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Review

Water resources management in the Brazilian agricultural irrigation

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The Brazilian agribusiness is growing fast, especially in the last fifteen years when the grains production almost two-folded. Besides the expansion in the agricultural frontier to the Amazonian Region, there are other drivers for the success. As one of the biggest country around the globe, Brazil has the largest water reserve in the world. Brazilian agriculture production and productivity are also related to the use of irrigation systems. Based on a bibliographic research, this paper presented the context of Brazilian agriculture expansion; its demands for water resources by means of irrigation systems; some advances in legislation with the creation of two main mechanisms of water resources management (granting and charging for use); and, discusses some practices in water resources management which are being implemented in some Brazilian regions. In conclusion, the water resources management applied in irrigation of Brazilian agriculture depends on the complete achievement in the Hydrographic Basin Committees' role to reach the legislation objectives and saving natural resources.

Key words: Hydrographic basin committees, granting for use, charging for use, Brazil.

INTRODUCTION

Concerns in relation to the use of the water resources for agricultural usage are also present in the Brazilian agri-business. Brazil presents one of the largest geographic land areas in the world and one of the largest areas for agriculture. Brazilian agriculture is exposed to wide atmospheric variations, especially rainfall. Pressures for increasing production and the need for minimizing risks are determinant factors in the expansion of agricultural irrigation use in Brazil. Although it detains a great part of all the fresh water reserves in the world, Brazil is far from being a country rich in water.

Main factor is the bad distribution of water around the national territory. As the larger water reserve, Amazonian basin attends just to a small portion of Brazilian population and practically is not used for agricultural irrigation. Therefore, Brazil has observed a great need to manage water resources in agriculture and several actions have been put into practice for using water in a sustainable way.

This paper aims to present the context of Brazilian agriculture expansion; its demands for water resources by means of irrigation system; some advances in legislation with the creation of granting and charging for water use as mechanisms of management; and, discusses some practices in water resources management which are being implemented in some Brazilian regions by presenting three cases study. A bibliographical research was carried to reach those goals.

In the next section some data is going to be presented, it characterizes the dimension of Brazilian agriculture. In sequence, some data about rainfall regimen in different regions of Brazil and the usage of irrigation system as a way to minimize risk from plantations and maximize the crops yield are presented. In the fourth section, aspects related to the water reserves in Brazil are discussed. A brief description of managing system of water resources in Brazil is presented in the beginning of the fifth section, with the presentation of cases about management of water resources for agricultural irrigation. In the sixth section, some final considerations about the future and the sustainability of agricultural irrigation in Brazil and the importance of water resources management are presented.

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BRAZILIAN AGRICULTURAL DIMENSION

Historically, the development of Brazil has been associated to agriculture. Since its discovery, three of the four most important development cycles were related to agricultural products: sugar cane cycle, coffee cycle, and the soybean cycle. Being one of the countries of largest geographic dimensions in the world, Brazil has responded to the world demand for food by implementing the cultivating area in relation to production technology. As a result, along the last thirty years Brazilian crops have obtained consecutive production and productive records.

From a total area superior to 850 million hectares, little more than 845 million hectares correspond to land areas and, therefore subject to be explored economically by agricultural activities or other kinds of use. According to FAO (2009), in 2007, Brazil used approximately 264 million hectares for agricultural purposes, approximately one third of the total land. The remaining land is designated to forestry, pastures, permanent crops and other uses. Between 1980 and 2007 Brazil has enlarged its agricultural area in approximately 40 million hectares, most of the area obtained by replacing forests.

In its agricultural lands in 2007 Brazil has produced more than 549 million tons of sugar cane, 57.8 million tons of soybean, 52.1 million tons of corn, 26.5 million tons of cassava, 18.6 million tons of orange, 110.6 million tons of rice, 4.1 million tons of wheat, 3.16 million tons of beans, 2.2 million tons of coffee, among other million tons of several cereals, vegetables and fruit (FAO, 2009). These numbers settles Brazil up as one of the main food suppliers, not only for internal consumption, but also for other markets for which are exported to. Among the main agricultural commodities, Brazil occupies world importance in the production of some of them. According to FAO (2009), in 2007 Brazil has been the main world producer for sugar cane, beans, orange, papaya and coffee. It has occupied second position in world production of pineapple, soybean, tobacco, triticale, pepper and beef. It has been the third producer for citric, banana and chicken. It has been the world producer of cotton and corn. it has been the biggest producer of cocoa, turkey meat and cassava. Brazilian rice production occupied tenth position, standing behind Asiatic countries. Such data reflect the dimension of the Brazilian agriculture and its important role in the world food production, besides transferring to the country the responsibility of producing each time more in a sustainable way.

As an answer to the challenge for producing each time more preserving natural resources, Brazilian agriculture has extending the yield of its main crops, making possible producing more or reducing planting areas using the land for other purposes. A comparative of the main Brazilian crops development in relation to planted area and yield may be seen in Table 1. Data confirm gains in yield for all analyzed crops between 1980 and 2005. During this period, the nine main ones extending the cropping area in 34.4% and the yield had increased by 70.0%. The main gains in yield were observed in wheat, rice, coffee, beans and corn crops.

Once it is an intercontinental country, Brazil presents regions more adapted for cultivating certain crops (Table 2). Therefore, in 2008, the South Region had a larger area for cropping corn with more than 5.0 million hectares, also it is the biggest rice, wheat and tobacco producer with areas equivalent to 1,265, 2,217 and 0,406 million hectares, respectively. Southeast Region is the main producer of sugar cane, coffee and orange, which areas planted in 2008 were 5,367, 1,760 and 0,629 million hectares, respectively. The Center-West Region is the main producer of soybean with a cultivated area superior to 9.4 million hectares.

Although the Northeast and North Regions do not occupy a highlighted position in the production of the selected crops, it is to the North Region that the bovine production and soybean has been growing. Northeast Region, in its turn, has become an important tropical fruit producer and exporter. This brief figure illustrates the dimension of Brazilian agriculture. Although the country's Gross Domestic Product for primary agriculture represents only 4.53% of the national GDP, when added to values aggregated by agribusiness activities as a whole, agribusiness GDP represents more than one-fourth of Brazilian GDP (CEPEA, 2009). Besides economic values, agriculture plays an important social role, not only by supplying food, but also by generating employment and profit. According to the Agricultural Census of 2006, more than 16 million people were directly occupied with agricultural activities (Agricultural Census, 2006).

Considering geographic distribution of agricultural crops in Brazil, the agricultural activity is constantly subject to rainfall regimen and to rain precipitation levels which occur at each one of the regions in particular and also in the country as a whole. For minimizing the negative effect of possible draught and increase the activity profitability, the Brazilian farmers have been investing each time more in irrigation systems as a way to guarantee the supply of water for the crops.

RAINFALL REGIMEN AND USE OF IRRIGATION SYSTEM IN BRAZILIAN AGRICULTURE

According to what was said before, there are different reasons for using irrigation systems in agriculture: crops yield gains, improvement in the product quality, reduction of risks, increases in the farmer's profitability by supplying products in off season, and by a biological need, such as the rice crop, for instance. The distribution of agricultural crops by different regions, according to their adaptation to soil and climate conditions, does not eliminate the risks of

Table 1. Yield of the main Brazilian crops, evolution between 1980 and 2005.

Crops	1980		2005		Var. % 1980 - 2005
	Harvested area (Million/ha)	Yield (Tons/ha)	Harvested area (Million/ha)	Yield (Tons/ha)	
Sugar cane	2,6	57,0	5,8	72,8	+27.72
Beans	4,6	0,424	3,7	0,806	+90.09
Orange	0,575	18,93	0,806	22,15	+17.01
Coffee	2,4	0,436	2,3	0,920	+111.00
Soybeans	8,77	1,727	22,95	2,230	+29.13
Tobacco	0,316	1,279	0,494	1,801	+40.81
Corn	11,45	1,779	11,55	3,040	+70.88
Rice	6,24	1,565	3,92	3,369	+115.27
Wheat	3,12	0,865	2,36	1,973	+128.09

Source: FAO (2009).

Table 2. Crops distribution into the Brazilian regions, 2008 (hectares).

	North	Northeast	Southeast	South	Center West	Brazil
Corn	544.323	3.000.081	2.351.125	5.077.162	3.774.558	14.747.249
Beans	163.172	2.260.777	627.693	709.913	205.963	3.967.518
Rice	434.767	699.379	93.310	1.265.692	376.137	2.869.285
Sugar cane	28.016	1.277.481	5.367.621	649.448	888.311	8.210.877
Tobacco	248	25.984	258	406.007	200	432.697
Soybean	508.024	1.580.796	1.396.542	8.146.896	9.431.463	21.063.721
Wheat	0	0	100.090	2.217.119	68.232	3.005.441
Coffee	184.597	175.729	1.760.810	96.618	32.737	2.250.491
Orange	18.396	127.674	629.823	53.297	7.841	837.031
Tomatoes	1.545	13.650	23.098	9.341	13.391	61.025

Source: IBGE (2009).

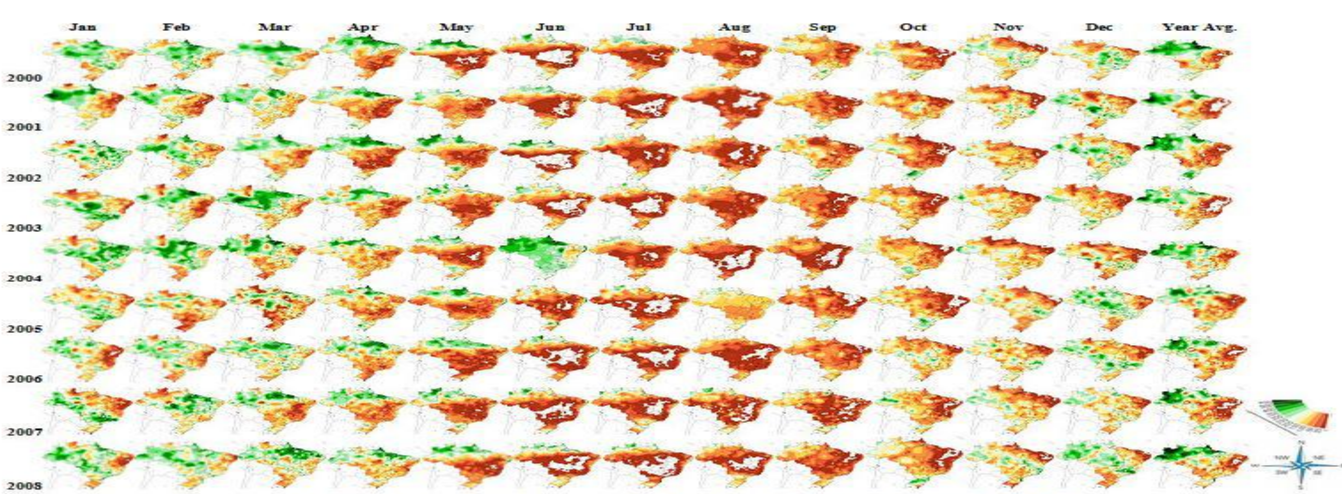

Figure 1 – Monthly Rainfall preciptation in Brazil from 2000 to 2008; Source: INPE (2009)

Figure 1. Monthly rainfall precipitation in Brazil from 2000 – 2008.
Source: INPE (2009).

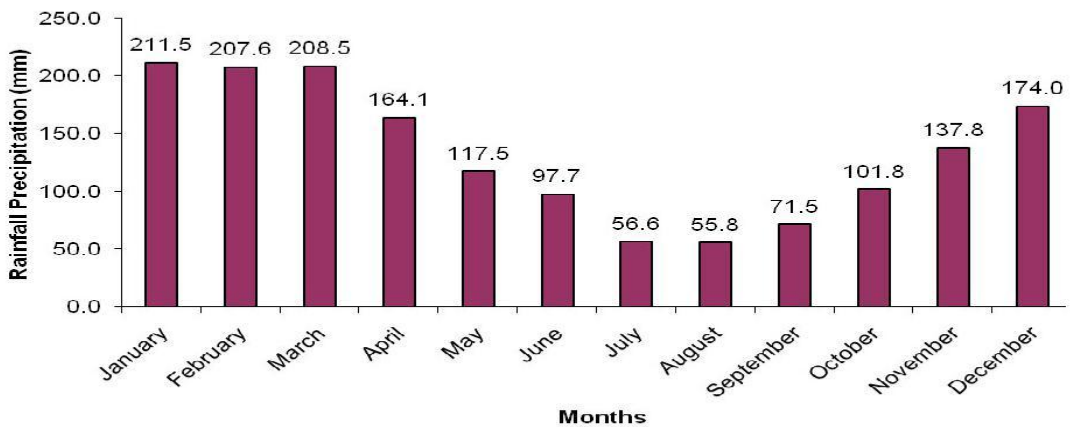

Figure 2. Average of rainfall precipitation per month; 2000 - 2008.
Source: authors from INPE (2009) data.

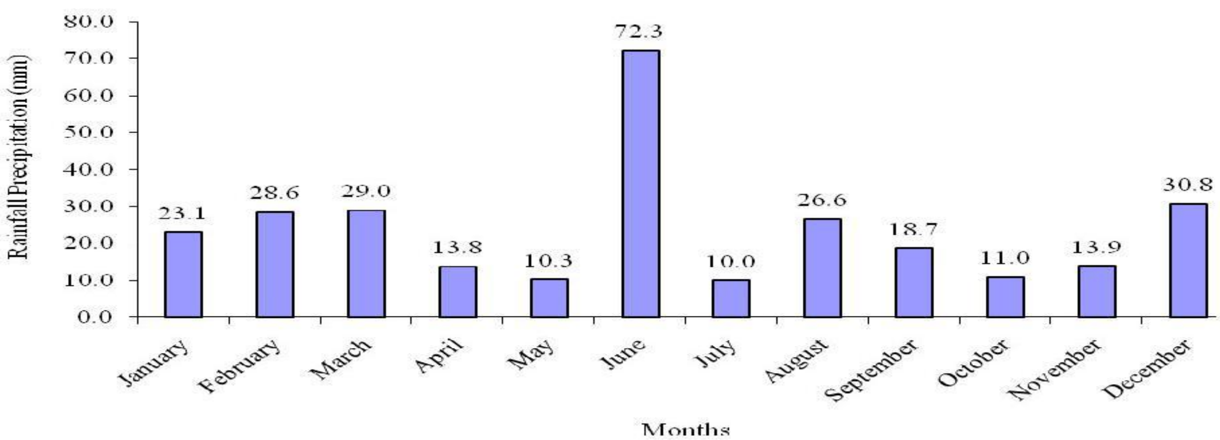

Figure 3. Standard deviation in the monthly rainfall precipitation – 2000-2008.
Source: authors from INPE (2009) data.

production losses caused by climatic factors.

The main climatic menace to agricultural crops is rainfall scarcity during stages of crops development. According to what is possible to visualize in Figure 1, rainfall regimen in Brazil is characterized by two distinct periods: the first which takes from November to April, in which precipitation levels stand just above annual average of 133 mm^3; the second period comprehends the months from May - October, which monthly rain precipitation stands under the annual monthly average of 133 mm^3 (Figure 2).

Analyzing the rainfall regimen and its distribution in different regions of Brazil, it is possible to observe that in the first period, rains are distributed more homogeneously between different regions, with some more intensity in Southeast, Center-West and North Regions. This standard in rainfall regimen favors the development of great part of the crops, which planting time and development stages coincide with those months. It is the case of soybean, corn, sugar cane, tobacco, beans, rice, and tomato crops. In the second period, besides precipitation inferior levels, rainfalls are more concentrated in the South and North Region. This favors the period of sugar cane harvesting and planting and the development of wheat crop, which main producer is South Region. Yet Northeast Region has a regimen of little rainfall in both periods, fact which brings difficulty for developing agriculture in that Region. On the other hand, dry weather conditions make Northeast Region favorable for cultivating tropical fruits under irrigation conditions.

Apparently, the Brazilian rainfall regimen would attend the need of crops in planting and development stages in terms of water amounts demanded by plants. However, the critical point is the distribution of rain throughout the year (Figure 3). The occurrence of long periods of scarcity in critic stages for plants development is not an occasional phenomenon. Some crops, such as corn, beans and tomatoes, for instance, are highly sensitive to

Table 3. Agricultural area irrigated in different Regions of Brazil according to irrigation method; 2002.

	Irrigation method (Hectares)					
Region	**Agricultural draining**	**Surface**	**Conventional aspersion**	**Central pivot**	**Localized**	**Total**
North	31.700	50.180	6.055	1.410	1.690	91.035
Northeast	35.085	155.644	242.506	122.006	138.421	693.662
Southeast	9.125	208.740	245.768	362.618	83.388	909.639
South	990.000	155.880	86.410	35.500	7.260	1.275.050
Center-West	41.460	21.853	34.072	192.115	15.328	304.828
Brazil	1.107.370	592.297	614.811	713.649	246.087	3.274.214

Source: adapted from Christofidis (2005).

instable or inconstant rain regimen. Lack of water in the flowering and grain formation stages may cause meaningful reduction in crops yield.

According to standard deviation values in the average of precipitation for twelve months (Figure 3), it is possible to notice that four of the biggest deviation occurs in months of the first period of rain regimen. As this is the time in which most of the main agricultural crops develops, it means an increase in the risk of losses in yield and in product quality.

For this and other reasons is that area for irrigated agriculture in Brazil has increased. According to information from National Integration Ministry - MIN, the first experience with irrigation in Brazil occurred in 1881 in the Rio Grande do Sul State since the private initiative for building a reservoir for irrigating rice crops. Irrigation of rice crops was initiated in 1903. In the 1930's the irrigation was also used for coffee cropping in São Paulo State and, later, in 1960's and 1970's, in the Northeast Region. Along the XX Century several acts for motivating the use of irrigation were created, such as the Inspector Service Against Droughts - IOCS, in 1909; the São Francisco Hydroelectric Company - CHESF, in 1948; and, the Company for Development of São Francisco Valley - CODEVASF, in 1974, among others (MIN, 2008). According to FAO (2009), in 1980 Brazil had an area equivalent to 1.6 million hectares equipped for irrigation. In 2007 that area surpassed 2.9 million hectares, increasing more than 80%. However, Brazil had only 1.0% of the world irrigated area.

Nevertheless, Christofidis (2005) estimated that the total irrigated area in Brazil may be superior to FAO's data, getting further than the 3.2 million hectares (Table 3). Amongst the Brazilian regions, the South Region is the one which has the largest irrigated area with more than 1.2 million hectares. The main method of irrigation is agriculture draining, widely used for rice cropping, one of the main crops in that region. Southeast Region has the second largest irrigated area, with approximately 900 thousand hectares. The main irrigation methods adopted in that region are: central pivot and conventional aspersion, responsible by the irrigation of more than two thirds of irrigated area. The third biggest irrigated area belongs to the Northeast Region, with 693 thousand hectares.

The main methods of irrigation present in that regions are: conventional aspersion, surface, localized and central pivot. The Center-West and North Regions are that ones which present the smaller irrigated area. In the Center-West Region the central pivot is the main method of irrigation used, while in the North Region agriculture draining and surface irrigation predominates. Summing up, the main irrigation methods present in Brazilian agriculture are: agriculture drainage, used in 33.8% of irrigated area; central pivot, present in 21.8% of irrigated area; conventional aspersion, used in 18.8% of irrigated area; and, surface irrigation, responsible for 18.1% of irrigated area. The method applied in smaller scale is localized irrigation, which scope is equivalent to 7.5% of irrigated area in Brazil.

It is worth to highlight that, amongst the main irrigation methods used in Brazilian agriculture, the one which has demonstrated more efficiency in relation to water use is the localized irrigation. However this is the method used in smaller scale. Or else, although the use of irrigation by Brazilian agriculture has grown along the last century, main methods used are worse in saving water. For each hundred liters of water captured and distributed amongst the crops, just 40 liters get to plants root system. The sixty liters remaining get lost for deficiencies in the capturing and distributing system or for evaporation process. This contributed in the increase for water demands by agriculture in the last decade. Nowadays it is estimated that agriculture is responsible for the consumption of approximately 60.0% of all the water consumed in Brazil. The increasing demand, allied to the little efficient usage of this resource, endangers the sustainability of the food production system based on the irrigation technology. Therefore, national water reserves have become an interesting variable when it is analyzed the potential and future of agricultural irrigation in Brazil.

WATER RESOURCES IN BRAZIL: AVAILABILITY AND DEMANDS

According to Christofidis (2005), 18.0% of cropping area in the world is irrigated. The irrigated area is responsible

Figure 4. Brazilian hydrographic division.
Source: ANA (2005).

Table 4. Reached area, outflow average and outflow in draught periods in hydrographic basins and in Brazil.

Hydrographic basins	Area (km^2)	Outflow average (m^3/s)	Draught outflow (m^3/s)
Amazonian	3.869.953	131.947	73.748
Tocantins/Araguaia	921.921	13.624	2.550
Occidental Northeast Atlantic	274.301	2.683	328
Parnaíba	333.056	763	294
Oriental Northeast Atlantic	286.802	779	32
São Francisco	638.576	2.850	854
East Atlantic	388.160	1.492	253
Southeast Atlantic	214.629	3.179	989
South Atlantic	187.522	4.174	624
Uruguay	174.533	4.121	391
Parana	879.873	11.453	4.647
Paraguay	363.446	2.568	785
Brazil	8.532.772	179.433	85.495

Source: ANA (2005).

for 44.0% of food production and generates 44.5% world agricultural production value. In Brazil, during 1990's, 5.0% of national cropping area was irrigated, responding for 16.0% of total food production and 35.0% value of national agricultural production (Santos, 1998). Or else, while in the world irrigation has an impact of 2,75 times over the value of production, in Brazil this impact gets to 7,0 times. This meaningful grow in profitability for agricultural activity motivates the interest in introducing and expanding the irrigation system usage.

Safeguarding the irrigation use by the Brazilian farmers depends fundamentally on the hydric resources availability and the continuous water supply. According to ANA (2005), Brazilian hydrographic division shows twelve main hydrographic basins: Amazonian, Oriental Northeast Atlantic, Occidental Northeast Atlantic, Parnaíba, Tocantins-Araguaia, São Francisco, East Atlantic, Paraguay, Paraná, Southeast Atlantic, Uruguay and South Atlantic (Figure 4).

According to National Integration Ministry - MIN, the average of annual outflow of rivers in Brazilian territory is 179 thousand m^3/s, corresponding to 5.660km^3/year. Such outflow is equal to 12.0% of hydric resource available worldwide. If considered outflow coming from outside the country, such as the entrance into Amazon basin (86.321m^3/s), from Uruguay basin (878m^3/s) and from Paraguay basin (595m^3/s), the Brazilian total water resources availability gets to 18.0% world availability, totalizing 267 thousand m^3/s (MIN, 2008).

Although the water volume outflow from Brazil is significant, the spatial asymmetrical distribution of water resources endangers water supply in some regions. Therefore, according to Borsoi and Torres (1997), water scarcity in Brazil is associated to below specific availability in the Northeast Region and high demographic densities in the South and Southeast Regions. Conflicts for water resources are situated in areas with great demographic density and intense industrial concentration (South and Southeast Regions). In Table 4 the values of reached area, outflow average, and

Table 5. Consumption and availability of water resources in Brazil – Selected hydrographic regions.

Hydrographic region	Destine of consumption $10^6 m^3$ per year				D (km^3)	A (km^3)	D/A
	Human	Desse-dentation	Irrigation	Industrial			
Amazonian	279.0	225.8	6,002.4	52.3	6,560	4,332.1	0.15
Tocantins/Araguaia	180.3	211.3	1,602.6	78.0	2,072	372.1	0.56
Atlantic N/NE	2,105.8	277.2	4,206.3	1,617.7	11,201	135.6	8.26
São Francisco	876.5	220.5	5,085.6	926.5	5,156	98.7	5.22
East Atlantic	2,705.8	13.3	380.0	2,056.8	4,482	137.2	3.27
South Atlantic	664.8	204.9	9,796.3	535.5	16,008	89.8	17.81
Paraná	3,251.8	1,379.2	7,858.6	3,518.6	7,109	346.9	2.05
Paraguay	127.2	325.2	1,287.0	35.0	1,774	86.1	2.06
Uruguay	249.5	282.0	4,942.3	12.3	5,486	130.8	4.19
Total	10,440.7	3,139.5	41,161.1	8,832.6			
m^3/s	331.1	99.6	1,305.2	280.1	59,848	5,729.5	1.04
% do total	16.4	4.9	64.7	13.9			

Note: D = Demand and A = Availability.
Source: adapted from FGV (1998).

outflow in draught periods of main Brazilian hydrographic basins are presented. Data in Table 4 indicate that Amazonian Hydrographic basin is the one which presents higher outflow, corresponding to 73.6% of total hydrographic basins outflow. Tocantins/Araguaia basin presents the second higher outflow and corresponds to 7.6% the country total outflow, followed by Paraná basin, with 6.4%. Basins with lower outflow are Parnaíba and Oriental Northeast Atlantic, with outflow equivalent to 0.4 and 0.8%, respectively. However, in draught periods the hydrographic basins may reduce the outflow to less than half. The most sensitive basins to dry periods are: Oriental Northeast Atlantic, which outflow may reduce more than 95.0%; Uruguay, which may have a reduction superior to 90.0%; Occidental Northeast Atlantic where the outflow may reduce more than 85.0%; and the South Atlantic and Tocantins/Araguaia basins, which may reduce more than 80.0% the average outflow. The basin less sensitive to dry periods is the Amazonian, which outflow may reduce in approximately 40.0%.

These data reveal that high water volume in Amazonian basin alters deeply the availability of water resources along Brazilian territory, leading to a scarcity of water in some regions. According to Borsoi and Torres (1997) , regional distribution of water resources is around 70.0% for North Region, 15.0% for Center-West Region, 12.0% for South and Southeast Regions (which presents higher level of water consumption), and 3.0% for Northeast Region. Besides deficiency of water resources, Northeast Region has its situation aggravated by an irregular rain regimen and by low soil permeability.

According to Rebouças (2001), Brazil has approximately 112 mil km^3 of water in underground reserves. These reserves are deposited in nine aquifer domains, subdivided in twenty-five main aquifer systems. Although the underground reserves are expressive, exploration via water well is relatively little used. Water taken from the subsoil is more frequent in Southeast and South Region of Brazil, where artesian wells are most frequent used for water water supply to human consumption and industrial use.

Data presented by Getúlio Vargas Foundation - FGV (1998) illustrate the concerning situation relating water demand and supply in Brazil. From selected hydrographic regions, researchers identified water consumption for distinct purposes in each selected region, as well as the consumption and annual availability for each of this hydrographic region (Table 5).

Data presented in Table 5 prove that use of water for irrigation is the main way of water consumption in Brazil. Data also reveal that the highest pressing consumption occurs in the following hydrographic regions: Paraná, with more than 25.0% demands accumulated from that selected regions, South Atlantic, North/Northeast Atlantic, São Francisco and Uruguay. The highest demand of water for irrigation are verified in South Atlantic, Paraná, Amazonian, São Francisco and Uruguay regions, which coincides with the geographic regions which have largest irrigated crop areas. Other interesting data is the relation between demand and availability of water in different hydrographic regions. It is important to outstand that more than 17.0% of South Atlantic region outflow is used for different purposes, but mainly for agricultural irrigation. North/Northeast Atlantic and São Francisco are other regions which have higher pressing demand, consuming 8.26 and 5.22% annual outflow. In the first case, the human consumption, irrigation and industrial use are the main destination. Yet in the second case, agricultural irrigation is the main water destination.

Although the average of national water consumption is slightly higher than 1.0% of total outflow, estimations from FGV suggest an increase in demands for hydric resources

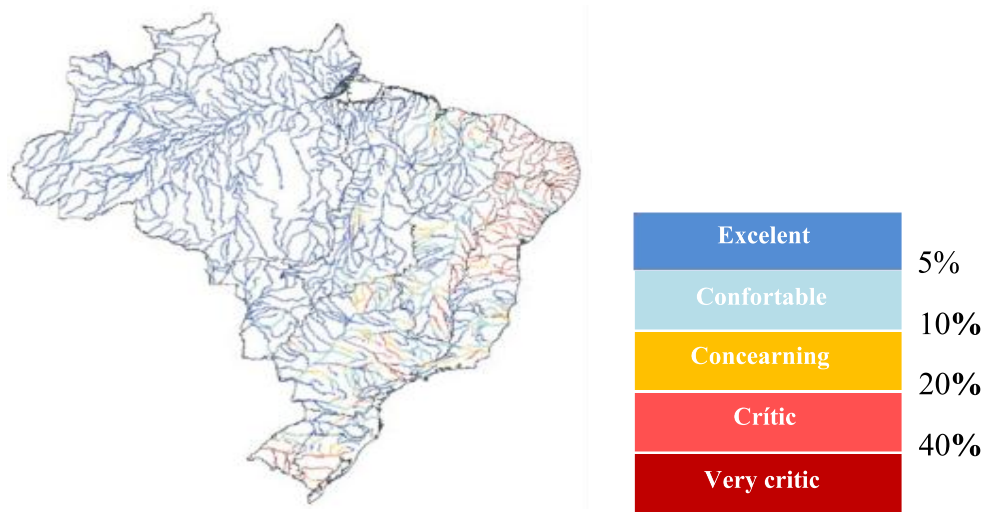

Figure 5. Relation between water demand and availability in the main hydrographic basins in Brazil. Source: ANA (2005).

in these regions in the coming years. Forecasts for 2015 indicate a meaningful increase in demands of São Francisco, North Atlantic/Northeast and South Atlantic regions, when annual demands are to surpass 15.0% the outflow of these regions (FGV, 1998). This scenario tends to worsen the concerning, critic, very critic situation already verified in several hydrographic basins in Brazil, especially in the South, Southeast and Northeast Regions, according to represented in Figure 5.

Figure 5 suggest a concerning to critic situation in some important food producing regions in Brazil, in which a great part of crop yield presents a strong relation with the adoption of irrigation systems. Therefore, future of irrigated agriculture in Brazil depends on a rational use of water resources. Rational use implies in the management of water resources as a whole, since the spring, until the use of more efficient irrigation systems. In this sense, some practices in water resources management driven to irrigation in Brazilian agriculture have been developed in some hydrographic basins.

WATER RESOURCES MANAGEMENT IN BRAZILIAN AGRICULTURAL IRRIGATION: TWO CASES

Brazilian legislation about use of water resources has begun to be defined in the first half of the XX Century. One of the first laws about this question was the “Water Code” of 1934. Although it was about an advance in water resources management, the practical effect of legislation was little effective. It is speculated that reasons for the unsuccessfulness were the model of centralized management which lead to conflictive relations among different stakeholders. In 1948, it was searched to migrate for a management model based on economic and financial aspects, with use of financial instruments as parameters for negotiation amongst interested ones. As a result, some companies were created linked to water sector which had the objective to promote regional and national development. Company as CODEVASF (Company for Development of São Francisco Valley) is an example of the water resources policy from that time.

More recently, with increasing concern in relation to water scarcity, rivers and lakes contamination, and indiscriminate use of water resources, public policies have searched to making discussions in relation to this issue more dynamic and make the process more inclusive. In January 8th, 1997 it was promulgated the Law N° 9.433/1997, also known as “Water’s Law”, which established the National Policy of Hydric Resources and created the National System for Managing Hydric Resources. The new legislation primes for a democratic and integrate management model, with participation of the State as well as civil society. In this law it was defined that the water resources management would be made by the Hydrographic Basins Committees - HBCs[1]. Until the end of 2009 at least 158 HBCs were implanted around the country. From these, 71 in the Southeast Region, 43 in South Region, 39 in Northeast Region, 4 in Center-

1 According to ANA (2010a), “the Hydrographic Basin Committees are collegiate organisms which make part of the National System for Hydric Resources Management that exist in Brazil since 1988. The diversified and democratic composition of the Committees contributes for all sectors of society interested in water in the basin have representation and decision power about its management. Members which compose the collegiate are chosen among their pairs, they may be from several water user sectors, from the organizations of the civil society or from public sector. Their main competencies are: approving the hydrographic basin resources plan; arbitrating conflicts for water use at first administrative instance; establishing mechanisms and suggesting the values of charges for water use; among others”.

West Region and 1 in the North Region (ANA, 2010a).

Later, in 2000, Law N° 9984/2000 was promulgated, creating the National Water Agency - ANA. The ANA's mission is "implementing and coordinating shared and integrated water resources management and regulating access to water, promoting its sustainable use in benefit of present and future generations" (ANA, 2010b).

The new legislation anticipates two main mechanisms for water resources management to be used by HBCs in relation to allocation of the rights to use: the granting for the use and charging for the use. Concession of grants for use is exclusively to public sector and must characterize demand and supply conditions of water resources and its social and environmental impact. Charging for water use may be used in the supply scarcity situations. The main aim of charging is to make the use more rational. The financial resources collected by charging should be invested in environmental improvement in the basin's area and in educating population for water preservation. Therefore, scarcer the water, higher should be the value charged. The implementation of water charging system is a slow and gradual process. Before this new conception of public policies for water resources management, some practices may already be noticed in Brazil. Following, three cases of practices in water resources management from this new perspective are going to be presented.

The water resources management for rice cropping irrigation: a case in the Rio Grande do Sul State

Rio Grande do Sul (RS) is the main rice producer State in Brazil. It is responsible for approximately 50.0% of national production. The main producing areas are the South and the coast parts of the State, where topographic conditions favors crop irrigation by flooding. The following case study was extracted from César's (2007) thesis, which was developed in the Coastal Hydro-graphic region of RS aiming to evaluate the influence of institutionalization of water charging in the water supply market for rice cropping.

This producing region is composed by the following hydrographic basins: Tramandaí, Litoral Médio, Camaquã, Mirim-São Gonçalo and Mampituba. Main hydric supply sources are: Patos' Lake, Mirim Lake, Mangueira Lake and Barros' Lake, besides small and medium size rivers. The study took into account the regions with highest number of water reservoir and rice production. Although the region may have good water resources availability, the distribution of these resources is harmed by the extension of the crops, making displacement of water in space and time harder. The main difficulty consists in the fact that not all the farmers have water available in his/her farm. Among the farms studied by César (2007), 40.0% of the area belonged to the farmers and 60% were rented. In relation to the origin of the water used for rice irrigation, 60.0% of the farms had their own water while 40% depended of water supplied by third parties. Such fact, associated to water collection and distribution imply a cost of around 10.0% of production costs.

Water supply for those farms which do not have its own reserves is made by third-parties. Enterprises specialized in irrigation have grant over water use and display a complete system for water collection and distribution, charging by consumed volume. Besides the specialized enterprises, there are also farmer's associations acting for creating a structure for collecting and distributing water. However, the use of these water resources generates costs for farmers. Other form of water commercialization is trading pairs among the farmers which have not. Summing up, water trading for rice crop irrigation is basically one market trading, among sellers and buyers, where the State do not plays any influence except in cases of litigation between parts. The cost for contracting irrigation systems varies depending on the distance of the collection source and water availability.

The key question is whether these formal and informal water trading systems, which are socially established and accepted among the stakeholders of that region, becomes conflicting to the new Brazilian legislation of water resource management, where water is seen as public good and charging it should be made by the HBCs. According to César (2007), during the study, from the HBCs of the studied region few were in operation and some were in the implementation phase and were not able to develop their function in full. Therefore, charging for water use by HBCs, as established in the Brazilian Law, does not exist in practice being just in phase of study regarding the impact of their effectiveness. After the implementation and effective performance of the HBCs, the key question on water resources management and use for rice crops irrigation at the coast of RS is: how the migration from a socially established system to a legally institutionalized system will occur? A set of scenarios proposed by César (2007) indicate that such migration may be strongly affected by farmers under-standing levels in relation to the attributions of HBCs and by the trust given to the public system of water resources management.

Water resources management for agricultural irrigation in São Paulo State: Jundiaí-Mirim and Ribeirão dos Marin's basins' cases

The Jundiaí-Mirim River basin's case is originated from Gramolelli (2004) study. Jundiaí-Mirim River basin is situated in the São Paulo State and reaches an area of 11.750 hectares distributed among the municipalities of Jundiaí (55.0%), Jarinú (36.6%) and Campo Limpo Paulista (8.4%). Jundiaí-Mirim River has a 16km extension and is one of Jundiaí River affluent. Near to Jundiaí River estuary there are two reservoirs which accumulate approximately 95.0% of the water used for public supply in the Jundiaí City. In São Paulo, the State Law N°. 7.663-1991, foresee charging for using water resources of State Rivers. However, this Law still is in regulation phase, which makes impracticable the implementation of the charging system. Charging is to be made according to water volume used or to the quality of effluents sent out to the receiver water body. Values to be charged may be defined by HBCs, which should prioritize charge over water pollution to simple water collection.

Small farm agriculture corresponds to most of agricultural establishments (85.0%) and occupies 80.0% of people. Main agricultural crops in that region are: grapes (543 ha), citrus (251 ha), horticulture (203 ha), several fruits (69 ha), annual crops (151ha), coffee (29 ha) and sugar cane (4ha). In relation to the main irrigated crops prevails vegetables (62.0%), peaches (6.0%), annual crops (5.0%), strawberries (3.0%), ornamental plants (3.0%) and pastures (2.0%), among others. Most of the farms use the conventional aspersion as irrigation system. The dropping and micro-aspersion systems are not much used.

The Gramolelli (2004) study suggests that there is not water resources management system implemented in that hydrographic basin. Water is freely consumed as a public good and there is no the occurrence of any managing mechanisms. Nor grants for use (except for public purposes), nor charging by water use. However, most of the farmers interviewed (73.0%) assured to know about the new legislation foreseeing charges for water use, which generates concern for most of them. Among the minority which did not show any concern with charging, some assured they intended to end up agricultural activities and others said they use little water and that such charging would have little effect over their activities.

The Ribeirão dos Marins basin's case - RMB was extracted from Faganello's et al. (2007) study. Ribeirão dos Marins basin is an affluent of Piracicaba River in São Paulo State. It has a 128,2km extension and reaches an area of approximately 5.973 hectares. Main crops in that region are: sugar cane (56.2% of all land area) and pastures (30.2%), besides the production of vegetables (80.0% of vegetables supply for Piracicaba Municipality). Main irrigation system used is conventional aspersion. In relation to the water resources management, the situation at RMB is similar to that one described in the case of Jundiaí-Mirim River basin. That is, the management mechanisms of granting and charging for water use are not yet implemented and the water resources are freely used. Farmers say they know the legislation which determines charging for water use. However, most of them do not agree with charging.

In both cases described for São Paulo State, as well as similar studies in other States in Brazil, such as in Minas Gerais State (Afonso, 2008) and in Ceará State (Gondim et al., 2004), the authors suggest that it is necessary raising the farmers' consciousness about the rational use of water resources. The authors suggest also farmer's training and technical assistance about the adoption of water saving technologies, the irrigation system management and in the safeguarding of water resources. In this direction, a broaden discussion about charging for water use is necessary for implementing the system gradually and in a less conflictive way.

FUTURE OF AGRICULTURAL IRRIGATION IN BRAZIL

Brazil remains an agricultural country. The importance of Brazilian agriculture goes beyond the boundaries of the country, supplying food for other areas worldwide. Growing demands for food, feed, fibers, fuels and forest are pressing the agricultural production. With limited land supplies, searching for crops yield gains became a constant. In this sense, use of irrigation techniques is essential, once they improve crop yield and reduce risks related to lack of rain. Climate effects derived from global warming tend to affect the development of agricultural crops, demanding still more irrigation use. On the other hand, the expansion of irrigated areas depends essentially from water availability, other naturally limited resource. Although water reserves in Brazil are meaningful, bad distribution of volumes among geographic regions around the country and the different levels of consumption results in regions where water scarcity is already a concerning question.

Therefore, the Ministry of Environment - MMA highlights some challenges for Brazilian agriculture. Among them, some are related to water resources use and management: guaranteeing water grants compatible with the potential demands of soils able for irrigation in order to adjust water supplies of a food producing country to an inside food security and to an outside demands; reducing water loss for irrigation systems, both in cropping methods and handling and in collecting and distributing infrastructure; preserving the water quality returning by the agricultural drainage systems, in order to make it free of harmful compounds for both environment and other users; and, guaranteeing water supply to the irrigation project, along its useful life (MMA, 2006).

Brazilian legislation about water resources management has evolved gradually along the last century, searching for good experiences in developed countries in the sense of making the water management more democratic and wide-ranging, including several stakeholders in decision-making about water resources. The water resources management should try to seek sustainability in water supply in water supply for several purposes, including agriculture. However, case studies suggest that Law application has been a slow process and there are rare cases in which the mechanisms of granting or charging by water use have been applied.

Future of agricultural irrigation in Brazil depends on practical actions in order to manage the water resources according to the legislation. These actions need to be implemented in short term, once along the implement-tation process conflicts there must appear and they need to be solved for letting management to advance. In more than one decade since Water's Law approval, in 1997, maybe the most effective action has been the creation of several HBCs in practically all round the country. The number of HBCs keeps growing and, certainly, they will constitute important forums for water resources manage-ment and conflicts solution. From HBCs implementation and an institutional support from State seem depends the future of agricultural irrigation in Brazil.

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