Facilitating concertation in a Brazilian periurban catchment: to what extend does irrigation compete with potable water supply?

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Abstract

Megacities development is putting an increasing pressure on water resources in their peri-urban areas. It particularly raises the challenge of the competition between potable water supply and irrigated agriculture, in a context of rapid land use changes, which results in increased pressures on water availability and quality. This is the case of the Tietê-Cabeceiras catchment in the Metropolitan Region of São Paulo (Brazil), the only metropolitan catchment where agriculture is being represented in the water committees - the negotiation and discussion body for water management at catchment level. While agriculture directly competes with domestic water uses, it also provides some environmental and social services: it contributes to the preservation of forest fragments, prevents illegal urban land occupation and probably contributes to the preservation of social network in its rural district which could counterbalance the negative social effect of urbanization. But urbanization is putting an high pressure on agriculture and its evolution is difficult to anticipate. An approach based on the development of simulation tools as mediating tools for concertation on this issue is presented.

Introduction

The number and the importance of megacities, i.e cities with more than 10 million inhabitants, are increasing all over the world. In the Southern countries, their continuous growth, in a context of high social inequalities, is resulting in increased environmental pressure on their surrounding areas (Baykal, 2000; Malsimovic et al., 2001). It particularly raises the challenge of the access to potable water for a growing number of consumers, in a context of limited financial resources and maintenance of networks weakened by the investment effort for their extension. Thus, the investment cost to guaranty potable water access to Latin America peri-urban dwellers was estimated to 6,2 billons USD (Nigam, 1995). Moreover, inadequate sanitation arrangements in the periurban district are resulting in increased pollution run-off (Baykal, 2000; Pegram et al., 1999). This challenge is all the more difficult to tackle than urban growth is affecting the hydrological functioning of these periurban catchment, which often provide in the same time essential environmental functions to the city, such water production, groundwater recharge zones, space for drinking water reservoir, absorption of rain water.

The growing demand in water and the degradation of its quality is increasing the competitions with other water users. The competition with agriculture is all the more severe that agriculture is often accused to waste water. It is generally estimated that 30 % only of the water removed in traditional surface irrigation is used by the crops. This number reaches 60 to 70 % in conventional aspersion and 90 % in micro-irrigation. Agriculture is also responsible for important diffuse pollution processes, especially with nitrates and pesticides. These factors provide strong case in favor of the reorganization of water allocation in case of growing tension on the resource. Thus, when the cities are growing, water resources are often diverted for domestic water supply, leaving only waste water for agriculture.

On the other hand, the local socio-economical importance of periurban agriculture in southern countries have been pointed out by various studies: It contributes to food security of poor periurban families, can represent an important complementation to family income, or be an alternative activity that facilitates economical ad social integration (Midmore, 2003; Nugent, 2001; Torres Lima et al., 2000). Its environmental role is more and more recognised, as it provides green areas for the city, ensures the reuse of waste and wastewater as well as sewage sludge (Bahri, 2001; Dulac, 2001; Thiébaut, 1996). It is thus estimated that 10 % of waste water are being used in irrigation all over the world (Strauss, 2001). But these practices remain badly integrated in most urban policies: Until the 80's, urban policies tended on the contrary to exclude agriculture from urban area and to focus on demographic, land, housing and transportations issues (Metzger, 1994). But, with increased tensions on water resources and the development of new environmental demand from urban dwellers, integration of water management strategies with urban planning is more and more looked for.

This is the case of Brazil, which has just adopted a new urban legislation. It also renovated its water policy in 1995 in order to promote participative and multi uses management of water at catchment level. The objective of this contribution is to analyse, through the example of the peri-urban catchment of Cabeiceras-Tietê in the Metropolitan Region of São Paulo (RMSP), the challenges raised by integration of irrigated periurban agriculture in an urban integrated water management. We argue that the process of integration of agriculture require the development of a concertation process within the management body on its role and future in the catchment.

The first part of the communication will present the organisation of water management in the area studied. The second part discusses the place and role played by the agriculture representatives in the committee by an analysis of the resolution of two conflicts that involved agriculture. The third part proposes a first quantification of the competition between agriculture and other water uses, and discusses the future of this activity in the catchment. We conclude by presenting an approach, based on the development of various simulation tools that aimed to facilitate concertation at catchment level on this issue.

A growing competition between agricultural sector and domestic water supply

A domestic water supply system which is reaching its limits

The Metropolitan Region of São Paulo (RMSP), which contributes for 18 % to the gross national product of the country, hosts some 18 millions inhabitants in a territory of 8050 km² managed by 39 municipalities. Thirty – seven percent of the territory is urbanized. Most of RMSP is included in the Alto-Tietê Catchment at the head of the river Tietê basin, which is part of the Rio Parana basin. In spite of an average pluviometry of 1400 mm, the city has been facing water shortage since the XIXth century, as the development of the water supply system has always been unable to pace with the high rate of population growth (SABESP, 2000). During the last decades, these difficulties have been accentuated by the degradation of the quality of superficial resources because of urbanisation and low sanitation rate.

The production of water of the Alto-Tietê Catchment itself is insufficient to satisfy to the domestic demand. Thus, 50 % of the domestic water supply (31 m^3/s) is imported from a neighboring basin and an estimated 8 % of demand is provided for by pumping in the subterranean resources. 15 % of the distributed water of the RMSP is used by the industrial sector (Porto, 2003). The water supply of the city relies on six main production systems integrated at metropolitan scale, each one made of a combination of various reservoirs, tunnels, pumping and treatment stations. These systems are managed by a state firm, the SABESP – Companhia de Saneamento Basico do Estado de São Paulo – which provides directly potable water for 80 % of the municipalities of the RMSP. In spite of the decrease of the demographic growth rate (Prette, 2000), the supply system is reaching its limits: Rationing, which was eliminated during the 90's thanks to an important investment effort, was reintroduced during the dry year of 2001 and 2003. Projections point out that water offer will only exceed demand by 2,5 % in 2010, even with a good control of the distribution losses. The situation is even more difficult in the long term (Porto, 2003). To face this challenge, new importations of water are being discussed. These resources will necessary transit trough two of the production catchment: the Guarapiranga or the Cabeiceras Tietê watershed. The latter one, with a surface of 1690 km² over 9 municipalities is one of the last periurban catchment where increasing water production remains possible. It is thus planned to collect a supplementary 5 m^3/s for São Paulo water supply in a close future thanks to the development of two new dams.

The tensions are all the more important than the quality of the water resources is affected by the urbanization processes especially by the rapid development of sub-normal settlements. In the context of high social inequalities of Brazil and poor housing policies, low income population had often had no other options than to settle in the margin of the city, preferentially in the spring catchment areas whose land value has been depreciated by the legislation that aimed to protect them (Bellenzani, 2000; Marcondes, 1999). It is estimated that nearly a million people had settled in the protected area of the municipality of São Paulo, in very precarious socio-economical conditions. These illegal settlements are lacking basic infrastructures such as water supply or sanitation networks. In 1996, It was estimated that if 86 % of the homes of the municipality were connected to a proper sanitation system, 20 % only of all collected sewage were actually treated (Prette, 2000). The urban centers in the periurban areas are particularly deficient and they are responsible for the production of important organic pollution. In the Guarapiranga catchment, with only 12 % of the homes connected to a sanitation network in 1996, domestic effluents generated some 245 kg/day of phosphorus during the dry season 1995 (Porto, 2003). The important effort in sanitation investment of the last 5 years[1] did not permit to compensate for the urbanization rate and to control pollution in the main drinking water reservoirs, especially during the low flow period. Thus, pollution level remains high in most of the strategic reservoirs, such as the Taiçubepa reservoir in the Cabeiceras-Tietê catchment, which has been facing an significant increase of Total P and DBO since 1997 (Porto, 2003).

The development of a new paradigm of water management

In this context of rapid growing demand and degradation of superficial resources quality, the water legislation has long focused on the protection of the water resources through the protection of the spring catchement. The initial strategy of land des-appropriation and the control of industrial pollution by specific laws proved insufficient to control the degradation of the quality with the expansion of the city. In the beginning of the 70's, a command and control type of legislation was implemented to control land occupation *(Lei de proteção dos Mananciais)*. It was based on an exclusive sanitation vision of the protected area (Marcondes, 1999) and permitted to protect 56 % of the Alto-Tietê catchment and a large part of the Metropolitan Region of São Paulo. These measures did not however succeed to significantly contain the urbanisation processes and reorient city growth (Bellenzani, 2000; Marcondes, 1999). In the same time, a corporatist vision of water management, resulting in a growing competition between the powerful hydroelectric sector, the water producer firm and the emerging sanitation industrial complex enhanced the development of technical sectorial solutions, such as importation of water from other water basin or the development of a centralised sanitation system.

During the 90's, Brazil has redefined its water policy, on the basis of integrated water management. Inspired from the French legislation, the new policy combines various legislative tools at federal level and state level in order to permit (i) water management at water basin level (ii) taking into account all the different users (iii) participation of civil society in the management process. In the São Paulo state, water committee has been implemented since 1995 as deliberative-consultative-normative body at catchment level. They are composed for one third of state entities, for one third of municipalities and for

[1] Which permitted to connect to sanitation network of 50 % of the homes in the Guarapiranga catchment .

the last third of representatives of various groups of interest such as universities, NGO, technical association, etc. (Porto, 1999).

One of the management units is the Alto-Tietê catchment with a surface of 5985 km² and 35 of the 39 municipalities of the RMSP. Because of its complexity, this catchment has been divided in 6 sub-catchments, each one with its own sub-committee. A water agency, the technical and "executive" body is in charge of implementing the strategies defined by the catchment committees with the support of a specific fund called FEHIDRO. The management relies on the definition and implementation of different tools such as the catchment development plan, information system on water resources, or a system of water licences system. In 1997, this policy was completed by the revision of the legislation of spring catchment protection (*Lei de proteção dos Mananciais*) in order to articulate it with the new water policy. The adaptation aimed to better co-ordinate land protection with water management at catchment level in the protected area, by the use of the same management tools.

The Cabeiceras-Tietê catchment, one of the sub-catchment has 64 % of its territory protected by the legislation of spring catchment. It is the only metropolitan catchment where the agricultural sector is being represented in the committee: Actually, 8000 ha are being irrigated mostly by individual pumping in superficial water resources. These 8000 ha correspond to annual cultivated area of 20200 ha mostly devoted to horticultural crops.

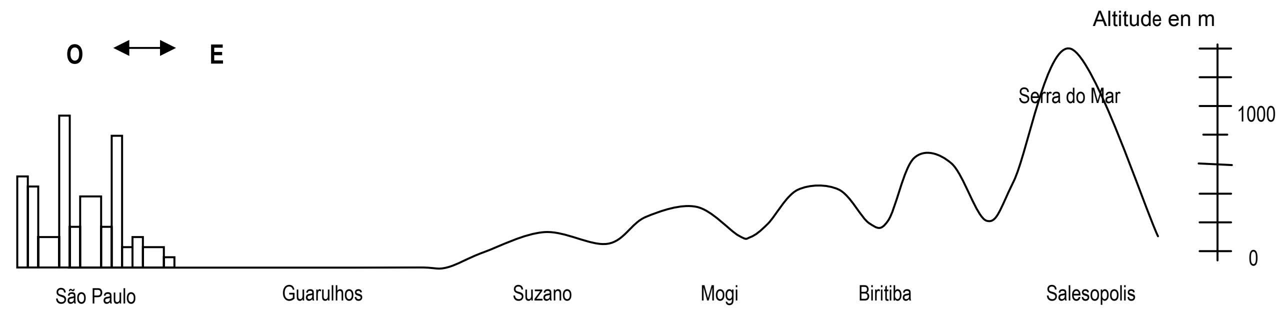
In the context of tensions between water supply and domestic water demand the place of agriculture in the catchment is being questioned. Some members of the committees are pointing out its competition role with domestic water uses and its pollution impact. The catchment plan estimates the average demand for agriculture to 2,56 m^3/ha (Porto, 2003). Others argue that agriculture provides for important local social and economic services: Respectively 35 % and 5 % of the horticultural market of the Sao Paulo state and Rio de Janeiro State come from the area. Some 40 % of the lettuces, 50 % of khakis and 25 % of flowers of the state are cultivated in the catchment, as well as 70 % of Brazilian mushrooms and 80 % of Brazilian medlars (Andrade et al., 2003). The area is producing no less that 170 different crops. But, this production mainly results from small farms in a state where agro-business farming is mainly dominated. The agricultural census of 1996 indicates that 74 % of the production units of the catchment have less than 15 ha, and 38 % less than 5 ha (Andrade et al., 2003; Vicente et al., 2004). This structure results from the installation through out the XXth of farmers of Japanese origin that specialized in small intensive family farm systems.

The landscape is structured by two main factors: the hydro-geomorphology of the basin and the urbanization processes. Three agro-ecological sets can be distinguished: (1) the alluvial areas corresponding to flooding areas of the rivers which enjoy a dark, organic soil which is sometimes hydromorphic. These areas are characterized by inundation problems and drainage deficiency during the wet season. They are mostly devoted to irrigated horticulture, production of raw material for construction, or natural vegetation. (2) The hilly areas with its well drained red soil, cultivated with horticulture or fruit crops. (3) The high slope areas, with poor soil, difficult access which are mostly devoted to water to cattle farming, eucalyptus production. The steepest slopes are covered by the remains of the Atlantic Tropical forest.

The pluviometry varies between 1200 and 1500 mm depending of the area with two main seasons: a “cold” dry season (called winter) from June to October, characterized by water deficit and a hot and humid season characterized by water excess. The seasonal transitions between autumn and winter (April-may) or spring and summer (October/November) are characterized by the occurrence of short dry and hot period events (locally called *veranico*) which are critical for the crops. Irrigation is thus necessary between April to September and during these events.

Globally, the demographic density is decreasing from west to east (Figure 1). While the municipality of Salesopolis at the eastern part of the catchment can be qualified as a rural municipality, the Guarulhos, Poa, Suzano zones are mostly urban, even if some cultivated and fallow areas are remaining mostly in the area prone to flooding. The urban fabric is almost continuous from the middle of the catchment (area of Mogi das Cruzes the oldest city of the catchment) to the Sao Paulo part at the west. Even in the most rural areas, urban nuclei of rapid growth have been developing for the last 20 years such as Biritiba Mirim (3,8 % of growth rate for the last 10) or Suzano 4,4 % per year (Ibge, 2000).

Figure 1 : Characterization of the 5 main municipalities of the Cabeiceras-Tietê catchment.



	Guarulhos	Suzano	Mogi	Biritiba	Salesopolis
Doming cropping system	Urban horticulture	Horticulture, poultry, eucalyptus	Horticulture, orchards and mushrooms	Horticulture, orchards	Herding, eucalyptus ,
Agricultural assets	Fertile lands	-Fertile lands -Close to market pole	- Fertile lands - Close to market	- Availability of water - average pollution level - close to market - fertile lands	- good water quality
Agricultural constraints	- Polluted water - Robberies common	- competition with industry on workforce - Water pollution - Common robberies	Competition with industry on work force - Water pollution	- Some area are of difficult access	- Sloping areas - Difficult access - Lands fertility limited
Urban Pression Density Growth rate/year (Ibge)	High, agriculture space is within the urban fabric 3384 hab/km² 3,6 % /an	Rural space is fragmented by numerous urban nucleus 1236 hab/km² 4,4 %	The city is expanding in various urban nucleus within the rural space 442 hab/km² 1,7 %	low but increasing 78 hab/km² 3,8 %	Very low, limited to the immediate proximity of the center 34 hab/km² 2,6 %/
Industrialization	high	high	developing	Very low	Very low
Perfil	Industrial and urban	Industrial and urban	Industrial, urban and agricultural	Agricultural	Sylvopastoral and touristic

As indicated in the first tab, half of the farming units in the 4 most agricultural municipalities include horticultural activities. The catchment is also experiencing the development of flower and mushroom production. Poultry farming is declining while eucalyptus production is increasing mostly in the remote and hilly areas.

Tab 1 : Some characteristics of agriculture in the studied municipalities

	Suzano	Mogi das Cruzes	Biritiba Mirim	Salesopolis	Total
N° Total of farms	453	1 458	450	528	2 849
Useable farm area (ha)	3 687	22 786	16 773	12 061	55 307
% of useable farm area of the municipality in natural vegetation	16%	30 %	48 %	16 %	
% useable farm area of the municipality in non permanent crop	35 %	26 %	31 %	41 %	
% useable farm area of the municipality in wood plantation (pines, eucalyptus)	35 %	26 %	31 %	40 %	
Surface in annual crop (ha) =	1 321	4991	1 101	891	8 305
Crop intensity (Surface harvested / surface annual crop))	2,01	5,5	*	5,10	

Source : LUPA 1995/1996 …. * data to be checked

A new issue: how to facilitate concertation on land and water management at catchment scale?

The legislation changes are focusing on strengthening the role of concertation between the different stakeholders in the management of the resources. Concertation and negotiation processes are thus expected either at catchment level - for example for the development of catchment plans -or at local level - to define local adaptation of the tools proposed at catchment level. Recent studies are however pointing out the functioning difficulties of the committees. They are weakened by an important asymmetry of information between the civil society, fragmented and poorly represented, the powerful mega-actors, and the municipalities whose strategies are often driven by short term electoral strategies (Ducrot et al., 2003; Neder, 2000). These difficulties are common in multi stakeholders platforms, as the French Water committees (Cacquard, 2001; Latour et al., 1995). But they are all the more difficult to overcome in the RMSP than inequalities of training and political power are high, and than the communities of the periphery are socially and economically marginalized. More over, management is dealing with issues that interfere with economical, social and political interests that can have high significance either at metropolitan level or even at state or national level. Strengthening theses institutions supposes to support the negotiation processes and to reinforce the participation in these processes of the most marginalized actors, more specifically family farmers, local dwellers and mayor of small municipalities.

An approach combining diagnostic at farm level and analysis of water committee representation

In order to facilitate these concertation and capacity building processes, the Negowat project is currently testing a companion modeling approach as defined by Barreteau (Barreteau, 2003). The methodology relies on the participative development of mediation supports combining multi-agent simulation models and role playing game. The methodology was divided in 3 main steps: (1) an analysis of the representations of the members of the committees on agriculture (2) A diagnostic of the strategies of farmers and farm system dynamics, by direct interviews with the farmers. (3) the participative development of a simulation tools, in this case a multi-agent model and 3 role playing game representing the catchment functioning.

To discuss the place of agriculture in the catchment from different (water consumptions, economical and importance, systems dynamics developed) in order better understand and quantify the competition and relationship between agriculture and other land and water users

1) The representation of the catchment committee members on agriculture and agriculture related conflicts were assessed by semi directive interviews, implemented in July and August 2004.

2) The diagnostic on the place of irrigated agriculture, its relationship with other land and water users was based on a farming system research methodology. The research was implemented in different time. After characterizing the main agricultural areas and production, 3 different agricultural areas were selected differentiated by the urban pression: an urban zone (in the municipality of Guarulhos), a rapidly urbanizing area (Balainho sub catchment), an outlying rural area with important growth rate (municipality of Biritiba Mirim). A typology of farming system was developed in each zone through the detailed interviews of 20 to 30 farmers in each area. The interviews aimed to identify the variability of production system, of irrigation strategies, water access modes and land tenure access. Our present studies focuses on the results from this zone, as the centre of the agricultural production. It presents diversified agro-ecological conditions, cropping systems and urban pression conditions. It was also a place was the tensions over water and the mining sector had been particularly difficult. Further work which is being finalized to (i) compare the situation with the other areas studied in order to identify the specificities of the farmers strategies and agricultural dynamics of this areas. (ii) Discuss the social organisation of farmers in the catchment.

The agricultural issue: a difficult integration in the committee agenda.

Agriculture in the Cabeiceras-Tietê is fully recognised as a water user in the catchment and as thus is represented in the sub-catchment committee. This is not the case of other sub-catchment of the RMSP, even if agricultural activities are developed in others areas. Irrigators are being represented by the local branch of the Syndicate of Rural Producers. This syndicate, of national scale, defends the sector-based and professional interests of agribusiness farmers. In the catchment, apart from a conventional service offer in accounting, this syndicate promotes the development of an agriculture model of "small agro-business". The other agricultural syndicates, which traditionally tend to represent the interest of small farmers and family farming, are little active in the area[2]. However, the development of a new agricultural settlement of the landless movement and conflicts with the mining sector has locally been calling into question the legitimacy of the representation. Precarious small farmers, often coming from the hinterland of the state, hardly identify themselves with the syndicate proposals. There are all the more excluded than the diffusion of technical information from the technical agriculture services often relies on the Japanese networks and social organization of which these farmers are excluded.

the subcommittee is one of the most recent of Alto-Tietê catchment has difficulties to plainly assume its role of as discussion and negotiation platform. It thus played a relative minor part in the two conflicts involving competitions between irrigators and other water and land users.

In 2001, in during a particularly severe low water season, the pumps of the Biritiba station which are diverting part of the river Tietê flow to the water supply reservoir were affected by the pumping of upstream irrigators. Most farmers irrigates twice a day mostly as the same time and their intake significantly decreased the water level of the river during the pumping time. The manager of the Biritiba pumping station had thus to stop and reinitiate its pumps twice a day. In order to promote the staggering of the agriculture intake during the day, a meeting was organized with the Rural Syndicate. The viewpoints differ on the results of this meeting on the irrigation practices. No formal assessment of the outcomes has been implemented. Many farmers met perceived this meeting as the occasion for Sabesp to present its difficulties and propose its own solutions rather than the initiation of a bilateral discussion on agriculture water use that could have led to the elaboration of a common developing plan.

The conflict with the mining sector mobilized the farmers and local media. Because of this mobilization, the municipality of Mogi das Cruzes has requested the elaboration of an mining and agricultural zoning of its territory. Even if the Rural Syndicate was associated to the monitoring of this zoning with the main mining syndicate, the zoning team was only composed of geologist. Thus it was chosen to solve the conflict through an administrative process, backed by scientific information. Thus the conflict was mostly viewed by the authorities as a technical problem and not an opportunity for social concertation on the future of wetlands areas. Thus a discussion is plainly part of the role of the sub committee

In the catchment plan, elaborated through a consultancy process the discussion over agriculture is limited to (i) the assessment of agricultural water demand, derived from a census of irrigators developed by Sabesp (ii) a discussion over

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[2] as in the whole Brasil, exept in the Southern and North-Eastern states

“the rational management of water”, view as the climatic demand of the soil-crop system (FUSP, 2002).

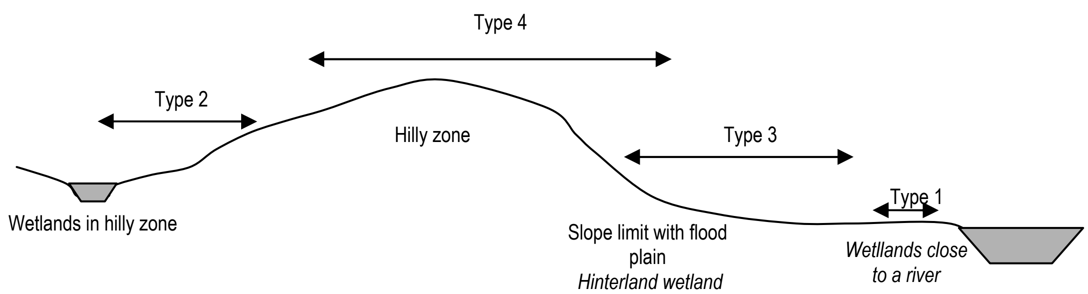
The agriculture of Cabeiceras-Tietê catchment : competing activities, polluting activities or protecting the resources ?

The most demanding crops in water are horticulture, mushroom production and eucalyptus but only horticulture is being irrigated, mostly by aspersion with electrical and/or diesel small pumps. Irrigation allows to (i) increase the number of crop per year, by cultivating even during the dry season. The number of crop by years have thus significantly increased during the last decades (FUSP, 2002) (ii) to control the transplanting percentage success (iii) to improve production in quantity but mostly in quality. Irrigation improves the visual appearance of the products as well as their size (Agena, 2000).

Four main modes of water access have been identified with their constraints and potentialities (Tab 2). The farmers met that had a permanent access to water (type 1) cultivated the biggest areas, were among the oldest established in the area and the better equipped. Farmers with precarious water access (type 4) were characterized by a smaller cultivated area, a precarious landholding situation and relative new establishment in the area (less of 10 years of farming in the area).

Tab 2 : The four main type of water access identified.

Type of water access	Type 2	Type 4	Type 3	Type 1
Water access	River with drying up risks	Infiltration or runoff water tank	Infiltration or runoff tank and river	Permanent river
Localisation	Hilly zones	Hilly zones	Limits between flood plains and hills, small hinterland wetlands s	Wetlands
Inundation risks	0	0	0	+++
Deficiency risks	++	+++	0	0



The average climatic demand of the horticultural crops has been evaluated with the Cropwat soft (FAO, s.d.)[3]. It estimates global water demand to an average of 0,405 l/s/ha without taking into account the soil characteristics for an irrigation demand of 0,108 l/s.

Our interviews indicate that farmers irrigate one or twice a day, between 10 and 40 minutes depending of the crop, its growth stage[4] and rain. We estimated the water uptake with this information on irrigation practices, which is without surprise much higher than the crop water demand (Tableau 2). This value is compared to other mode of assessment of agricultural water demand found in the literature.

Tab 3 : Assessment of water consumption depending on the farmers irrigation practices.

	Min	Max	Comments
Assessment from interviews	3,60 mm /j (0,416 l/s/ha)	36,7 mm/j (4,24 l/s/ha)	Min : 10 minutes of irrigation by day, 1 or 2/ day Max : 40 mn of irrigation one or twice a day. 2 irrigations a day during the rooting phase and the maturing phase Aspersers of 3,53 m^3/h located in parallel lines with 18 m spacing each to another. Rain is not taken into account
Assessment trough the monitoring of 2 plots (source : Agena and al, 2000)	16,8 mm/j (1,94 l/s/ha)	41,1 mm/j (4,75 l/s/ha)	Min : irrigation of a lettuce crop in a wetland plot (no slope). Monitoring of 30 minutes extrapolated to one hour Max : irrigation on an hilly slope, monitoring of 30' extrapolated to one hour Irrigation estimated by day.
Assessment through calibration of recharge in subterranean water (Mancuso Cavalcanti, 2002)	19,9 mm/j (2,30 l/s/ha)		In Hilly areas only, 6 months a year 35 % only of water is infiltrating into in-depth layer of the soil Extrapolated to the irrigated surface in hilly zones.
Census of irrigators (Sabesp, 2001, cited in FUSP, 2002)	1,31 l/s/ha		

Thus water intake for irrigation is varying depending on the assessment mode between 0,416 and 4,75 l/s/ha (Tab 3) higher than the 0,327 l/s/ha used is the catchment plan to estimate agricultural water use (FUSP, 2001). Our estimation mode by direct interviews does not take into account limitation of irrigation in rainy time and thus represents the maximum water intake.

In the wetlands areas, were the water sheet is very superficial, irrigation losses (difference between crop demand and irrigation intake) might be considered as insignificant, as the water not used directly by the crop and not stored in soil returns to the hydrological system. Actually, the main flood plain area of the river Tietê, which is partly cultivated, is considered by the manager of the SPAT as a water reservoir, whose retention time can be compared to the time taken to transfer water from the most distant reservoir (Punta Nova) to the downstream reservoir of Taiçubepa - time step of a day. A study of the recharge of the

[3] With the crop coefficient calculated by IPT work (Agena, 2000)].

[4] Farmers are differentiating a rooting stage, a growing stage and end of cycle stage (pre-harvesting)

aquifers in the hilly areas indicated that irrigation provide for an important contribution to the recharge of the subterranean water, estimated to 19,9 mm/day in the 6 months when total rain amounted to less than 30 mm (Mancuso Cavalcanti, 2002). This subterranean sheet plays an important role in the water supply of rural dwellers that represents 15 % of the homes of Suzano and mogi das Cruzes, 40 % in Salesopolis and Biritiba (Ibge, 2000). The study estimates that 14 % of sub-surface runoff (rain and irrigation water) are lost during the transfer process.

Thus water used for horticultural crop was estimated of 0,110 l/s/ha (average climatic demand of the crop) in the wetlands areas and 0,745 l/s/ha in the hilly areas (intake of 2,3 l/s/ha of which 35 % is infiltrating to the subterranean aquifers and return to the hydrological system, 6 months a year).

Image satellite analysis was used to estimate the repartition of irrigated agriculture between hilly areas and flood plains area. In hilly areas, mixed cropping system combining orchards and horticulture could not be differentiated by image treatment, but pure horticulture area (all irrigated) appeared clearly (Moraes et al., 2004). Table 4 presents the results for the four main municipalities of which the SPAT system belongs, as well as the data for the whole catchment (with downstream municipalities). 7392 ha of horticultural crops were identified for the 4 municipalities, 50 % in flood plains area, 50 % in hilly zones (Tab 4). A census of irrigators developed by Sabesp in 2001 identified an irrigated area of 7561 ha. Considering 51 % of this area in the hilly zone, the water demand for irrigated agriculture can thus be estimated to 0,435 l/s/ha, corresponding to an agriculture water consummation of 3,29 m^3/s, that is 29 % of the total flow[5] of the basin.

This number is 33 % higher than the agricultural demand used in the catchment plan (0,327 l/s/ha). It remains however limited if compared to the 70 % attributed to agricultural consumption at global scale, which is still being referred to by many people when discussing the agricultural water use of this specific catchment. This relatively small agricultural demand has to be linked with the limited size of the irrigated area of the catchment that represents less than 5 % of the total surface of the catchment. More over, most of this irrigated area is devoted to horticultural crops which are high value production, giving a good economical return by drop of water used. First estimations indicates that an average margin for a lettuce crop of 3700 R$/ha for a 45 days cycle.

[5] 4,04 m^3/for domestic demand and 4,13 for industrial demand (Fusp, 2001)

Tab 4 : Localization of the main irrigated areas

		Flood plain		Hill zone		High slope area		Total	
		ha	%	ha	%	ha	%	ha	%
Suzano	Horticulture[1]	1.094	*40*	1.627	*60*	0	*0*	2.721	
	Mixed[2]	104	*33*	210	*67*	0	*0*	314	
	Sub-total	1.198	*39*	1.837	*61*	0	*0*	3.035	*100*
Mogi das Cruzes	horticulture	1.352	*51*	1.289	*49*	0	*0*	2.641	
	Mixed	1.122	*51*	1.068	*49*	7	*0*	2.197	
	Sub-total	2.475	*51*	2.357	*49*	7	*0*	4.839	*100*
Biritiba	horticulture	1.206	*62*	746	*38*	0	*0*	1.952	
	Mixed	285	*29*	679	*70*	12	*1*	975	
	Sub-total	1.491	*51*	1.425	*49*	12	*0*	2.928	*100*
Salesopolis	horticulture	29	*38*	48	*62*	0	*0*	77	
	Mixed	6	*18*	29	*82*	0	*0*	35	
	Sub-total	36	*32*	76	*68*	0	*0*	112	*100*
4 munici-palities	**horticulture**	**3.682**	***50***	**3.711**	***50***	**0**	***0***	**7.392**	
	Mixed	**1.518**	***43***	**1.986**	***56***	**18**	***0***	**3.522**	
	Sub-total	**5.199**	***48***	**5.696**	***52***	**18**	***0***	**10.914**	***100***
Catchment	horticulture	4.493	*44*	5.726	*56*	0	*0*	10.220	
	Mixed	1.518	*43*	1.986	*56*	18	*1*	3.522	
	subTotal	6.011	*44*	7.712	*56*	18	*0*	13.741	*100*

Source : Satellite image analysis, Negowat project, Apta-Iac, Image 2001.

1 : Horticulture crop : irrigated
2 : Mixed crop : Orchards (non irrigated) and horticulture (irrigated), could not be differentiated by satellite image analysis

There is little available information on the quality of the water used by agriculture, but our interviews indicate that some farmers are already suffering from the degradation of water quality. Various strategies to limit its impact on their production and income was stated by farmers: Some were trying to avoid direct pumping in polluted rivers either by development of specific tank or sometimes pumping in subterranean water, most of them are washing the products with potable water before commercialization, and some of them have changed their crop system to less water demanding system in order to limitate the use of polluted water. A couple of farmers were thinking of leaving the area for a less polluted one.

The table 5 is summarizing the available information of diffused pollution in the Metropolitan Region of Sao Paulo.

The estimations from the Hidroplan study appear to be very different from the other data available, but it was not based on local study but estimated on the basis of coefficient from the Guanabara Bay. All the estimation however underlines the relative importance of low pattern urbanization. A previous study cited by S Eiger (1999) assessed the pollution source of phosphorus in the Guarapiranga catchment, a much less agricultural than Cabeiceras Tietê: Cultivated area in the catchment is estimated to 1530 ha (Vicente et al., 2004), some 1,7 % of the total catchment surface. This study estimated than 88 % of the 532 kg/day of total hydrolisable phosphorus came from domestic effluents, 10 % from rural runoff and only 2 % from urban runoff. During rainy events, concentration of total phosphorus from rural areas was varying between 0,18 and 0,24 mg/l against 1,6 to 9,2 mg/l. 62 % of all total annual charge in phosphorus were due to domestic effluents, 27 % from diffused urban pollution and 11 % only from rural diffused source. None of the information differentiates the origin of non point source pollution depending of the crop systems : irrigated agriculture which is much more intensive is likely to contribute more than other crop system. However, organic agriculture is raising a growing interest in the area either for economical reasons (lowering production costs) or ecological reasons, as indicated by the development of one of the few agricultural organizations[6] of the area. Further work appears necessary to estimate better the contribution of the different crop systems in the pollution charge.

Tab 5 : Exportation coefficient in the litterature for diffused pollution in the Metropolitan Region of Sao Paulo.

		DBO Kg/km².day	N total Kg/km².day	P Total Kg/km².day
	CCN 1997 [1]		6,84	
	MQUAL model [4]	DBOc 7,564	2,96	0,346
	Plano Sabesp [2]	7,000	2,63	0,180
AGRICULTURE	Hidroplan [3] (dry season)	21,000	11,00	0,300
	Hidroplan [3] (rainy season)	29,000	18,00	0,420
	Plano Sabesp	1,400	1,4	0,090
	MQUAL	DBOc : 1,302	0,6	0,039
FOREST	Hidroplan (dry season)	3,000	3,2	4,500
	Hidroplan (rainy season)	4,500	5,1	0,280
PASTURE	Plano Sabesp	3,000	0,700	0,040
	MQUAL	1,079	0,028	0,500
"CHACARAS[5]"	MQUAL	2,000	0,900	0,050
URBAN (without sanitation)	Plano Sabesp	22,600	4,900	1,530
URBAN (Low quality level))	Mqual	DBOc : 8,000	2,548	0,135
URBAN (medium level)	MQual	4,000	1,274	0,034
URBAN sanitated	Plano Sabesp	13,700	2,500	0,800
URBAN (dry season)	Hidroplan	123,000	27,00	4,000
URBAN (rainy season)	Hidroplan	185,000	43,00	5,600

Source :
1 : Cited by Mancuso Calvancanti, 2002
2 : Cited by Fusp, 2001
3 : cited by Fusp 2001, This study aimed to assess the pollution level in the Billings catchment. The coefficient were taken from previous study in the Guanabara bay/RJ, bibliographic study and local observation.
4 : Exportation coefficient used in the MQual model V1.5 used in the poject of Specific Lei of Guarapiranga and elaborated by PRIME engheiria.
5 : district of very low housing density (end of week-end housing)

Agriculture does not have only negative impacts on water resources. According to the legislation, landowners have to keep 20 % of the total area of their property in forest or natural vegetation. This norm is globally respected as indicated in Tab 1 and this forest fragments contribute to the preservation of the springs. Different studies tend to indicates that agriculture could play an

[6] APROS, whose activities and members are mostly developed in the Salesopolis municipality.

important role to locally contain urbanization: urbanization mostly increase at the detriment of forested or fallow areas. Cultivated areas are seldom affected. (Bellenzani, 2000). Most of the landholders of Japanese origin that have chosen to migrate to Japan during the last 15 years in search of better economic opportunities are trying to rent their land to a farmer even at a very low price in order to limit the risks of invasion or illegal occupation on their property. The preservation of a dynamic agriculture with its cultural and religious networks also contribute to maintain a strong social network in the rural districts, limiting the negative effect of rapid urbanisation. The Guarapiranga area, were agriculture is particularly weak is characterized by extreme violent rate and poor social indicators (unemployment, alphabetization, income…).

Discussion

Is there a future for irrigated agriculture?

Analysis of the evolution of agriculture in the catchment indicates a diminution of 31 % of agricultural surface in the catchment between 1988 and 2001. the decrease was mostly due to the diminution of annual non irrigated crops (29 %). In the same time, urban areas increased of 14 % (Moraes et al., 2004). Horticulture and orchards area decreased of 40 % between 1978 and 1988. The diminution was especially important in the municipally of Suzano and Mogi das Cruzes whose agricultural surface (all type of production included) went respectively from 11000 ha to 1500 ha and 43 000 ha to 20 000 ha (Vicente et al., 2004).

Agriculture development is limited by various factors: (1) a high competition on land with other land users such urbanization, mining sector hydraulic infrastructure (2) the limitations related to the environmental legislation (3) uncertainties on the economic viability of the activity.

The proximity to the city is increasing land prices. In the very urbanized area of Guarulhos, price offers for agriculture land was reaching 84000 R$/ha while the most expansive land in Mogi das Cruzes was 12000 R$ /ha[7]. Urbanization is also linked with a high demand in construction materials, which are mostly available in flood plains, also the most suitable agricultural zones. This has already led to open conflicts between both sectors. The agricultural areas are also affected by the development of hydraulic infrastructure. In order to increase water production of 5 m^3/s, two new dams are being built, of a total surface of 18 km². 210 landowner will be expropriated in the inundation area of the Biritiba dam (Mancuso Cavalcanti, 2002). In parallel, the water firm is looking to better control the management of the SPAT (that is still managed by the Water Department). This conflict is accompanied by a centralization of water management of the system materialized by the automation of the management. This process could exclude local water users such as farmers whose practices are not well known and consequently difficult to take into account in the soft underdevelopment.

[7] In 1995, 1 R$ = 1 $US : en 2002 3 R$ for 1 USD

The agricultural practices are directly affected by the environmental legislation: agricultural development is limited to existing deforested areas. Modifications of the irrigation system, especially the maintenance of the water tanks, necessitate an administrative authorization. The legislation also prohibits some activities of interest for agriculture such as composting at large scale. Moreover the devaluation of Brazilian currency has led to an augmentation of the production costs while the crop prices remained stable. Farmers are stating a diminution of their income.

Many young people of Japanese origin tend to give up agriculture. Our interviews underlined two main processes in the evolution of agriculture (1) the establishment in precarious land tenure conditions of farmers from the hinterland of the state, (2) the establishment of young farmers of Japanese origins well trained and capitalized, which are specializing either in innovating productions (flowers, hidroponic gardening) and/or on-farm transformation of the production.

It is thus difficult to assess the future of agriculture of the area, and thus the agricultural water demand which is submitted to three conflicting forces (1) a centrifugal expulsion force that support the establishment of small farmers in precarious situation (2) the consolidation of small agribusiness farmers developing innovating activities (3) the emergence of new urban demands that support the development of new activities at the margin of agriculture : production of organic matter for garden, green areas and recreational zones.

An approach to facilitate the concertation

Integration of agriculture by the committee supposes the building of a common representation (1) on the impact of agriculture on the resources (2) a concertation on the possible scenarios of evolution of this activity and its impact depending of socio-economical context and policies options. The Negowat project is testing the use of simulation tools as a mediation tool to support this concertation as a way to clarify the point of views of the different actors, to facilitate mutual understanding and collective social learning during the different phases of model development and simulation (Pahl-Wostl, 2002). This includes the building phase of the model and scenarios, the phase of social validation and the discussion of simulation results.

In this aim, various simulation tools are simultaneously being developed : (1) a multi-agent simulation models named SpatMas, developed with the Cormas platform (Bousquet, 1998) (2) Three roles playing game, as simulation games where the players are assuming the role of a specific stakeholder of the system represented. The games are organized around some scenarios in which the players have to interact with each others, to take decisions relative to the virtual resources and implement them in the virtual system.

The model SpatMas combines (i) a spatial representation of the catchment area of the watershed permitting to account for the changes of land use and occupation at catchment scale (ii) a representation of the most important actors such as the managers of the reservoir system, the manager of the water supply and sanitation systems, the mayors of the different municipalities.Their interaction with water resources are limited to the processes: water allocation between users, development of water and sanitation infrastructure by the mayor and water firms, evolution of urbanization viewed as the densification of land occupation (iii) an hydrological representation of the basin that relies on an water allocation model of arc node type and a representation of quality processes. At this stage only the water allocation and spatial modules have been developed (Iv) dynamic of land use changes depending of demographic and socio-economic dynamic of urban and rural dwellers.

Three games are currently being developed. The first one - JogoMan - represent a watershed made of 3 municipalities and one potable water reservoir. The players (mayors, a water firm manager, land owners, and homeless representatives) have to take decision related to land use of their properties (type of use, building development), or to investment in urban or water infrastructures. The economical consequences of this decisions (represented by the cashbox of each players, the unemployment tax of each municipality, the % of taxes and water invoices paid) as well as their impact in the water quality in the reservoir are simulated in the Cormas platform: This results are provided to the players to help them to assess the consequences of their decisions and undertake new choices for the next game round. Each round includes the meeting of a "virtual water committee" whose objectives are undertake a collective assessment of the watershed situation and facilitate collective decision making. This game is currently being tested. The second game is aiming at facilitating the understanding of the internal rules of the complex SpatMas model, in order to facilitate its collective validation. It focuses on the water allocation rules between stakeholders with assessment of the results in term of water availability for each represented use, and water quality. The third game is being developed with representative of the civil society, in order to facilitate appropriation and understanding of a specific environmental law which currently being elaborated. The games will represent the land use and occupation dynamics in a typical upstream area of a drinking reservoir.

The different tools are based of the same conceptual framework and will integrate an explicit representation of the farmers, their irrigation and land tenure strategies, assessed by the previous study. Scenarios of dynamics of agriculture and irrigated agriculture will be built with the farmers. The validation of the tools includes a social validation of the functioning rules included. The tests will asses how best to combine them in order to help the stakeholders to understand the different processes represented at local (between 100 and 50 km²) and catchment level, to build their capacity to negotiate at local level and collective levels on the related issues.

Our approach relies on the hypothesis than concertation processes are less facilitated by the outcomes of the simulation, than by the building of common representation and scenarios. The different steps of the modeling process, including role playing game session, aim to enlighten the points of view of the actors, including those of the scientists, their value and sensibility to risk. We have chosen to simplify the representation of the biophysical processes, assuming that it was more important to have a representation validated by all actors rather than a detailed and complex representation of processes that would only make sense for some of the actors. Former experience have indicated that the use of simplified biophysical models, whose outcomes are less predictive that illustrative are interesting in participative approaches (Voinov et al., 2004). But a specific attention is given to the choice of management indicators that are really used by the actors in their current management process.

Conclusion

As many periurban areas, the competition over land and water is increasing between agriculture and other users. The continuous increase of the urban water demand could accentuates this tensions in the future as the 3,3 m3/s of water used by irrigated agriculture could be viewed as strategic by the potable water sector. The consequences of this appropriation on water resources availability is difficult to assess as the weakening of agriculture could results in urbanization with higher pollution rates and degradation of socio-economic indicators as in the Guarapiranga catchment.

At mid term level, the total agricultural water demand will depend on the evolution of irrigated surface and the mode of irrigation in the catchment. Drip irrigation is often presented as the solution to economize water. This technique is not easy in implement to short cycle crop systems, and supposes good quality water resources and investment that not be possible for many farmers of the areas.

In the RMSP, urban pression promotes the development of precarious small scale agriculture. After an increase of cultivated area between 1940 and 1970, the area is facing a rapid decrease of agriculture areas. This decrease was especially important in the Guarapiranga catchment. For some people, durability of agriculture in the catchment supposes its transformation in agri-business production, with a process of standardization of the production quality and a better food chain organization. Competition with other production zone with cheaper land and less polluted water resources could however jeopardize this model. In line with the national food security policy, others beginning to defend a model of urban and periurban agriculture for food security and social integration of poor families of the periphery. They particularly stress the possibility collective horticulture gardening and the preservation of sanitary quality of the product. We argue that the maintenance of durable and protective agriculture for water resources supposes the development of a negotiated development plan, that could facilitates less polluting practices, , capacity building of farmers on irrigation practices, wastewater use taking int account the new strategies linked to urbanization processes. This supposes the implementations of specific sectorial measures as contemplated in the urban and water legislation. The definition of this mechanisms and plan is plainly a matter for the catchment committee.

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