Integrating land tenure, infrastructure and water catchment management in São Paulo's periphery: lessons from a gaming approach

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ABSTRACT Much of São Paulo's urban expansion is driven by the development of informal settlements on its periphery, which includes the catchment areas that provide important environmental services such as open space and catchments for drinking water reservoirs. In such areas, governance of land, water services and water resources, traditionally administered separately, are in fact interdependent. A role-playing game was built to explore the interactions between different actors (mayor, water company, district representatives and landowners of different types) in land tenure insecurity, water and sanitation infrastructure and pollution in the periphery of São Paulo. An assessment of the game sessions revealed the different points of view of local and institutional actors about the main issues and the possible negotiation arrangements. Institutional actors misunderstood the hierarchy and diversity of community actors' preoccupations, which were related more to land tenure, access to public transport and other aspects such as health and education rather than to water and sanitation infrastructure. Institutional actors also failed to recognize how access to infrastructure and land tenure is shaped by power-based relationships. While community actors appreciated the game and felt that they had learned from the experiment, institutional actors were more critical. These discrepancies call into question the potential effectiveness of the legal, technical and institutional solutions that the institutional actors are promoting to address the pollution issue.

KEYWORDS infrastructure / land tenure / peri-urban area / pollution / role-playing game / sanitation / São Paulo

I. INTRODUCTION

Urban growth in Latin American cities is associated with a process of peri-urbanization. In the context of high social inequality, most poverty is concentrated in the expanding peri-urban fringe of many cities in Brazil, Bolivia and Mexico.(1) Low-income groups often have no option but to occupy low value land that is generally environmentally unsuitable (and vulnerable to floods, landslides and other hazards).(2) They must also rely on unauthorized channels to access affordable land and housing. Land use changes at the urban edge are the result of a combination of market mechanisms ranging from speculation to unauthorized occupation, which leads to more or less secure land tenure, inadequate access to basic services, and social and economic exclusion of a certain segment of the population.(3)

Research has long pointed to the relationships between the provision of basic services and land tenure security. The title-first approach[4] presupposes that formal land titles encourage not only private investment and housing improvement but also public infrastructure, since government is more willing to invest in settlements viewed as permanent. However, it is now recognized that the perception of land tenure security is more important for housing improvement than actual land title[5] and that multiple dimensions around the quality of living conditions interact and influence each other, including provision of basic services, the quality of housing and neighbourhoods, and location in terms of public amenities (schools, parks, easy transportation) and safety. This implies the need for programmes that address both land tenure and infrastructure to create incentives for upgrading.[6] However, tenure (either of land or water) means social relationships of appropriation and exclusion; consequently, it cannot be dealt with in strictly technical terms.[7] Vulnerability and security of land tenure is also a matter of the ability to mobilize different social resources (political connections, information, social networks, etc.) to defend one's interests. Migration, rapid urbanization and different forms of insecurity tend to weaken social ties and community memory, and social cohesion can be particularly poor in unauthorized settlements on the edge of urban areas.[8] Moreover, informality and illegality have a derogatory connotation, which further affects the ways residents and other actors such as developers and public authorities interact.[9]

Peri-urban areas, in transition between predominantly rural and urban features,[10] are characterized not only by land speculation and multi-dimensional poverty but also by economic activities of higher productivity, the emergence of informal and often illegal activities, and institutional fragmentation.[11] These areas can play a key role in providing materials and perishable foods to the city and in providing space for such essential infrastructure as airports and electric power plants. Some of these areas fulfil specific hydrological functions for the city, i.e. a catchment area includes space for drinking water reservoirs and allows for groundwater recharge, functions that are altered by densification and land-sealing.

An expanding population in a context of uncontrolled urbanization puts great pressure on public authorities attempting to provide urban infrastructure, often with restricted financial resources. In the water sector, authorities are responsible for the development and management of potable water and sanitation services as well as the regulation of multiple water uses and protection against flooding and pollution at the basin level. Water services, water resources and land governance – traditionally handled separately – are in fact interdependent in these areas.

This paper aims to contribute to the discussion of the relationship between land tenure security, environmental protection and access to basic services in peri-urban areas from an environmental perspective. It argues that the problems encountered by public actors when considering the interests of local communities may limit the impact of new regulations integrating land and water resource issues for catchment protection in the periphery of São Paulo, Brazil.

The first part of the paper looks at how tools for urban land management and water resources are being integrated into the institutional framework of São Paulo. The next section presents the development of a game that addresses water resource management, urbanization mechanisms and infrastructure development and implements; it also describes game

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1. Xavier Barros, Joana (2004), "Urban growth in Latin American cities: exploring urban dynamics through agents-based simulation", Bartlett School of Architecture and Planning, University College London, 209 pages; also Torres Lima, Pablo, L M Rodriguez Sanchez and B I Garcia Uriza (2000), "Mexico City: the integration of urban agriculture to contain urban sprawl", in Nico Bakker, M Dubelling, S Gundel, U Sabel-Koshella and H de Zeeuw (editors), *Growing Cities, Growing Food: Urban Agriculture on the Policy Agenda*, DSE, ZEL, pages 263–390.

2. Baross, P and J J van der Linden (1990), "Introduction", in P Baross and J J van der Linden (editors), *The Transformation of Land Supply Systems in Third World Cities*, Aldershot, Avebury, pages 57–82; also Douglass, M (1992), "The political economy of urban poverty and environmental management in Asia: access, empowerment and community-based alternatives", *Environment and Urbanization* Vol 4, No 2, October, pages 9–32.

sessions with different actors representing local communities and public institutions. The following section compares the discussions during different game sessions and the mismatch between different actors' and institutions' perspectives. The last part analyzes the significance of these results in terms of the implementation of improvements to the socio-environmental situation of the catchment area.

II. THE SANITATION CONFLICT IN THE PERI-URBAN HEADWATER CATCHMENTS OF SÃO PAULO

The Metropolitan Region of São Paulo (RMSP), a conurbation of 39 adjacent cities, is the most highly populated and industrialized region of Latin America, with 18 million inhabitants in 2000. The Alto Tietê watershed includes most of metropolitan São Paulo. Urbanization processes have had an enormous impact on the catchment, especially its peri-urban areas. While population growth has fallen to 1.4 per cent per year citywide, peripheral areas continue to grow at an average rate of 3–5 per cent.[(12)] The water supply system in the metropolis is managed by a public–private enterprise, SABESP (Companhia de Saneamento Básico do Estado de São Paulo), which is also in charge of sanitation. Drinking water distribution is close to 100 per cent in urban areas but there is less coverage in peripheral areas. Only an estimated 65 per cent of domestic effluent was collected in 2000 and only 32 per cent treated,[(13)] and wastewater collection is especially low in peri-urban areas.

A large part of the peri-urban area is located in the headwater catchments, which have been protected by legislation that has controlled land occupation since the 1970s. This legislation, however, failed to significantly contain occupation,[(14)] and unauthorized settlements with no sanitation infrastructure continue to spread and contribute to the rapid degradation of the quality of water resources in the main drinking water reservoirs.

The problem is particularly acute in the Guarapiranga–Cotia catchment, an area covering 900 square kilometres, comprising seven municipalities and the Guarapiranga reservoir, and providing 15 per cent of the metropolitan area's domestic water supply. The upper third of the reservoir area is nearly completely urban, and inadequate sanitation and wastewater collection in unauthorized settlements have contributed to high organic pollution rates here since the 1970s.

To rehabilitate the reservoir, improve the water quality and reduce wastewater treatment costs, a large-scale investment programme, the Programa Guarapiranga, was implemented in 1990 supported by the International Development Bank. This innovative programme from an environmental, urban governance and institutional point of view[(15)] promoted integrated inter-sectoral cooperation and discussion at the municipal level.[(16)] However, it also gave priority to structural activities over participation, capacity-building and support of economic activities. Given population pressures, the programme did not manage to reduce water pollution in the catchment area. However, it was able to test tools related to land and water use, which influenced new legislation for catchment management. After years of discussion, the Lei Específica de Guarapiranga (Law specific to Guarapiranga) was finally approved by the state legislature in 2006.

3. Gutberlet, Jutta and Angela Hunter (2008), "Social and environmental exclusion at the edge of São Paulo, Brazil", *URBAN DESIGN International* Vol 13, No 1, pages 3–20.

4. de Soto, H (2000), *The Mystery of Capital: Why Capitalism Triumphs in the West and Fails Everywhere Else*, Bantam Press, London, 276 pages.

5. de Souza, Flavio A M (2001), "The future of informal settlements: lessons from the legalization of disputed urban land in Recife, Brazil", *Geoforum* Vol 32, No 4, pages 483–492; also Van Gelder, Jean-Louis (2007), "Feeling and thinking: quantifying the relationship between perceived tenure security and housing improvement in an informal neighbourhood in Buenos Aires", *Habitat International* Vol 31, No 2, pages 219–231; Payne, Geoffrey (2002), *Land, Rights and Innovation: Improving Tenure Security for the Urban Poor*, ITDG Publishing, London, 228 pages; and Macedo, Joseli (2008), "Urban land policy and new land tenure paradigms: legitimacy vs legality in Brazilian cities", *Land Use Policy* Vol 25, No 2, pages 259–270.

6. Gulyani, Sumila and Debabrata Talukdar (2008), "Slum real estate: the low quality, high price puzzle in Nairobi's slum rental market and its implications for theory and practice", *World Development* Vol 36, No 10, pages 1916–1937; also Payne, Geoffrey (2004), "Land tenure and property rights: an introduction", *Habitat International* Vol 28, No 2, pages 167–179.

7. Durand-Lasserve, A (2006), "Informal settlements and the Millennium Development Goals: global policy debates on property ownership and security of tenure", *Global Urban Development* Vol 2, No 1, pages 1–15.

8. See reference 3.

9. See reference 5, De Souza (2001); also see reference 7.

10. Allen, A, J D Dávila and P Hofmann (2006), *Governance of Water and Sanitation Services for the Peri-Urban Poor: A*

This law was designed to integrate water resource management, land management, and management of the urban systems, including dwellings and transportation.[17] In each catchment, a river basin committee brings together representatives of state institutions, cities and organized civil society for discussions and consultation. Because of the complexity of water management in this urban catchment, the Alto Tietê was divided into five sub-catchments, each with its own sub-committee. The Guarapiranga–Cotia sub-committee is one of them. Each catchment must provide specific regulations adapted to the local context.

Municipalities are in charge of land management, and in 2001 a federal city statute (Estatuto da Cidade) was adopted to address urbanization in a different way. This legislation formalizes the shift from legality to legitimacy in Brazil's urban land policy.[18]

Contrary to the previous catchment legislation, the new Guarapiranga law includes tools to recuperate degraded areas and proposes a decentralized management with shared responsibility by the state, municipality and civil society. Target levels for phosphorus in the water are defined at catchment and municipality levels, and environmental reclamation involves integrated upgrading projects for unauthorized settlements, including land tenure regularization. Municipal land planning has to be compatible with the law's norms and targets. Other innovations include the possibility of financial compensation in certain cases.

a. A gaming approach to discuss the implementation of the legal framework

To strengthen the participation of community leaders in collective decision-making processes related to land and water management, a Companion Modelling (ComMod) approach was developed.[19] This involves simulations designed to represent social processes and decision-making and to integrate the different stakeholders' points of view. This approach has been tested in different situations where collective management of resources and territory are required, for example in the management of the watershed,[20] of irrigated areas,[21] of fire in a peri-urban environment[22] and management of the development of water infrastructure.[23] An assessment of 20 case studies reveals the main contributions and challenges of the approach.[24] The approach contributes to knowledge-sharing and knowledge-building as well as learning, and helps develop interaction, communication and negotiating capacities. In the ComMod approach, role-playing games facilitate the learning of social and/or biophysical processes as well as discussions on the underlying conceptual model.

The main challenge lies in the legitimacy of the discussion arena, the tools used and the solutions proposed. The legitimacy of the discussion arena depends on the choice of participants, their representativeness, existing power relationships and the relative position of the mediator. The legitimacy of the tools depends on their use, their transparency and how well the underlying conceptual model fits the participants' perceptions. Participatory modelling during the design stage of the tools helps achieve the right balance between a representation of real life complexity and the simplification necessary for an effective discussion platform. If the tool is too close to reality, discussion often comes to a standstill because of real

Framework for Understanding and Action in Metropolitan Regions, Development Planning Unit, University College London, 126 pages.

11. Butterworth, John and Jeroen Warner (2007), "Introduction", in J Butterworth, R Ducrot, N Faysse and S Janakarajan (editors), *Peri-urban Water Conflicts: Supporting Dialogue and Negotiation*, IRC International Water and Sanitation Centre, Delft, the Netherlands pages 9–23.

12. FUSP (2000), "Plano da bacia hidrográfica do Alto Tietê", FUSP, São Paulo, available at http://www.dq.ufscar.br/Labs/biogeoquimica/qualised/qualised-files/arquivos/Plano_Alto_Tiete.zip; also Torres, H, H Alves and M A D Oliveira (2007), "São Paulo peri-urban dynamics: some social causes and environmental consequences", *Environment and Urbanization* Vol 19, No 1, April, pages 207–223.

13. Porto, M (2003), "Recursos hídricos e saneamento na região metropolitana de São Paulo: um desafio a tamanho da cidade", Banco Muncial, Brasília DF, Brazil, 84 pages.

14. Bellenzani, M L R (2000), "A apa municipal do capivari-monos como uma estratégia de proteção aos mananciais da região metropolitana de São Paulo", PROCAM–USP, São Paulo, 204 pages; also Marcondes, M J A (1999), *Cidade E Natureza: Proteção Dos Mananciais E Exclusão Social Studio Nobel*, Editora da USP, FAPESP, São Paulo, 236 pages.

15. See reference 10.

16. Porto, Monica (1999), "Sustaining urban water supplies: the metropolitan region of São Paulo, Brazil", Keynote lecture at the Ninth Stockholm Water Symposium, Urban Stability through Integrated Water-related Issues Management, Stockholm, August 8–14, pages 107–112.

17. Jacobi, P R (2004), "The challenges of multi-stakeholder management in the watersheds of São Paulo", *Environment and Urbanization* Vol 16, No 2, October, pages 199–211.

conflicts. If it is not real enough, the game is perceived as fun to play but does not contribute to real life solutions. Alternating game sessions with plenary sessions helps participants to relate the game to real life situations, but it requires adequate facilitation. The need for simplification means that simulation does not have a predictive or optimization value, and solutions discussed during a game are rarely ready to implement. It is more an opportunity for players to experiment with innovative technical, organizational or communication solutions, and it results in changes in perceptions and values, which pave the way for changes in practices and projects.(25)

The game session is one of a series of activities involving different tools that were developed using a participative methodology that brings together the points of view of scientists from several disciplines as well as local actors.(26) Particular attention was paid to the perceptions and interests of local actors, notably community leaders. A first census of settlements and their organization was implemented in the district of Parelheiros (São Paulo). Then a focus group expanded on the settlements' development problems, pollution, water access issues and relationships with the other actors. Participants came from different types of settlements and had different profiles – for instance, someone with a genuine interest in the collective well-being of the inhabitants, or a community leader close to land speculation interests. Simultaneously, the land market mechanisms in the area were studied using a post-Keynesian economic theoretical framework.(27) The development of four neighbouring settlements was analyzed and compared from an institutional economic perspective.

The mechanisms identified and actors' perceptions were indirectly incorporated into the underlying model of the game through specific contributions from the scientists who mediated the focus group. The underlying model was used to develop a computerized role-playing game called Ter'Aguas, using Cormas, a multi-agent computer programme. The game aims to simulate negotiations and interactions related to water infrastructure development at the local scale in a couple of districts or settlements within a peri-urban municipality area (Box 1).

18. See reference 5, Macedo (2008).

19. Barreteau, Olivier et al. (2003), "Our companion modelling (ComMod) approach" (La modélisation comme outil d'accompagnement), *Journal of Artificial Societies and Social Simulation* Vol 6, No 1, available at http://jasss.soc.surrey.ac.uk/6/2/1.html.

20. Raj Gurung, Tayan, Francois Bousquet and Guy Trébuil (2006), "Companion modelling, conflict resolution and institution-building: sharing irrigation water in the Lingmuteychu watershed, Bhutan", *Ecology and Society* Vol 11, No 2, available at http://www.ecologyandsociety.org/vol11/iss2/art36/.

21. Daré, W and O Barreteau (2003), "A role-playing game in irrigated system negotiation: between play and reality", *Journal of Artificial Societies and Social Simulation* Vol 6, No 3, available at http://jasss.soc.surrey.ac.uk/6/3/6.html.

22. Etienne, M, M Bourgeois and V Souchère (2008), "Participatory modelling of fire prevention and urbanization in southern France: from co-constructing to playing with the model", in M Sànchez-Marrè et al. (editors), *iEMSs 2008*, International Congress on Environmental Modelling and Software, Barcelona, Catalonia,

BOX 1
The Ter'Aguas computerized role-playing game

Ter'Aguas is a computerized role-playing game designed to simulate negotiations related to land use planning in a peri-urban municipality.

Seven types of actors are represented: the mayor, the water company, four district representatives, two small farmers, two big landowners with speculative strategies, one business representative and one owner of a weekend house who is sensitive to environmental issues.

The players make decisions about investment strategies (urban infrastructure, property development and land use activity), economic activities (buying and selling plots, subsidies and taxes on land), licensing land uses and activities, and allocating land to migrating families in the area. The computer simulation assesses the impact of land use changes, on the quality of reservoir water, on the cash assets of players and some social indicators of the municipality. After a round of decision-making, all players gather to try to find a more collective planning strategy and to try to implement it in the following round. The interactions can focus on strategies for urbanization, investment in urban infrastructure (sanitation, pipes, wells, roads, etc.) and land use planning and land market dynamics.

TABLE 1
Participants and roles in the Ter'Aguas game

		Participants	Role	Number of rounds in the game
Community games	Focal group game 1	Local community leaders Local business representative Municipality: Head of Planning SABESP: member of Water Resources Department	Each in his/her own role	2
	Focal group game 2	Local community leaders Municipality: Head of Agricultural Department SABESP: member of Water Resources Department	Municipality/SABESP switched	4
	Embu game	Health agents and executives Local NGO Municipality: Head of Planning SABESP: no one represented	Two most active leaders playing two roles: municipality and SABESP – no change in other roles	4
	Parelheiros game	Local community leaders Local business representative Municipality: Head of Planning SABESP: member of Water Resources Department	Two most active leaders playing two roles: municipality and SABESP – no change in other roles	4
Institutional games	Sub-committee game	Representative of an urban municipality Department of the Environment Environmental NGO Two members of local NGO (dealing with housing issues in urbanized areas)	Role inversion. Two non-institutional players (representatives of local NGO) playing two roles: municipality and SABESP	4
	Training sessions	Engineers and water specialists	Role inversion (by definition)	4

A demonstration of the game was proposed to members of the Guarapiranga sub-catchment committee – who had not attended previous game sessions – as a way of presenting the methodology to regional decision makers and facilitating its institutionalization and large-scale dissemination. We also expected that it could provide the basis for discussions on the implementation of the specific law, notably integration of different components that had been conceived and discussed in separate group sessions within the catchment committee. Later on, some of the participants in this demonstration game asked to use the game in training courses for water specialists. The game was played four times with representatives of institutions and organizations (referred to in this paper as "institutional games") and four times with representatives of local institutions (the municipality and the water agency) and local leaders (referred to as "community games"). Two of the community games were included in a series of activities analyzing the underlying model of the game[28] and two others were played on their own. In community games,

July 7–10, pages 972–979, available at http://www.iemss.org/iemss2008/uploads/Main/S11–07-Etienne_et_al-IEMSS2008.pdf.

23. Moglia, M, P Perez and S Burn (2008), "Urbanization and water development in the Pacific Islands", *Development* Vol 51, No 1, pages 49–55.

24. Etienne, M (2009), *La Modélisation d'Accompagnement: Une Démarche en Appui au Développement Durable*, Quae Editions, Paris, 384 pages.

25. Kuper, M, M Dionnet, A Hammani, Y Bekkar, P Garin and B Bluemling (2009), "Supporting the shift from state

TABLE 2
The different game sessions

		Game only	Teraguas approach[29]
With representatives of local communities, the municipality and SABESP	Focal group	2 (as part of the elaboration and validation of the game)	
	Embu-Guaçu northern districts		1
	Parelheiros southern districts		1
Only with representatives of "institutional actors"	Sub-committee	1	
	SABESP training	2	
	Technician training	1	

players were assigned their role in real life except for the landowner's role, which was played by a community representative; the more active leaders were assigned to work along with local institutions' representatives. In institutional games, roles were switched for all players.

Two people observed the behaviour of players during game sessions, which were also video monitored. The main tensions during discussions and the debriefing were transcribed. Two short questionnaires focusing on the perception of the issues at stake and knowledge and learning were completed by participants immediately before and after the session, and their responses were analyzed. Ten months later, qualitative interviews were done to explore what was learnt. Twenty-nine participants from the community games and one from the institutional games (sub-committee game) were interviewed. Different types of learning were differentiated, such as the acquisition of new skills, technical knowledge or relational learning, learning concerning the issue as a whole in its integrated dimensions, and situational learning concerning the development of networking, collective memory, knowledge-sharing and the rules of social interaction.

III. INTEGRATING DIFFERENT MECHANISMS AND PERSPECTIVES: PRESENTATION OF THE MODEL AND LESSONS FROM THE SIMULATION

a. Ter'Aguas: a model that integrates various dimensions of the problem

Companion Modelling (ComMod) games are intended to provide a framework for a complex adaptive system that makes it possible to explore key mechanisms during simulation. These key mechanisms are selected in a participative way during the building of the underlying model. In this particular urban environmental system, three dimensions are considered, namely pollution, urbanization and infrastructure development.

For the pollution processes, the game referred to the underlying model of the calibrated MQUAL model (one of the legislative tools) and focused on the eutrophication process in the reservoir as a result

water to community water: lessons from a social learning approach to designing joint irrigation projects in Morocco", *Ecology and Society* Vol 14, No 1, available at http://www.ecologyandsociety.org/vol14/iss1/art19/.

26. Ducrot, Raphaèle et al. (2008), "Elaboração multidisciplinar e participativa de jogos de papéis: uma experiência de modelagem de acompanhamento em torno da gestão dos mananciais da região metropolitana de São Paulo", *Ambiente e Sociedade* Vol 11, No 2, pages 355–372.

27. Bueno, Ana Karina da Silva (2004), "A lei de proteção aos mananciais e mercado de terras: um estudo sobre loteamentos clandestinos", Instituto de Economia Campinas, Masters' thesis, Universidade de Campinas, Brazil, 151 pages.

28. That we called the Teraguas approach.

29. Ter'Aguas is the name of the game; Teraguas is the name of the approach which includes different activities and the game.

of phosphorus concentration. Regarding urbanization, fieldwork has distinguished two main processes. First, an initial division by the formal landowner of a rural parcel, with subsequent tenants forming small and very disorganized urban nuclei; and second, a single process mobilizing more actors, namely landowner, developer, politician, broker, financial sponsor and community member. We chose to limit the representation of urbanization processes to the latter mechanism so that the speculative process could be represented without having to represent the plot division mechanism.

Because of the chosen catchment scale, and to avoid any possible bias due to the small number of players allowed in the role-playing game, both population growth and pollution were computerized in the game (Box 2). Urbanization was driven by the land market process and its parameters (Box 2 and Figure 1). While calibration of the hydrological processes was forced to create a pollution crisis and hence influence subsequent game dynamics, the socioeconomic parameters, including those concerning

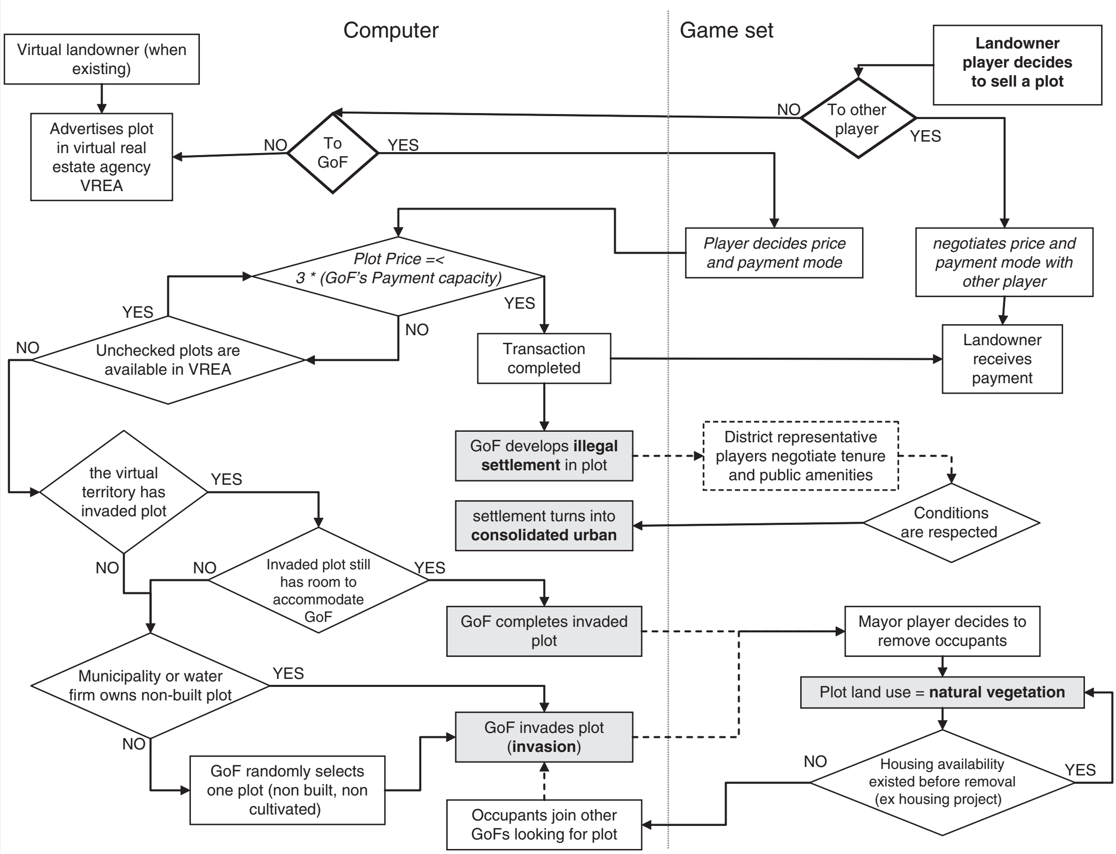

FIGURE 1
Representation of the semi-automated urbanization process

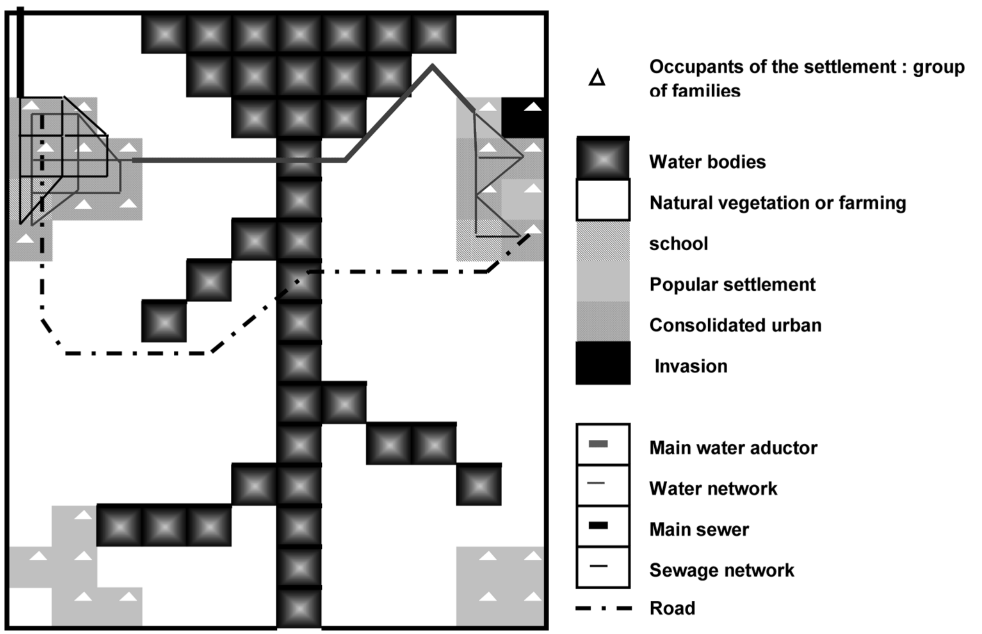

FIGURE 2
Diagram of the initial situation of virtual catchment

the land market were calibrated proportionally (false units but realistic ratios between parameters). Thus, as in real life, the semi-computerized urbanization dynamics and the calibration of the model favoured an urbanization process based on the development of self-built unauthorized settlements that were purchased in an informal but institutionalized manner rather than plot invasion, allowing explicit speculation processes.

The fairer the political basis of the negotiation between the different actors in the speculative process is, the better the resulting urban pattern of the unauthorized settlement. Thus, the frauds, swindles and conflicts that occur during the settlement process are associated with a high occupation density, disrespect of the urbanization plan, invasion of institutional areas and less proactive community behaviour directed towards the betterment of the settlement.[30] This makes the regularization process linked to the development of infrastructure and environmental compensation more difficult. Although residents of settlements located close to core urbanization borders and subjected to population rotation and other problems often lack a sense of place, some communities have developed a strong territorial sense over the 20 years or more they have lived in the area. Loose social control results in possible invasion of areas preserved for future regularization (such as land for public amenities or forested areas), leading to high internal heterogeneity of some settlements. It was decided to maintain the diversity of unauthorized settlements, and the game includes four settlements differing in terms of land tenure, internal heterogeneity, public amenities and water services.

30. See reference 27.

BOX 2
The semi-computerized urbanization dynamics in the Ter'Aguas game model

Representation of the migrants
In each round, two virtual groups of 100 families (GoF) with a given capacity for payment are created by the computer. They have to settle in the area. Players receive a "letter" from each GoF asking for a place to settle. The letter states the group's payment capacity (100 or 50).

Players' land strategies
Players who own land can develop an income-raising activity in each plot provided they can afford the investment cost. Landowners can also do the following: sell their plots to other players (price and payment mode are negotiable); advertise the sale in a virtual real estate agency; or directly sell a plot to a GoF.

As the plots can be purchased in three parcels, landowners can sell the plots at three times the GoF's payment capacity, i.e. a significantly higher price than the average price of the plot (100).

Semi-automated urbanization process (Figure 1)
After the purchase, the plot is virtually divided, self-built and occupied by the GoF. The original land use is transformed into a "popular settlement" whose occupation density is higher than the maximum authorized density, and thus irregular. If a GoF is not offered any plot, the computer allocates it according to Figure 1.

Depending on the number of players, some roles may not be fulfilled. In this case, the virtual landowner(s) randomly offers four plots with natural vegetation for sale in the virtual real estate agency.

Calibration of the initial price of the plots and speculation opportunities
The initial price of a non-built plot in the virtual catchment varies between 80 and 140 according to the following table. The price of a built or cultivated plot is further increased by the price of the buildings or crop ("investment cost").

	Proximity to road	Proximity to urbanized areas	Proximity to a school	Risk of inundation (wetlands close to a river or reservoir)
Modulation of initial price (100)	20%	20%	10%	-20%

As GoFs have a payment capacity of 50 or 100 for each turn and a payment can be completed in three turns, it is possible for a plot to be purchased at a maximum price of 150 or 300 (monthly payments over two to four years is generally the rule in real life). The maximum gain over the market price is thus 375 per cent. Real life gain as observed in three settlements was more than 300 per cent.* Annual return by land use varied from 100 (sand mining), to five (horticulture), to zero (natural vegetation).

The different types of built land use
Built land uses were differentiated by their occupation density, as presented in the following table.

	Density: maximum number of families per plot	Initial land tenure status
Consolidated settlement	150	Regular
Housing project	100	Regular
Popular settlement	100	Irregular
Invasion	200	Irregular

Unlike popular settlements or invasions, a housing project is supposed to strictly follow the legal framework represented by virtual "legal zoning" zones, constraining land uses and maximum occupation density.

Upgrading process
A plot with popular settlement is automatically upgraded into a consolidated settlement (with a higher housing capacity) provided it is regular, included in a settlement with public amenities and has access to both water and sewage collection and treatment.

BOX 2
(Continued)

Infrastructure investment cost

	Water network	Sewage network	Road	School	Health centre	Housing project
Investment cost per plot	200	500	50	1,000	500	4,000

*Bueno, Ana Karina da Silva (2004), "A lei de proteção aos mananciais e mercado de terras: um estudo sobre loteamentos clandestinos", Master's thesis, Instituto de Economia Campinas, Universidade de Campinas, Brazil, 151 pages.

Any player could request the regularization of their plot. This was a decision for the mayor, who was guided in considering settlement density (as a city planning indicator), zoning (environment-specific law) and potential compensation either in the form of a plot or payment.

The focus group underlined the fact that the population of these settlements was more focused on land tenure, an official address, improved housing conditions, household welfare, public transportation, health and education services and security and violence control than they were on water preservation and sanitation. There are many different ways to access water in this headwater catchment, including unauthorized connections to the SABESP network and the use of the many springs that rise here. Tap water is not always perceived as being of good quality because of poor maintenance of house water tanks and infiltration as a result of unauthorized connections. Perception of pollution is limited to its most visible aspects (trash or chemical pollution, for example) and sanitation is often perceived as a mere comfort device. It is rare that inhabitants connect it with health problems or rodent invasion. Lack of an official address is resented because it makes administrative procedures difficult.[31]

31. See reference 3.

Consequently, desirable interventions other than water and sanitation projects have to be proposed, without giving too many options in order to avoid unnecessary complexity. Two public amenities were therefore proposed: a school and a health care centre. Household welfare was addressed through an indicator of unemployment (as a ratio between number of families and number of land uses, each land use providing a certain number of jobs). Social indicators within the municipality (unemployment, number of students per teacher, health) were made available to both the municipality and those players with a strong local connection (as opposed, for instance, to weekend or absentee owners). Information was distributed among players. For example, only the mayor had a complete view of the land uses of the area, while the players only had information on their property. Only the water company had indicators about water quality.

Although other mechanisms such as wetlands management can be mobilized, pollution could only be reduced through the collection and treatment or exportation of domestic effluents (depending on the number of family members) or industrial effluents. Several technological options exist for sewage collection and treatment despite the legislation stating that connection to the SABESP network should be the standard procedure and other options only accepted in isolated settlements. However, public authorities sometimes prefer options that do not involve them financially, such as individual septic tanks, an option resented by the residents who have to finance the full cost and maintenance of a system perceived as sub-par. SABESP also complains that many inhabitants do not connect to their network to avoid connection costs and higher water bills. Various technological options were therefore offered in the game (Table 3) as well as the possibility of sharing costs among the main actors.

b. Differences among players

Apart from the first practice session, all games proved stimulating and entertaining. In the first session, insufficient preparation of the players and a spatial representation too close to reality led to a standstill. The game was then modified and it went well in later sessions. Most players had no problems playing after the first round, although a few needed the second round to participate fully.[32] To avoid problems with illiteracy, help was given to community players in filling out the interface sheet, but not to institutional actors. The latter also did not have the opportunity to discuss the underlying model. Perhaps for these reasons, the assessment found that the game was more challenging for the institutional players than for the community leaders. Their roles were indeed more complex, but also, unlike the community players who felt that their roles were close to their actual situation, the institutional players felt that the game had little connection with reality or at least their reality. Surprisingly, this was true of the sub-committee members who had been involved during the previous six months in the elaboration of the Lei Específica de Guarapiranga focusing on planning management in the catchment area.

Game sessions with and without community representatives were very different. In the three games where community leaders were involved, the negotiations basically revolved around interactions between the big landowner, district representatives and the mayor, and focused on the possibilities of land regularization given the legal constraints of the virtual situation, and possible trade-offs between regularization of unauthorized settlements and development of sanitation infrastructure.

32. Jacobi, P R and S I B Granja (2006), "Monitoramento e análise dos jogos – agualoca e teráguas. Negowat project", PROCAM–USP, São Paulo, 185 pages.

TABLE 3
The different technological options for water services

		Type of option	
WATER	Treated water	Collective	Network connected to adductor, itself connected to treatment station
		Collective	Network connected to isolated deep well
		Collective	Truck supply
	Raw water	Individual	Deep well without network: only for individual undertaking (industry for example)
SEWAGE	Treated	Collective	Network connected to main sewer (exported outside the territory): no pollution
		Collective	Network connected to isolated treatment station: no pollution
		Individual	Septic tank: no pollution
	Only collected		Network not connected to main sewer or isolated treatment station: local pollution release

In these games, the institutional players were particularly attentive to orienting community leaders towards legal aspects (in the form of zoning), but offered many alternatives in public housing settlements or regularization options. Other preoccupations emerged as well, such as minimizing unemployment or attempting to form coalitions between business players and district representatives. Attempts to use the land market mechanisms to organize land uses and occupation also emerged, but unsuccessfully.

By comparison, games with only institutional actors and water technicians were oriented to the municipality/environmental NGO/business trio. Discussions focused on the role of business actors and economic incentives or tools to orient land use and activity development. Surprisingly, legal zoning was used very little as a tool to manage the urbanization process. The district representatives in these institutional games mostly demanded access to potable water and sanitation, while in other games, their demands extended to other aspects such as schools, transportation, security or land regularization. Institutional players playing a district representative role protested less actively than actual community leaders. Big landowners did not demonstrate such a speculative orientation as in community games, and were more cooperative. During the debriefing phase of these institutional games, the players related the weak collective performance related to the lack of environmental policing and control in the game, a role that was intentionally not included because it is so slow and inefficient in real life.

The games resulted in social learning but little change in practices, as indicated in another paper.[33] Capacity development was particularly important for community leaders. Institutional actors who had played with community leaders also reported learning and practice changes. Although at the time they justified their participation as merely the chance to tell community leaders what should be done, a few months after the intervention they mentioned that they were less prone to a top-down approach, more attentive to community positions and points of view and more inclined to develop collective solutions. Participants in institutional games, on the other hand, did not mention significant learning or change in practices apart from the two community members. They came from an already consolidated urban area, and for them the game provided a broader and more detailed vision of urbanization and environmental issues and led to change in practices in their work and interactions with others.

In both types of game, players mentioned that the easy and cooperative meetings between institutional actors and community leaders provided by the games were unlikely to occur in reality. They thought that it would be useful to develop such an approach not only with community leaders but also with grassroots community members.

33. Ducrot, R and V Barban (2008), "From re-vindication to proposition: capacity-building in negotiation about water management in peri-urban areas", in Proceedings of the XIIIth World Water Congress 2008: Global Changes and Water Resources, Montpellier, France, 1–4 September, available at http://wwc2008.msem.univ-montp2.fr/index.php?page=proceedings&abstract_id=78.

IV. DISCUSSION AND CONCLUSIONS

Role-playing games have proved to be more accurate in predicting decisions during conflicts than game theory or unaided judgement.[34] While the small number of sessions precluded drawing firm conclusions

34. Green, K C (2002), "Embroiled in a conflict: who do you call?", *International Journal of Forecasting* Vol 18, No 3, pages 389–395.

from this experience, the emergence of a negotiation pattern (depending on the type of player) seems worth emphasizing.

The new catchment legislation reflects the shift in land policy from legality to legitimacy[35] – as well as an effort to better integrate sectoral policies, institutions and levels of management – in developing sustainable solutions to complex environmental issues in Brazil. However, the strategies deployed during institutional games point to an underestimation of the importance of land tenure issues for communities. Although not incorporated into the formal land market, this type of development is a well-institutionalized and acceptable means of attaining low-cost land and housing in Brazilian cities for a certain sector of the population. But in this protected catchment, the sense of security for the residents is challenged by environmental concerns and the discourse opposing tension between land tenure and water resource preservation. In one community, some individuals retreated from the process when they perceived that the emphasis was on the interactions between settlements and water resource issues and not only on settlement problems. Projects that have only provided access to water and sanitation have not been accompanied by a full sense of security.[36]

Players in the institutional games represented different organizations or office related to environmental concerns. By contrast, in the community games, municipalities were represented by those in charge of land planning. Hence, the environmental perspective was more present in institutional games, although virtual zoning, which underpins the specific law in real life, was comparatively little used and discussed. It is true that the institutional preoccupation of the sub-committee was less the implementation of the law at the local level than at the catchment level, with specific issues related to this scale of intervention not included in the game, for example articulation and coordination between the municipalities.[37]

Negotiations and discussions in each game were of course related to personality, but the difficulty that institutional game players experienced in putting the different land management instruments into action reflects the distance that remains to be bridged between land, environmental and infrastructure perspectives in the catchment area. Similarly, urban planners find it difficult to take into account water management tools – such as the need to work at micro-catchment scale when implementing such recuperation projects as settlement upgrading.[38]

Three main areas of learning resulted from these Companion Modelling approaches, namely the integrated quality of issues, other parties' interests, perspectives and values, and interaction and negotiation.[39] These were reported by participants in community games but not in the first institutional games. Switching roles was only valuable in gaining a better understanding of other parties' interests when this involved direct confrontation between actors. Institutional players clearly underestimated the diversity of demand and the preoccupations of local actors, and assumed that access to water and sanitation infrastructure was their main objective, which was not actually the case. Thus, it only moderately raised technicians' awareness of communities' concerns.

The focus group discussions clearly point to the need to train communities. The lack of environmental education is viewed as a major limiting factor in the development of sustainable solutions and the implementation of legislation.[40] Like participation, it is often oriented more towards paternalistic communication and prescription than

35. See reference 5, Macedo (2008).

36. See reference 3.

37. Ducrot, Raphaèle (2009), "Gaming across scale in peri-urban water management: contribution from two experiences in Bolivia and Brazil", *International Journal of Sustainable Development and World Ecology* Vol 16, No. 1, pages 240–252.

38. Refinetti Martins, Maria Lucia, Luciana Nicolau Ferrara and Isadora Lemos Tsukumo (2007), "A microbacia como unidade de projeto em intervenções de recuperação e qualificação urbano-ambiental na área de mananciais da região metropolitana de São Paulo", Fórum De Difusão Científica Para Inovações De Pesquisa E Extensão – Ciência, Ação Social & Sustentabilidade Da Bacia Hidrográfica Do Alto Tietê, available at http://tietevivo.wordpress.com/microbacias/.

39. Daré, W et al. (2009), "Apprentissage des interdépendances et des dynamiques", in M Etienne

(editor), *La Modélisation d'Accompagnement: Une Démarche Participative en Appui au Développement Durable*, Quae Editions, Paris, 384 pages.

40. Instituto Socioambiental (2008), "Lei específica da Guarapiranga: contribuições para sua compreensão e implementação", Programa Mananciais da Região Metropolitana de São Paulo, available at www.manancíais.org.br/upload_/leiespecificaguarapiranga_isajul08.pdf.

towards understanding and integrating other perspectives and promoting empowerment. This orientation encourages competition between local residents' associations for material advantages from municipalities or other powerful actors. These patron–client relationships are deeply entrenched (and are reflected also in the relationships between leaders and residents). This leads institutional actors to limit the social dimension of solutions to mere support measures for technical processes – whether related to land tenure or access to infrastructure. They often fail to acknowledge how relationships can constrain access to and use of resources made available through public intervention. In the game, equity and fairness were approached through cost-sharing or purchase price. However, this led to overvaluing their economic dimension over the social dimension. Debriefing also indicated that many institutional actors felt insecure with the multi-directional dimensions of the discussions and negotiations during the game, and regretted that it was not organized toward collectively finding one solution. This ideal of dialogic democracy underpins a great deal of policy discourse in natural resource management[41] and often underestimates the political basis of negotiations – lobbying, networking, coercion and political pressure and other countervailing power strategies.

41. Molle, François (2008), "Nirvana concepts, narratives and policy models: insight from the water sector", *Water Alternatives* Vol 1, No 1, pages 131–156.

42. Adamatti, D F et al. (2005), "Jogoman: a prototype using multi-agent-based simulation and role-playing games in water management", CABM-HEMA-SMAGET, Bourg-Saint-Maurice, Les Arcs, France.

43. For example, as some residents have developed an actual sense of place, young couples prefer to settle close to their parents' homes and settlement.

In the game, migrants had no representative. A previous version of the game[42] included one homeless representative with unrealistically great bargaining powers due to the low number of players; and the simplified land market mechanisms meant that most of the blame for the urbanization was placed on him. The parameters chosen in the Ter'Aguas game corrected this bias by allowing explicit speculation processes on a realistic basis. But non-economic determinants of urbanization such as the specific choice of location are not included.[43] Mayors and community players could in theory help accommodate migrants' demands, but they were often too occupied with other tasks to get involved. The landowners' strategy, most often based on economic maximization, favours the urbanization of environmentally unsuitable and isolated plots such as riverside wetlands. This is also the case with the computerized land market process. While the subsequent urbanization pattern is not unrealistic, these settlements are likely to be forgotten in the negotiations between the different players. This may generate a significant bias if the mayor chooses to reallocate these isolated settlements. When newly settled plots are located in the immediate vicinity of an existing district, the player representing that district often includes the new plots in negotiations with other players. But in real life, the heterogeneity of the resulting community's and representative's legitimacy for new residents may prevent such involvement.

44. See, for instance, Winayantia, Lana and Heracles C Lang (2004), "Provision of urban services in an informal settlement: a case study of Kampung Penas Tanggul, Jakarta", *Habitat International* Vol 28, No 1, pages 41–65.

45. See reference 6, Gulyani and Talukdar (2008).

Several studies have indicated that community mobilization around provision of basic services or settlement upgrading enhances social capital.[44] Our field research points out that even within an unauthorized and speculative context, community cohesiveness and fairness in urbanization processes also results in practices with less impact on the environment. This has different implications; to the fourth dimension of "quality of living conditions"[45] should be added the social capital of the community. Improving social cohesion and the political abilities of communities prior to any intervention can contribute to obtaining fairer negotiating terms. In that sense, incremental or integrated programmes can be particularly interesting for improving local ownership and consequently the sense of place.[46] But capacity-building and empowerment interventions for community leaders are not sufficient to change practices without an adequate scaling-up process and the institutionalizing of the learning process, as highlighted by the assessment of the process.

Communities need to better understand the interactions between land use and occupation, the sanitation infrastructure and pollution of *their* drinking water resource in order to get beyond the perceived tension between their housing rights and environmental necessities, and to understand the means by which they can secure a sustainable residence in the area. However, institutional actors must also recognize communities' concerns and how the power-based relationships around land tenure and infrastructure can affect the sense of local ownership and involvement in collective or environmental projects. Only when mechanisms are explicitly acknowledged can they be used for the benefit of all rather than just the few.

Finally, in both types of game, players struggled to take into account the rapid changes typical of peri-urban areas. They paid more attention to social and environmental issues in existing settlements than to accommodating population growth in less damaging ways. This was partially related to the game structure, but it mirrors the real difficulties faced by municipalities and public actors. Since decision makers face diverse and urgent needs that are already difficult to respond to, it is difficult for them to think in terms of future changes. Only a few participants mentioned gaining knowledge regarding these dynamics and the related development trajectories, and they were those who already had an overall vision of the issues. This may suggest that acquiring this vision is a necessary preliminary to integrating change processes.

It is too soon to assess whether the new legislation will succeed in reducing the pollution levels in the catchment area but deadlines have already passed, raising the risk of further legal incompatibilities. A reorientation of urbanization can only be dealt with at the scale of the metropolis, for example by addressing the processes that lead to the decline of inner-city areas and to gentrification. The new legal framework can be an important step towards proposing decentralized and integrated management, operational directives and guidelines, along with some flexibility in the implementation necessary for the sustainability of the metropolis. However, given the complexity of the situation and emerging uncertainties, it also seems important to enhance the learning capacity of all actors and to explore innovative ways of using the relationships between actors for the benefit of all city residents.

46. McGranahan, G, D Mitlin and D Satterthwaite (2008), "Land and services for the urban poor in rapidly urbanizing countries", in George Martine, Gordon McGranahan and Mark Montgomery (editors), *The New Global Frontier: Urbanization, Poverty and Environment in the 21st Century*, Earthscan, pages 77–98; also Van Horen, B (2001), "Developing community-based watershed management in Greater São Paulo: the case of Santo Andre", *Environment and Urbanization* Vol 13, No 1, April, pages 209–222.

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