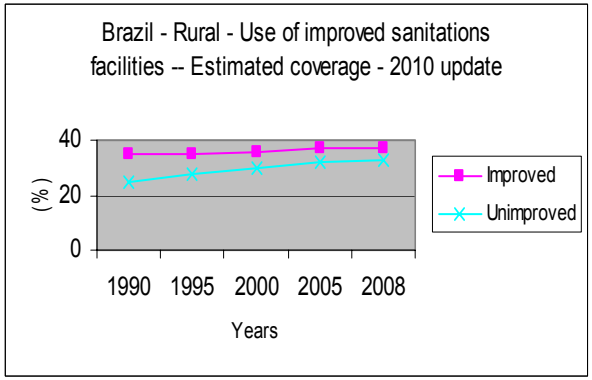
Variation intervals	Rate	Argentine	Brazil	Paraguay	Uruguay
Water resource management (general appreciation): Efficiency and Coherence, transparency, **Tariffs, metering**… by water resources agencies (public in general) and their directions (Ministries) (data related essentially to achievements – WHO/Unicef reports principally, Water profil of countries - FAO…).	3	1.5	2	0.5	2.5
Consented efforts in the exploitation of alternative resources and respect of the environment in a perspective of a sustainable development.	2	1.5	1.5	0.5	1.5
Criteria which are linked to the knowledge degree of the resources: databases updated. Identified and modelled water reserves… (last study: World Bank, 2009)	2	1.25	1.25	1.25	1.25
Planning concerted with the users within agencies of basins for example, communication with the users (dialogue and cooperation)… (Concerted management and dialogue with local populations - GEF, 2009)	1	0.5	0.5	0.5	0.5
Existence of structures which treat territorial or use conflicts and the respect of the ethics of the use of water –Existence of treaties or agreements concerning the shared water resources: multilateral agreements in the framework of the La Plata Basin (Pochat, 2010) - Agreement concerning the GAS signed in August 2010 by the four countries in the framework of Mercosur (Biason, 2011)	1	0.75	0.75	0.75	0.75
$PIR = 2 * (10 - \sum PIR_{(indicator)})$		9	8	13	7

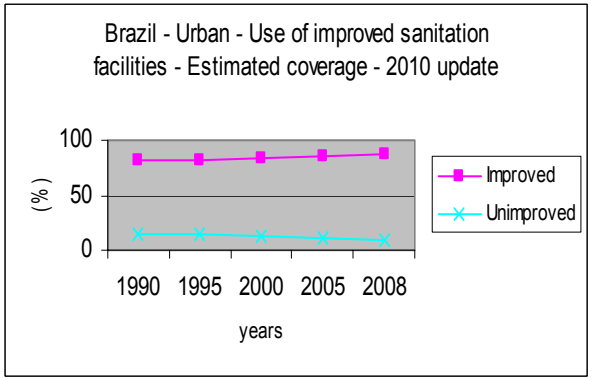
The weakest dimension for this indicator is 1 obtained as follows: [10 – 9] = 1.

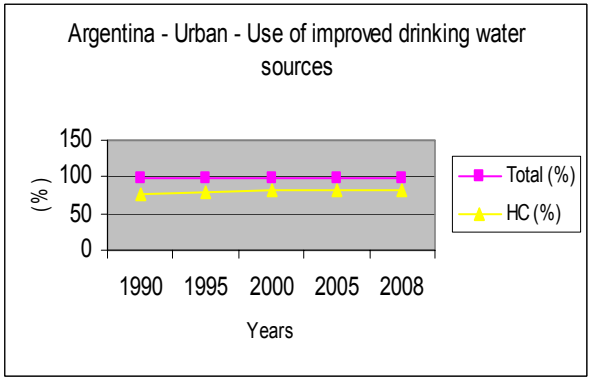
Partial index of minimum risk (PIR_{min}) = 2 - Partial index of maximum risk (PIR_{max}) = 18

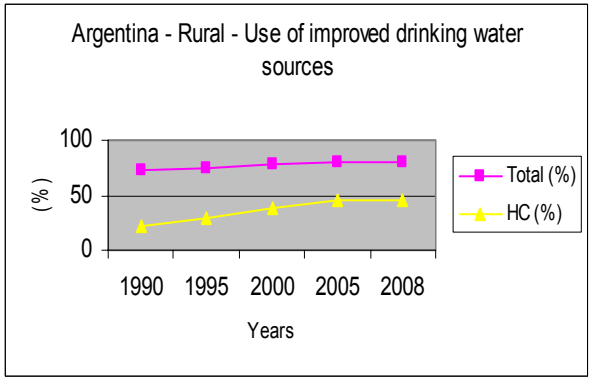

Brazil - Rural - Use of improved drinking water sources
100
50
0
(%)
1990 1995 2000 2005 2008
Years
Total (%)
House connexions (%)

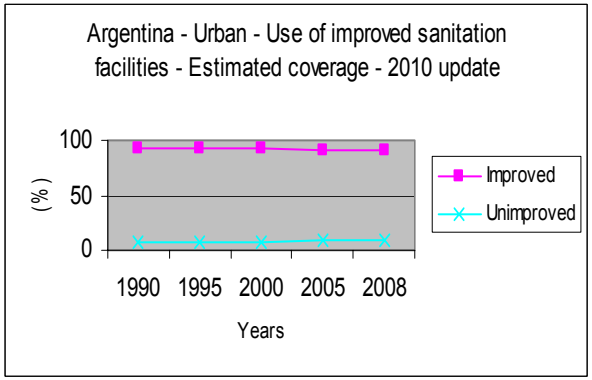

Brazil - Urban - Use of improved drinking water sources
100
95
90
85
(%)
1990 1995 2000 2005 2008
Years
Total (%)
HC (%)

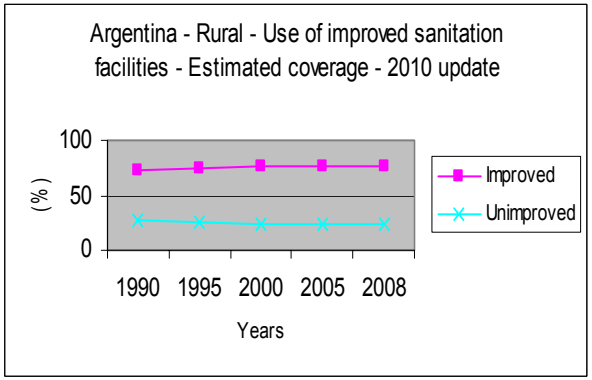

Brazil - Rural - Use of improved sanitations facilities -- Estimated coverage - 2010 update
40
20
0
(%)
1990 1995 2000 2005 2008
Years
Improved
Unimproved

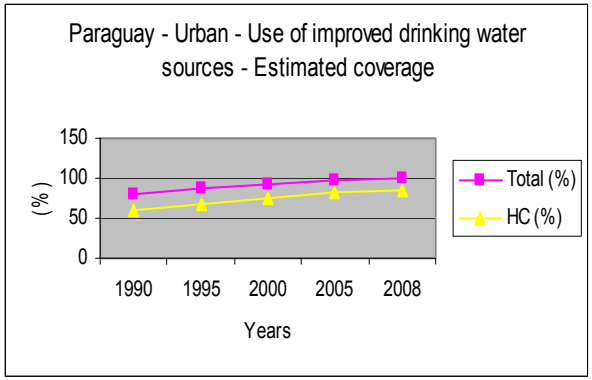

Brazil - Urban - Use of improved sanitation facilities - Estimated coverage - 2010 update
100
50
0
(%)
1990 1995 2000 2005 2008
years
Improved
Unimproved


Argentina - Urban - Use of improved drinking water sources
150
100
50
0
(%)
1990 1995 2000 2005 2008
Years
Total (%)
HC (%)


Argentina - Rural - Use of improved drinking water sources
100
50
0
(%)
1990 1995 2000 2005 2008
Years
Total (%)
HC (%)


Argentina - Urban - Use of improved sanitation facilities - Estimated coverage - 2010 update
100
50
0
(%)
1990 1995 2000 2005 2008
Years
Improved
Unimproved


Argentina - Rural - Use of improved sanitation facilities - Estimated coverage - 2010 update
100
50
0
(%)
1990 1995 2000 2005 2008
Years
Improved
Unimproved


Paraguay - Urban - Use of improved drinking water sources - Estimated coverage
150
100
50
0
(%)
1990 1995 2000 2005 2008
Years
Total (%)
HC (%)

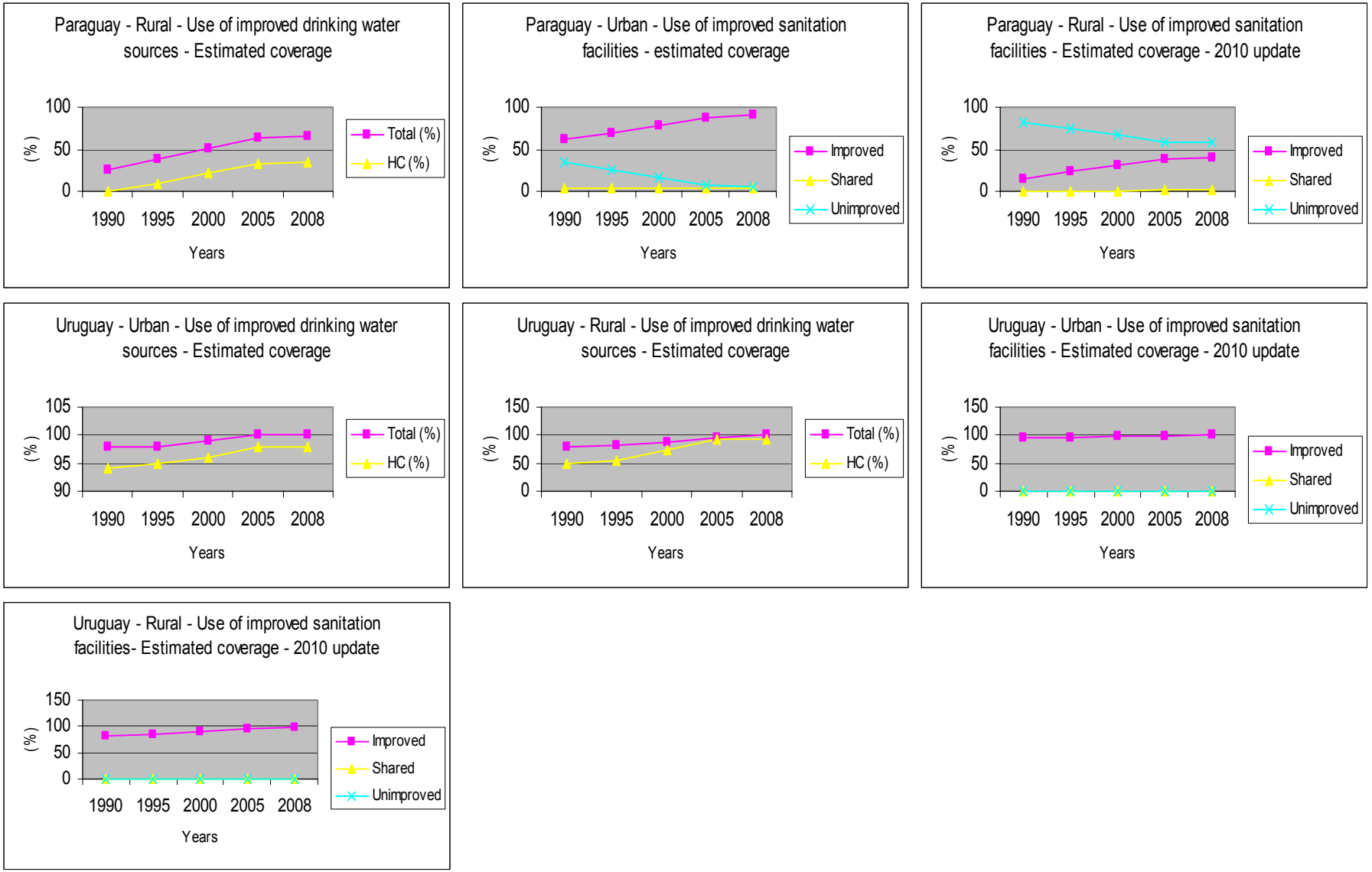


Figure 4. Evolution of the improved drinking water and the improved sanitation coverage in the 4 countries.

Table 15 - Sub-indicators related to the water governance and the coverage of access to safe drinking water supply and adequate sanitation

	Tariffs	Management Institutional indicators	Service quality	Levels of metering	Levels of consumption	Access to water and sanitation (WHO/Unicef, 2006) (2010update)	Responsibility for operating and maintaining water and sanitation services
Argentina	Relatively low m^3 water supply: 0.48 US$ and 0.31 US$ for sewerage in 2000 (WB/IDB, 2005 a)	- All six Guarani aquifer provinces are represented on the Argentina Federal Water Resources Council (GEF, 2009). - Federal laws (water pollution) - Provincial Law (Entre Rios)	- Mostly reasonable service quality. - Mostly continuous supply (PAHO/WHO , 2000)	Low (WB/IDB, 2005 b)	High levels of consumption for those with access to services. An average of 410 l/c/d (WHO/Unicef , 2006) The rate of consumption is one the highest in America Latina and in the World	Urban (90% of the population / Rural (10% of the pop.) **Water** Broad Definition Urban 98 % / Rural 80 % / Total 96 % House Connections Urban 83 % / Rural 45 % / Total 79 % **Sanitation** Broad Definition Urban 92 % / Rural 83 % / Total 91 % Sewerage Urban 48 % / Rural 5 % / Total 44 %	-Responsibility for policy setting: Ministry of Public Works - 1650 urban service providers - 19 provincial water and sewer companies -More than 100 municipalities, more than 950 cooperatives - Cooperation and dialogue with users and local populations: The project "Environmental protection and sustainable development of the GAS project" focused on efforts to build greater awareness among the wider public and indigenous communities in the concerned countries (GEF, 2009). - Concerted planning: The concerned states approved to place the secretariat of the project in Uruguay, in order to coordinate their common action which was supported by national units (GEF, 2009). -Number of Multilateral Agreements between riparian countries in the La Plata basin (Pochat, 2010) - Partially privatized water or wastewater services (Gleick, 2002). - Partial web-based information for IWRM (Usunoff, 2010)
Brazil	m^3 water supply: 0.82 US$ (SNIS, 2006) a high level of cost recovery	- The river basin is the territorial unit for water management - Federal and provincial Laws on water resources and water quality (LAC, 2010) - Agreement on the GAS management signed by the four countries in August 2011	- Mostly reasonable service quality and Mostly continuous supply - Technical and financial innovations such as condominial sewerage - Various Master plans at water basin level elaborated	Share of household metering 76% (IBN, 2010) Share of collected wastewater treated 35% (IBGE, 2000)	143-217 l/c/d Increased metering and tariffing policy have played a role in the reduced water use.	Urban (84% of the population / Rural (16% of the pop.) **Water** Broad definition Urban 96 % / Rural 57 % / Total 90 % House Connections Urban 91 % / Rural 17 % / Total 79 % **Sanitation** Improved Sanitation Urban 83 % / Rural 37 % / Total 75 % Sewerage Urban 53 % / Rural 5 % / Total 45 %	- Responsibility for policy setting Ministry of Cities -National water and sanitation company - no decentralization to municipalities **-** The National Water Supply and Sanitation Plan PLANASA -27 state-owned water and sanitation companies (Companhias Estaduais de Saneamento Básico or CESBs). - Brazil has integrated groundwater considerations into its National Water Resources Plan. - EMBRAPA: research and development of processes of irrigation (economical processes – FAO, 2008) - The National Water Resources Council (CNRH) is the highest normative with the mandate to promote the co-ordination of water resources planning, monitor the execution of the National Water Resources Policy; establish criteria for granting of water usage rights and pricing mechanisms. It is the strict competence of the Federal Government to legislate on water (FAO, 2008).

	Tariffs	Management Instit. indicat	Service quality	Levels of metering	Levels of consumption	Access to water and sanitation (WHO/Unicef, 2006) (2010update)	Responsibility for operating and maintaining water and sanitation services
Paraguay	-Low tariffs -Low level of cost recovery -Urban utility tariffs are set below cost recovery levels and are adjusted infrequently. This makes it impossible to finance the investments in the field of water.	- The new Water Resources Law (2007) includes groundwater : institutional framework partially effective - Water pollution; inadequate means for waste disposal pose health risks;	- Services (house taps and sewers) remains low compared to demand and to other countries in the region (Jouravlev, 2004).	Very low	217 l/c/d (WHO/Unicef (2006)	Urban 58% pop. / Rural (42% pop. / Total 86 % **Water** Broad definition Urban 99 % / Rural 68 % / Total 86 % House Connections Urban 82 % / Rural 25 % / Total 58 % **Sanitation** Broad definition Urban 94 % / Rural 61 % / Total 80 % Sewerage Urban 16 % / Rural 0 % / Total 9 %	-Responsibility for policy setting : Ministry of Public Works and Communications - Public company for sanitation ESSAP-SENASA -Regulatory Agency for Sanitation (ERSSAN) - 1 large public urban service provider and 500 small private -2500 rural service providers - The Juntas are grouped in 10 associations which supply water to more than half of country's population. - Emergence of independent private suppliers "aguateros" since the 1970s. Their efforts account for a significant share of the expansion of urban water coverage in the area of the capital. Aguateros are private, informal service providers who operate small-scale systems with up to 3,000 connections. An estimated 500 private suppliers serve some total of about 500,000 people. Tariffs by Aguateros fully recover costs and compare favorably with tariffs charged by the public sector.
Uruguay	Average urban water and sewer bill US$ 22/month (2007). - Water and sewer tariffs: nearly 8% of households' income in 2003: very high ratio which has probably further increased since then.	Constitutional amendment in October 2004 prohibited any form of private sector participation in the water sector. -Creation of a national Guarani Management Unit (GEF, 2009)	Water service quality is considered good, with practically all localities in Uruguay receiving disinfected water on a continuous basis.70% of wastewater collected by the national utility was treated.	Share of household metering 93%	-Average urban water use (l/c/d) 183 - water production per capita is high at 411 l/c/d - water use is much lower than in neighboring Argentina, where metering is not widespread	Urban (93% of the pop. / Rural (7% of the pop.) / Total 100 % **Water** Broad definition Urban 100 % / Rural 100 % / Total 100 % House Connections Urban 97 % / Rural 84 % / Total 96 % **Sanitation** Broad definition Urban 100% / Rural 99 % / Total 100 % Sewerage Urban 81 % / Rural 42 % / Total 78 %	-Responsibility for policy setting: Ministry of Housing, Land Management and Environment -National water and sanitation company - The state owned national utility Obras Sanitarias del Estado (OSE) which provides water and sewer services to all of Uruguay except Montevideo, where the municipality provides sewerage and OSE provides water services only. -To enhance sector performance, new institutions have been recently created, including: the Regulatory Entity for Energy and Water (URSEA); the National Directorate of Water and Sanitation (DINASA) in the Ministry of Housing, Land Management and Environment, responsible for creating national sector policies on WSS; and the Advisory Commission on Water and Sanitation (COASAS).

4. The Global Conflict Risk Index around the transboundary water resources

Table 16. Global Conflict Risk Index around the GAS

Indicators	PIR			
	Argentina	Brazil	Paraguay	Uruguay
Dependence degree to the transboundary water resources	10	50	30	30
Satisfaction degree of the water needs	4	14	6	6
Geopolitical context of the zone of conflict	3	3	3	3
Geographical position in relation to the water resources	6	0	0	0
Water governance by parts in conflict	9	8	13	7
Global Risk Index per country	32	**75**	52	46

The same method applied to the Jordan basin (Menani, 2009) has given the indexes of risk below (table 17).

Table 17. Global Index of Risk around the transboundary water resources of the Jordan basin

	Lebanon	Israël	Syria	Jordan	The West Bank	Ghaza
GIR	**80**	**101.5**	**105**	**128**	**142.5**	**151**

It seems that the risk indexes related to the two cases reflect globally the “tensions” degrees which prevail currently around the transboundary waters of the two regions; the value of the global risk index varying between a minimum of 25 and a maximum of 158.

5. Impact of the climate change

This analysis will not be complete if one doesn't discuss problems of the global climatic changes and their impact on the risk of conflict around the GAS. One will not focus in this paper on the increasing frequencies and intensities of floods which concern surface waters and their management inside their transboundary hydrographic basin (La Plata basin).

According to World Bank (2009) and some authors cited by Cooley and al. (2009), as impacts of the climatic changes on the GAS's area, it's expected a higher evapotranspiration as consequence of the increase of precipitations and temperatures. Consequently, some areas of GAS can face a deficit of water, particularly in certain zones of Paraguay and Brazil. Groundwater recharge will also be affected by precipitations' changes which are not expected to be lower. These impacts will increase certainly the pressure around the GAS like a strategic reserve.

Admittedly, it becomes more than necessary to integrate this parameter in the management of shared waters, like that was already expressed by Goldenman (1990).

The climate changes' indicator is very delicate to quantify and to predict, even if new technologies allow to hope for a better approach of the phenomenon, such the program GRACE (Gravity Recovery and Climate Experiment) developed by NASA in 2006 (Cooley and al., 2009) of which one of the applications is the survey of the movement of water around the globe, particularly groundwater about which little is known.

The changes, which can affect a given situation, are indirectly taken into account by the GIR method according to the variable indicators cotes (Menani, 2009). Let us take the example of the water needs which will know spectacular changes in particular in the agricultural field, which is about 70 % of the currently world uses. The climatic changes which will affect the hydrological cycles will consequently influence these indicators' cotes, differently according to the regions. The cotation system suggested in the method considers precisely intervals of change of satisfaction of the water needs, as well in the agricultural sector as in other uses.

6. Conclusion

The objective of this paper is to present the actual situation of the critical issues related to the Guarani aquifer system according to the GIR method indicators and to express the current situation by conflict risk indexes around these transboundary water resources.

For this purpose, available data's related notably to the dependence degree to the GAS groundwater for satisfying the different uses of close countries, the geopolitical context, the water governance… were analyzed and served to evaluate the conflict risk indexes.

According to this method, Brazil occupies the first rank with a GIR of 75 points which expresses its large dependence to this shared aquifer for satisfying the uses of its big population living in the GAS region (nearly 80 millions inhabitants).

The position of the Paraguay with 51 points is in relation notably with its dependence to the GAS, the weak achievements related to the coverage in approved water supply and sanitation, serious problems of pollution and the very weak score in term of water governance compared to riparian countries.

Uruguay whose index of risk (46) is slightly lower than that of Paraguay differs however by its better water governance.

Argentina occupies the last position with a risk index of 39 points, in relation with its weak current needs to the GAS water resources, except in the recreation field (thermal waters).

Solutions for a better management of the shared water resources, by the improvement of the institutional framework, the dialogue and the cooperation largely approached by many authors (Wolf, 1998 and 2003) constitute arguments to defuse crises or to prevent them. This aspect was not treated in this paper because the proposed approach of the global risk of conflict around the GAS water resources is a diagnostic of the situation which prevails actually. The GIR may change if the situation in relation with any considered indicator changes.

References

ALVARADO R., REBORATTI C. (2006). Géopolitique de papier : usines de cellulose et conflit environnemental dans le Cône sud. Éditions La Découverte-Hérodot, 2006/4 - n° 123 : 133-148. http://www.cairn.info/article.php?ID_REVUE=HER&ID_NUMPUBLIE=HER_123&ID_ARTICLE=HER_123_0133.

AMORE L. (2003). Transboundary management of the Guarani aquifer system. Information to support sustainable water management. From local to global levels. Proceedings mtm-iv - transboundary management of the Guarani aquifer system, September 15 -18, 2003 The Netherlands: 259-266. http://www.mtm-conference.nl/mtm4/docs/259-Amore%20final.pdf.

AMORE L. (2009). Guarani Aquifer System (GAS): from knowledge to governance. Environmental Protection and Sustainable Development of the Guarani Aquifer System Project. UNESCO – GEF 5th IWF' 2009, Cairns, October 24-29, 2009.

ARAUJO L. M., FRANÇA A.B., POTTER P. (1999). Hydrogeology of the Mercosul aquifer system in the Paraná and Chaco-Paraná basins, South America, and comparison with the Navajo-Nugget aquifer system, USA. Hydrogeology Journal, 7:317-336.

BIASON C. (2011). Governance and Scarcity: the Example of the Guaraní Aquifer. Intern, Global Health Security. STIMSON, February 04, 2011. http://www.stimson.org/spotlight/governance-and-scarcity-the-example-of-the-guarani-aquifer/

CAMPOS H.C.N.S. (2000). MAPA HIDROGEOLÓGICO DEL ACUÍFERO GUARANI. - Campos1. 1st Joint World Congress on Groundwater. Fortaleza, Brazil, July 31 to August 4, 2000. http://www.sigrh.sp.gov.br/sigrh/ARQS/RELATORIO/CRH/CBH-PARDO/GUARANI-RP/998/abas220.pdf. 15 p.

COOLEY H., CHRISTIAN-SMITH J., GLEICK P.H., ALLEN L., COHEN M. (2009). UNDERSTANDING AND REDUCING THE RISKS OF CLIMATE CHANGE FOR TRANSBOUNDARY WATERS. Pacific Institute in cooperation with the UNEP. www.pacinst.org.

FALKENMARK M., WIDSTRAND C. (1992). Population and water resources: A delicate balance. Population Bulletin, 1992, Vol. 47, N° 3, p. 1-36.

FISCHHENDLER I. (2004). Legal and Institutional Adaptation to Climate Uncertainty: a Study of International Rivers. Water Policy, 6: 281–302.

FAO - Water profile of Brazil (2008) – The Encyclopedia of Earth (April 17, 2008). http://www.eoearth.org/article/Water_profile_of_Brazil?topic=49483

FAO-AQUASTAT. (2009). Databases. Water resources indicators. http://www.fao.org/nr/water/aquastat/maps/AQUASTAT_water_resources_and_MDG_water_indicator-March_2009.pdf

GEF (2009). From Ridge to reef. Water, Environment and Community Security. GEF action on transboundary water resources: 21-25.http://www.thegef.org/gef/sites/thegef.org/files/publication/GEF_RidgetoReef_CRA_lores.pdf

GOLDENMAN G. (1990). Adapting to Climate Change: A Study of International Rivers and Their Legal Arrangements. Ecology Law Quarterly, 17(4): 741-802.

GWP. Effective Water Governance: Learning from the dialogues. Global Water Partnership, 2003. Available at: http://www.gwpforum.org/servlet/PSP?iNodeID=215& temId=473

GLEICK P.H., WOLFF G., CHALECKI E.L., REYES R. (2002). The New Economy of Water: The Risks and Benefits of Globalization and the Privatization of Fresh Water. Pacific Institute. Oakland, California.

IBGE (Brazilian Institute for Geography and Statistics): National Survey of Basic Sanitation (PNSB) 2000.

IBNET (2010). International Benchmarking Network for Water and Sanitation Utilities.

ICJ - International Court of Justice (2010). Judgment. Case concerning pulp mills on the River Uruguay (Argentina *v.* Uruguay), 20 april, 2010, 80 p. http://www.icj-cij.org/docket/files/135/15877.pdf

JOURAVLEV A. (2004). Drinking water supply and sanitation services on the threshold of the XXI century (databases year 2000). United Nations publication. CEPAL - SERIE Recursos Naturales e Infraestructura. N°74, 64 p. http://www.eclac.org/ and http://www.cepal.org.

LAC. (2010). Texts of LAC legislation and regulations on *water* and sanitation. http://www.temasactuales.com/laws_policies/legislation_water_san.html.

MENANI M.R. (2009). A Numerical Method to Index the Risk of Conflict around the Transboundary Water Resources. Validation by a Studied Case. Water Resources, Vol. 36, n°6, pp. 731–742. © Pleiades Publishing, Ltd., 2009.

MVOTMA_Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente (2004). "Segunda Comunicación Nacional a la Conferencia de las Partes en la Convención Marco de las Nacional Unidas sobre el Cambio Climático". Unidad del Cambio Climático. pp. 226–227. http://www.cambioclimatico.gub.uy//index.php?option=com_search&Itemid=5&searchword=Segunda+comunicacion&searchphrase=any&ordering=newest

OAS - Organization of American States Office for Sustainable Development and Environment. (2005). Environmental Protection and Sustainable Development of the Guarani Aquifer System. 10 p.. WATER PROJECT SERIES, October, n° 7: 10 p. http://www.oas.org/dsd/Events/english/Documents/OSDE_7Guarani.pdf

PAHO - Pan American Health Organization / WHO - World Health Organization (2000). "Evaluación de los Servicios de Agua Potable y Saneamiento 2000 en las Américas - Argentina - Informe Analítico". http://www.cepis.ops-oms.org/eswww/eva2000/argentina/informe/inf-00.htm. Retrieved 2008-02-14., Situación de la prestación de los servicios de agua potable y saneamiento

PEREIRA H.A. (acceded 2010). Transboundary groundwater management in South America: identifying barriers for policy implementation. London School of Economics and Political Science, London, United Kingdom, 4 p.
http://www.inweb.gr/twm4/abs/PEREIRA%20Henrique%20de%20Almeida.pdf. Acceded on June 2010.

POCHAT V. (2010). Institutional challenges in the La Plata basin, South America. MRC international conference “Transboundary Water Resources Management in a Changing World”, Hua Hin, Thailand, 2-3 April 2010.

PROJECT GENERAL SECRETARIAT (2003). Guarani Aquifer System Project web page. (www.sg-guarani.org).

SNIS (2006). Diagnóstico dos Serviços de Água e Esgotos – 2006. Ministério das cidades. Secretaria Nacional da Saneamento Ambiental.

SOARES L.C.R., GRIESINGER M.O., DACHS N.W., BITTNER M.A, TAVARES S. (2002). Inequities in access to and use of drinking water services in Latin America and the Caribbean. Rev Panam Salud Publica/Pan Am J Public Health 11(5/6), 2002. http://www.scielosp.org/pdf/rpsp/v11n5-6/10723.pdf.

TUJCHNEIDER O., PEREZ M., PARIS M., D´ELIA M. (2006). The Guaraní Aquifer System: State-of-the-art in Argentina. Proc. International symposium Aquifers Systems Management, 30 may-1th june 2006, Dijon, France.

USUNOFF, E. (2000). Web-Based Information of Integrated Water Resources Management of a Multi-National Aquifer. III Water Information Summit, Florida Center for Environmental Studies,Miami, Florida, USA.
http://www.waterweb.org/wis3/presentations/30_Usunoff_paper.pdf

VIVES L., USUNOFF E., CAMPOS H., JÁUREGUI C.F. (2006). Preliminary numerical model of the regional Guaraní Aquifer System and information management proposal. http://www.sigrh.sp.gov.br/sigrh/ARQS/RELATORIO/CRH/CBH-PARDO/GUARANI-RP/1031/madras_guarani.pdf

WHO/UNICEF. (2006). Argentina. World Health Organization. Meeting the MDG drinking water and sanitation target: the urban and rural challenge of the decade.
http://www.wssinfo.org/pdf/JMP_06.pdf.

WHO/UNICEF. (2008). Water supply and sanitation in Brazil. Progress on Drinking Water and Sanitation, 41-53.
*World Bank. Water supply and sanitation in Uruguay - Obras Sanitarias del Estado; Data on population and deflators: World Bank World Development Indicators database

WHO / UNICEF. (2006). Joint Monitoring Programme for Water Supply and Sanitation. Estimates for the use of Improved Drinking-Water Sources Updated March 2010. Argentina http://www.childinfo.org/files/WAT_Argentina.pdf

WHO / UNICEF. (2006). Joint Monitoring Programme for Water Supply and Sanitation. Estimates for the use of Improved Sanitation Facilities. Updated March 2010.Argentina
http://www.childinfo.org/files/SAN_Argentina.pdf

WHO / UNICEF. (2006). Joint Monitoring Programme for Water Supply and Sanitation. Estimates for the use of Improved Drinking-Water Sources Updated March 2010. Brazil http://www.childinfo.org/files/WAT_Brazil.pdf

WHO / UNICEF. (2006). Joint Monitoring Programme for Water Supply and Sanitation. Estimates for the use of Improved Sanitation Facilities. Updated March 2010. Brazil
http://www.childinfo.org/files/SAN_Brazil.pdf

WHO / UNICEF. (2006). Joint Monitoring Programme for Water Supply and Sanitation. Estimates for the use of Improved Drinking-Water Sources Updated March 2010. Paraguay http://www.childinfo.org/files/WAT_Paraguay.pdf

WHO / UNICEF. (2006). Joint Monitoring Programme for Water Supply and Sanitation. Estimates for the use of Improved Sanitation Facilities. Updated March 2010. Paraguay
http://www.childinfo.org/files/SAN_Paraguay.pdf

WHO / UNICEF. (2006). Joint Monitoring Programme for Water Supply and Sanitation. Estimates for the use of Improved Drinking-Water Sources Updated March 2010. Uruguay http://www.childinfo.org/files/WAT_Uruguay.pdf

WHO / UNICEF. (2006). Joint Monitoring Programme for Water Supply and Sanitation. Estimates for the use of Improved Sanitation Facilities. Updated March 2010. Uruguay
http://www.childinfo.org/files/SAN_Uruguay.pdf

WOLF A (1998). Conflict and Cooperation along International Waterways. Water Policy, 1998, Vol. 1, N° 2, p. 251–265.

WOLF A, YOFFE S, GIORDANO M. (2003). International waters: indicators for identifying basins at risk. Dept of Geosc., Oregon State University. UNESCO/IHP/WWAP. IHP-VI/ Technical documents in Hydrology/ PCCP series, 2003, n° 20, SC-2003/WS/58. Available at http:// *unesdoc.unesco.org/images/0013/001333/133306e.pdf*

WORLD BANK. (2002). Environmental protection and sustainable development of the Guarani aquifer system project. Report n°: 23490-lac. Project appraisal document on a proposed global environment facility trust fund grant to Argentina, Brazil, Paraguay and Uruguay. May 17, 2002. 142 p.

WORLD BANK. (2006). An Independent Evaluation of the World Bank's Support of Regional Programs. Case Study of the Guarani Aquifer Project. Washington, D.C. 50 p.
http://siteresources.worldbank.org/EXTREGPROPAR/Resources/GuaraniAquiferProject.pdf

WORLD BANK. (2009). Implementation completion and results report (Project ID: P068121 L/C/TF Number(s):TF-50950 TF-51223). Report n°: ICR00001198. Environmental protection and sustainable development of the guarani aquifer system project. July 31, 2009. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2009/08/13/000333037_20090813231853/Rendered/PDF/ICR11980P068121IC0disclosed08112191.pdf
Consulted 04/24/2010.

WORLD BANK/INTERAMERICAN DEVELOPMENT BANK (IDB) (July 2005) a. "Infrastructure in Latin America: Recent evolution and key challenges. (Seven country briefs) -C.B. 1/7: Argentina". http://www.worldbank.org/transport/transportresults/regions/lac/cb-argentina-260705.pdf. Retrieved 2008-02-18., p. 65

WORLD BANK/INTERAMERICAN DEVELOPMENT BANK (IDB) (July 2005) b. "Infrastructure in Latin America: Recent evolution and key challenges. (Seven country briefs) -C.B. 1/7: Argentina". http://www.worldbank.org/transport/transportresults/regions/lac/cb-argentina-260705.pdf. Retrieved 2008-02-18., p. 64. Primary data are from a regional survey undertaken by PAHO/WHO in 2000.