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Environmental inducers of schistosomiasis mansoni in Campinas, Brazil

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Abstract. Human occupation/activity in the suburbs of the large cities in Brazil, together with high social vulnerability associated with poor living conditions, influence the dynamics of schistosomiasis mansoni as well as several other emerging and re-emerging diseases. Previous notification data surveys for Campinas, São Paulo state, Brazil, carried out by the Information System for Notification Disease, show that there are distinct prevalence differences across health-care districts of the city. This paper supports the hypothesis that the distribution of schistosomiasis is not random and that the centralized location of cases are linked to human behaviour, in particular to human activities that interfere with basic landscape structure. This paper analyzes the spatial patterns of the parasitic worm *Schistosoma mansoni* and its intermediate host *Biomphalaria* comparing disease prevalence with natural conditions and the current pattern of territory occupation by the population. The spatial and hierarchical distribution of factors related to the environmental conditions and land use that indicate the risk for schistosomiasis has been surveyed. It was found that landscape characteristics define the areas at risk for this endemic disease and, as a result, a risk map comprising different risk classes was established. This risk map highlights the regions prone to become new foci for infection or that serves to maintain an existing focus. The research approach used attempts to introduce "geotechnology", i.e. a social application in which better knowledge about these foci, designated endemic "hot spots" can assist preventive public intervention measures in a way that is inexpensive and easy to handle.

Keywords: schistosomiasis, risk, inducers, landscape ecology, geographical information system, Brazil.

Introduction

Schistosomiasis is a major parasitic disease relying on water for its transmission accommodated by freshwater intermediate host snails. Since humans depend on access to water, urban settlements run the risk of contributing to its spread. Several authors have pointed out that the progress and dissemination of schistosomiasis in the Brazilian cities are related to space occupation and organization, social vulnerability and domicile, which all play a role in the propagation process of this endemic disease (Lima, 1995; Katz and Peixoto, 2000; Coura and Amaral, 2004). The metropolitan region of Campinas, São Paulo state, Brazil, is a good example since it has been suffering for a long time from a chaotic urbanization process. This has led to a situation where occupation of peripheral areas of the city (the suburbs) prevails as the dominant demographic scenario, a trend interfering with the control of intra-urban transmission of various endemic diseases (Lima, 1993; Martelli, 1995).

In the past, there was a supposition that migration was the most important cause in the dissemination and transmission of schistosomiasis in the city of

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Campinas (Piza and Ramos, 1960), obfuscating the influence of other factors. Today, there is clear evidence that the mere introduction of an individual with a high parasite load in a given area is not enough to establish a disease focus since transmission requires a combination of different factors (Jordan and Webbe, 1982). Examples include lack of sanitary conditions, occupation of river banks and presence of locations favourable for breeding sites of the intermediate snail host. Some man-made, environmental changes influence schistosomiasis transmission, and prevalence may increase or decrease depending on the type of change. This happens when the change alters the lifecycle of the parasite and the living conditions of the host. A clear understanding of how natural disturbances and perturbations induced by human influence the parasite-host relationship enables healthcare technicians to anticipate location, abundance and transmission of parasites for vulnerable host species (Anaruma Filho et al., 2007; Mckenzie, 2007).

This study supports the hypothesis that the investigation of a disease such as schistosomiasis mansoni requires the identification of the ecological components related to the disease transmission. These factors can be obtained by prior knowledge of the biology of the agents involved and of the elements in the landscape which relate to the lifecycle of this organism. Regarding this line of investigation, some premises of landscape ecology is an effective path to indicate spatio-temporal relations among environmental elements and their connectivity. Thus, relationships such as these could be instrumental in identifying areas with high transmission and considerable risk for infection, i.e. endemic "hot spots". However, the mapping of disease and risk requires geographical information system (GIS) tools such as capture, storage, handling, analysis, demonstration and reporting of geographically referenced data. In addition, the utilization of GIS in health-related research promotes higher speed in spatial data flow, enables the identification of factors and risk areas and assists in the outlining of control strategies by orienting more accurately the interventions suitable for a given endemic disease (Beck et al., 2000; Correia et al., 2004; Chaves and Rocha, 2006; Gazzinelli and Kloos, 2007). Within this context, the search for a relation between the pattern of land use and its role in inducing disease might be a significant contribution to the understanding of the schistosomiasis dynamics in a particular area. This work aims to identify potential risk areas by surveying the spatial and hierarchical distribution of factors that induce schistosomiasis mansoni with special emphasis on landscape ecology. The results should eventually support environmental planning concerned with the prevention, monitoring and control of the disease.

The city of Campinas was selected as study area and model due to its current low level of endemicity for schistosomiasis. Previous studies have shown that schistosomiasis is not distributed in a homogenous way in the population and it was neither directly related to the low socio-economic index, nor to the lack of basic sanitation commonly related to endemic disease dynamics in Brazil (Lima, 2000). Health managers still do not know exactly what the ecological factors that provide this heterogeneous distribution are. According to information from the Authority Supervising Endemic Disease Control (SUCEN), the snail breeding sites in Campinas are found in all healthcare districts. However, Lima (2000) observed that the schistosomiasis distribution is not as random as it appears and that the centralizing locations of cases are related to human activities, in particular those that interfere with the basic structures of the landscape. According to data available from the Information System for Notification of Disease in Brazil (SINAN), the mosaic structure of Campinas, the South Healthcare district, may contribute to the higher number of schistosomiasis mansoni cases reported from January 1998 to August 2005 (Fig. 1). Thus, this district was chosen as a sampling area (Fig. 2). The city of Campinas has 1,039,297 inhabitants spread over a total area of 796 km^2 (Brazil, 2009). The South Healthcare district has 276,578 inhabitants and covers approximately 130 km^2.

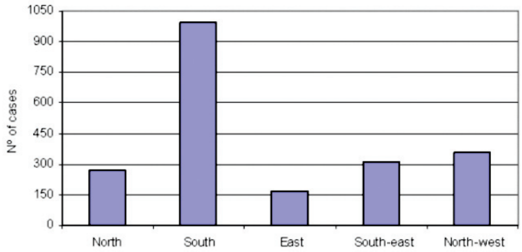

Fig. 1. Schistosomiasis mansoni cases reported by SINAN, from 1998 to 2005, in the healthcare districts of Campinas, São Paulo, Brazil.

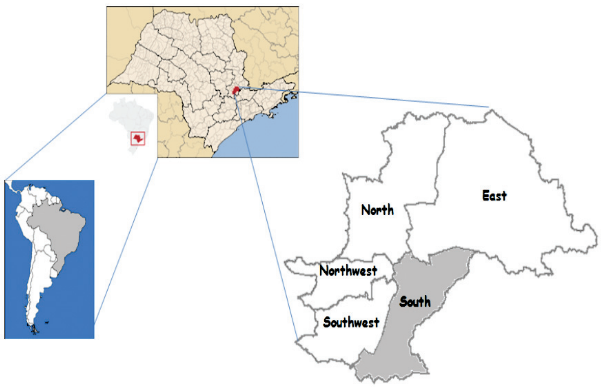

Fig. 2. The geographical situation of Campinas, São Paulo, Brazil with the division by healthcare districts, highlighting the South district.

Materials and methods

To evaluate possible relations between the characteristics of landscape occupation patterns and their capacity to contribute to schistosomiasis, disease inducers were identified by bibliography, which expresses conditions related to the presence and maintenance of breeding sites and disease foci. Based on the Batelle method logic (Dee et al., 1973), all inducers received a value (from 1 to 10) as a function of the relative importance of the criterion for acquiring the disease. Due to the possibility of errors arising from information generalization, insufficient information gathered or error of interpretation, these values were in turn corrected (between exponential values from 0.1 to 0.3) according to the degree of information confidence achieved in the field. Seven professionals from the fields of landscape, health and earth sciences received a checklist of 62 disease inducers and asked to assign a value to each, calculating the averages to obtain final scores.

In order to identify and represent the spatial distribution of the disease inducers related to the landscape, a base-map was plotted with the free GIS software SPRING 5.0 (Câmara et al., 1996). Data were obtained from planimetric maps of the São Paulo Metropolitan Planning Company (EMPLASA) for the year 2001, scale 1:10,000; planialtimetric maps of the Geographical and Cartographical Institute (IGC) for the Metropolitan Region of Campinas for the year 2005, scale 1:10,000; and different layers in *Shapefile* format, provided by the Campinas City Hall. The information provided by these maps includes hydrography, topography, roads and urban zone delimitation.

The parameters that contribute to or hinder the occurrence of *B. glabrata* breeding sites and schistosomiasis mansoni foci (Table 1) were mapped using the SPRING software and based on the aerial photographs provided by Campinas City Hall for the years 2002 and 2005. Viewing scales between 1:3,000 and 1:5,000 were chosen as this was the level of detail required for the targets selected as indicators. Bibliographical data and maps of the region produced by SUCEN and the Planning, Development and Environment Secretariat of Campinas City Hall (SEPLAMA) supported by images from Google Earth free software (http://www.earth.google.com) as interpretation support. Data related to pollution by urban waste were obtained by interpreting occupation patterns and by basic sanitation data from the census for the year 2000 from the Brazilian Institute for Geography and Statistics (IBGE) (Brazil, 2001). These data appear in the legend of the maps as "sewage disposal", "sewage without disposal" or "direct sewage discharge into the river".

For the purpose of localization and assignment of values for the disease inducers, i.e. preferred locations in water streams and ponds used for human activities (bathing, sporting, fishing, dish washing as well as presence of water springs and small garbage dumps), 15 interviews were carried out with residents and health technicians from public institutes. The number of interviews varied according to the location and the number and availability of people to interview. They were therefore not treated as representative, significant values in statistical terms but used as a general trend measure of risk for disease. Six visits were made to the field in order to confirm the map of disease inducers by observing success and mistakes in the recognition of land use patterns. The control points were achieved with a global positioning system (GPS) (Trimble - GeoExplorer II) equipment. After the spatial distribution of the inducing factors, seven professionals defined their importance in relation to disease. As a consequence, a risk value was obtained for each map polygon, according to the equation:

$$R_{pn}= \sum [(IR_n)^c]$$

where: R_{pn} is the risk of occurrence of schistosomiasis mansoni in polygon n, IR_n the relative importance of the incident inducer and the exponent ^{c} the information confidence degree.

The risk factors R_{pn} were groped at five levels (very high, high, medium, low and very low) and the map was accordingly reclassified. This map expressed the potential of the area for the occurrence of new cases of schistosomiasis mansoni. To verify the accuracy of the map, two layers were built with annual data for: (i) the distribution of *B. glabrata* collection stations (carried out by SUCEN - Campinas); and (ii) the distribution of locations with evidence of schistosomiasis transmission (evaluated by SUCEN - Campinas). This subsequently information was added to the risk map.

From a database provided by SINAN, all the reported schistosomiasis cases, from January 1998 to August 2005, of individuals with complete and fixed addresses were georeferenced (for each year) and the data plotted on the base-map using the SPRING software. A loss of 62% of reports was experienced, basically due to incomplete or incorrect filling-in of the registration forms that comprise the SINAN database. Thus, it became necessary to: (i) map the individuals with domicile perfectly localized; and (ii) use all the other registration forms by separating them by neighbourhood and putting them on the centroid point of each neighbourhood. The domicile was localized over the map of addresses with their respective land lots, scale 1:10,000. The domiciles were plotted as points centered on the front line of the land lots.

The evaluation of data for SUCEN Campinas, related to the sampling stations of *B. glabrata* and transmission foci, revealed imprecision in their punctual localization. Thus, it was necessary to make a map to design the sampling stations and transmission focus as polygons; in other words, the delimitation of the places that encompass the presumable area of occurrence.

Results and discussion

Table 1 provides a general chart of disease inducers for schistosomiasis mansoni, which may be applied to any region characterized as endemic for the disease. Sixty-one inducers, expressing conditions related to the presence and maintenance of breeding sites or disease focus, were identified. Among the inducers described in the literature, only 23 were identified in the study area (Table 2 and Fig. 3). Among them, agricultural activities, sewage discharge into the river and presence of ponds were found to be correlated to increased risk.

Agricultural activities represented coverage of 13.0% of the total study area. The district is characterized as a concentration of several small familiar properties distributed in three subsets in the south-west, sout-heast and north-east regions of the study area and aimed at cultivation of fruits and vegetables. The arrangement of the elements is peripheral to the urban area.

In the region of Campinas, some agricultural practices require different ways of storing water for

Table 1. Disease inducers that favour the formation and maintenance of breeding sites or schistosomiasis foci.

Inducer group	Inducer number	Type of inducer	Relative inducer importance	Degree of reliability (weight)	Transmission evolution
Annual and subsistence agriculture	1	Irrigated rice plantation	8	0.3	Cultivation → aggradations and puddle creation → higher probability of breeding site formation Cultivation → water impoundment for irrigation → snail fixation, feeding, shelter and reproduction → higher probability of breeding site formation
	2	Dry rice cultivation	2	0.3	
	3	Sugar cane plantation (ethanol production)	1	0.3	
	4	Onion cultivation	5	0.3	
	5	Bean cultivation	1	0.2	
	6	Cassava cultivation	1	0.2	
	7	Corn cultivation	1	0.2	
	8	Sorghum cultivation	1	0.2	
	9	Tomato cultivation	4	0.3	
	10	Soybean cultivation	1	0.2	
	11	Vegetable/strawberry cultivation	6	0.3	
	12	Flowers/vivarium	5	0.3	
	13	Chayote plantation	3	0.3	
Semi-annual or perennial agriculture	14	Coffee (dripping)	5	0.2	Cultivation → aggradations due to soil movement → increased puddle creation → higher occurrence of breeding sites Cultivation → water impoundment for irrigation → snail fixation, feeding, shelter and reproduction → higher occurrence of breeding sites
	15	Banana plantation	4	0.3	
	16	Avocado plantation	1	0.1	
	17	Persimmon plantation	2	0.1	
	18	Grape plantation	2	0.1	
	19	Fig plantation	2	0.1	
	20	Guava plantation	2	0.1	
	21	Citrus plantation	3	0.2	
	22	Mango plantation	2	0.1	
	23	Passion fruit plantation	2	0.2	
	24	Peach plantation	2	0.2	
Permanently or occasionally flooded areas	25	Swampy area	8	0.3	Water depth → snail fixation, feeding, shelter and reproduction → frequent human water contact → higher occurrence of breeding sites
	26	High density of people (fishing point, local information and footprints on river banks, etc.)	8	0.3	
	27	Medium density	6	0.3	
	28	Low density	4	0.1	
Natural meanders and canals	29	>0.3 m/s	5	0.2	Water flow less than 0.3 m/s → higher occurrence of breeding sites
	30	<0.3 m/s	9	0.3	
Artificial channels for carrying water and trenches for irrigation	31	High density of people (fishing point, local information and footprints on channel/trench banks)	9	0.3	Minor channel inclination → slow water flow → vegetation growth → snail fixation, feeding, shelter and reproduction → frequent human water contact → higher occurrence of breeding sites
	32	Medium density	8	0.3	
	33	Low density	6	0.1	

Continued

Inducer group	Inducer number	Type of inducer	Relative inducer importance	Degree of reliability (weight)	Transmission evolution
Straightened meanders	34 35	>0.3 m/s <0.3 m/s	5 8	0.2 0.3	Water flow less than 0.3 m/s → higher occurrence of breeding sites
Habitats near water streams likely to be contaminated with human waste	36 37 38	With sewage disposal Sewage without disposal, but with septic tank Direct sewage discharge in the river	1 6 9	0.3 0.2 0.3	Sewer → faeces with *S. mansoni* eggs → water contact → major disease focus
Fish farming ponds	39 40	With vegetation Without vegetation	6 4	0.2 0.2	Water → certain fish species → snail predation → minor breeding site formation
Aggraded or shallow pond	41	Ponds with the presence of floating aquatic vegetation or macrophytes (water plants) fixed at the bottom	9	0.3	Water → floating aquatic vegetation or macrophytes → shelter and substrate for snail fixation, feeding and egg laying → major breeding site formation
Lakes or water streams used for sports, fishing, dishwashing and bathing	42 43 44	High density (local information, footprints on river banks, field on hot weather holiday) Medium density Low density	9 6 5	0.3 0.3 0.2	Water → human access → faecal contamination → human water contact for large areas of the body for extended periods of times → major disease focus
Presence of water springs or spouts	45 46	With trampling Without trampling	8 7	0.3 0.2	Water → areas of human and animal trampling → puddle formation → snail attraction point → human water contact → major disease focus
Swamp	47	Flooded lowlands with or without abandoned meanders	6	0.3	Water → puddle creation → snail attraction point → major breeding site formation
Sandy deposits close to rivers, without vegetation	48 49	Water speed >0.3 m/s Water speed <0.3 m/s	2 4	0.3 0.3	Sand → minor occurrence of snails → minor breeding site formation Sand → place without vegetation → easy water contact point → higher contact with water (leisure) → focus formation

Continued

Inducer group	Inducer number	Type of inducer	Relative inducer importance	Degree of reliability (weight)	Transmission evolution
Human activities close to water streams	52	Sand port	4	0.2	Water → human contamination → water contact point → major disease hotspot
	53	Dishwashing place	9	0.2	
	54	Sports	9	0.2	
	55	Bathing	9	0.3	
	56	Fishing	9	0.3	
	57	Pump for irrigation/domestic use	5	0.3	
Preparation of agricultural areas	58	Agricultural preparation area	3	0.1	Soil preparation → source of aggradations and creation of puddles → more breeding sites
Vegetation coverage	59	Riparian forest and forest fragments	4	0.2	Deforestation → aggradation of stream beds → water overflow → creation of puddles → more breeding sites
	60	Reforestation (*Pinus* or *Eucalyptus*)	2	0.2	Cultivation → source of aggradations and creation of puddles → more breeding sites
	61	Successional stage start area	5	0.2	

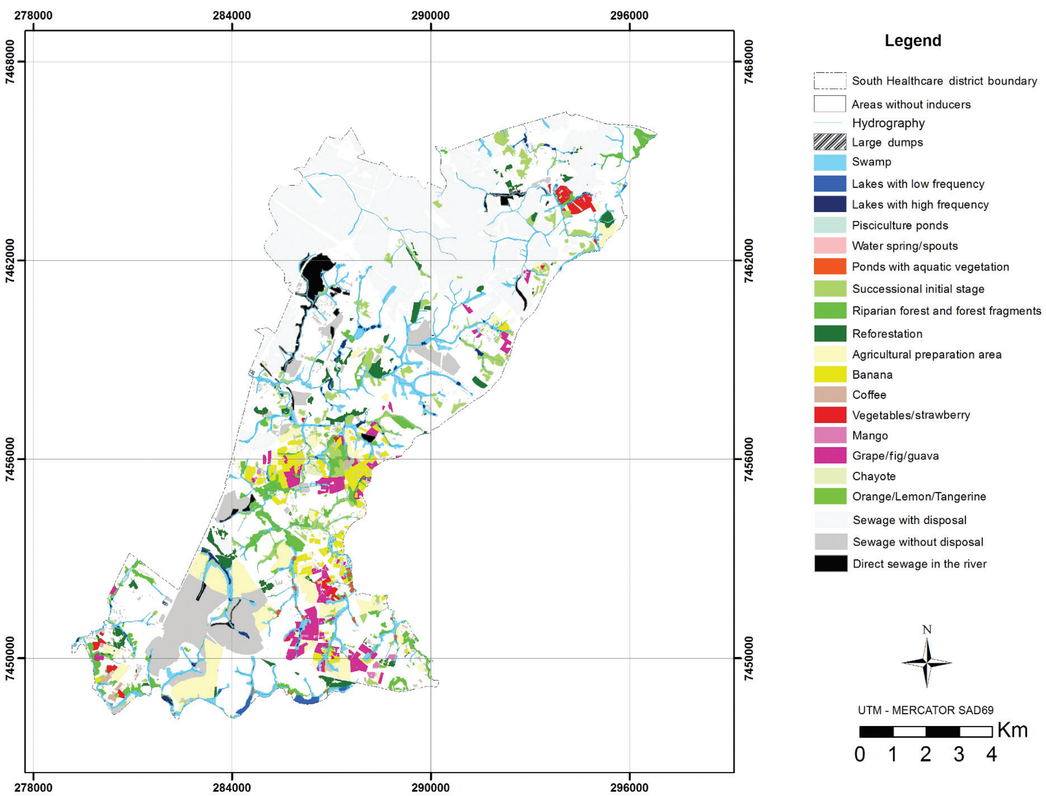

Fig. 3. Map of disease inducers that contribute to the formation and maintenance of breeding sites or foci for schistosomiasis mansoni in the South Healthcare district of Campinas, São Paulo, Brazil.

irrigation with varied consequences for the generation of *B. glabrata* breeding sites or schistosomiasis foci. Poorly managed agriculture frequently leads to soil erosion, river aggradations (sediment deposition) and macrophyte establishment (aquatic plants rooting in the sediment) causing reduction of the speed of water flow and thus favouring snail propagation. Scenarios like these, together with lack of basic sanitation, are key point in the schistosomiasis transmission dynamics in the city. Agricultural areas should therefore receive special attention in terms of destination of their domestic sewage to prevent the pollution of downstream areas as a prophylactic measure with regard to this disease.

Sewage collection and disposal are performed by the use of a general sewage system, a sewage system without separation (septic tank) and *in natura* discharge into water bodies. In the Mosaic of the South Healthcare district, sewage collection and disposal are only available in 34.7% of the area. Thus, only a third of the district has a lower risk of acquiring the disease. Domiciles that have a septic tank totaled an area of 10.9%. Although these areas are of minor relative importance in relation to the risk, there is the possibility of water body contamination in the surroundings due to overflow of poorly structured septic tanks (Table 2 and Fig. 3). Locations with domiciles that discharge their sewage directly into the water bodies comprised 1.3% of the study area, and thus have a large epidemiological importance, as they

Table 2. Inducers of *B. glabrata* breeding sites and schistosomiasis foci found in the Mosaic of the South Healthcare district in the city of Campinas, São Paulo, Brazil.

Inducer number	Inducer	Area (ha)	Coverage (%)[a]	Class of risk
22	Mango cultivation	15.1	0.1	Very low
20	Guava cultivation	37.6	0.3	Very low
18	Grape cultivation	119.5	0.9	Very low
19	Fig cultivation	139.1	1.1	Very low
60	Reforestation	276.0	2.1	Very low
58	Agricultural preparation	658.0	5.1	Very low
36	Sewage with disposal	4,425.5	34.7	Very low
21	Citrus cultivation	7.6	0.1	Low
13	Chayote cultivation	20.7	0.2	Low
14	Coffee cultivation	22.4	0.2	Low
59	Riparian vegetation	391.3	3.0	Low
61	Successional, initial stage	497.6	3.8	Low
47	Swamp	853.6	6.6	Moderate
40	Fish farming without vegetation	13.2	0.1	Moderate
15	Banana cultivation	307.3	2.4	Moderate
50	Debris with access	3.6	0.0	High
11	Vegetables/strawberry	88.6	0.7	High
44	Low leisure pond	33.8	0.3	High
37	Sewage without disposal	1,413.2	10.9	High
45	Water spring with trampling	7.1	0.0	Very high
41	Pond with water plants	24.5	0.2	Very high
42	Pond for leisure with high density	138.8	1.1	Very high
38	Direct sewage discharge in river	173.8	1.3	Very high
	Total number of inducer areas	9,668.1	75.1	75.1
	Total number of areas without risk	3,228.8	24.9	24.9
	Total area of healthcare districts	12,996.9	100.0	100.0

[a] Percentage of inducer in relation to the area of the Mosaic of South Healthcare district.

increase the risk to the environmental health, both in their surrounding areas and downstream.

Figure 4 provides a risk map, which includes the various inducers in the landscape (Table 1), valued from the weighs estimated by the risk equation above and classified according to Table 3.

The analysis of risk in the Mosaic of the South Healthcare district disclosed a clearly distinctive distribution pattern. The areas (polygons) defined as "very high" risk, many times characterized by small territorial portions, were primarily associated with river banks that cross districts and water reservoirs located in farms close to populous regions, thus forming corridors associated to a watershed. An example of this pattern is the area surrounding the Bradesco farm (Fig. 5).

Areas with "very high" risk corresponded to regions most favourable to transmission of schistosomiasis mansoni in the Mosaic and they are thus the ones with higher priority of intervention by the public institutions. In some of the regions identified as "very high" risk, no transmission focus were in the SUCEN report and no domiciles were found with cases reported to SINAN, probably because they are isolated or distant from the more populous neighbourhoods. However, this result does not invalidate the need for immediate intervention since all other requirements for the schistosomiasis transmission cycle were found there. The arrival of individuals with active schistosomiasis in this environment is probably the key to transform an endemic "hotspot" into a new disease focus.

The regions considered as "very high" are few. They have small territorial proportions (0.1 - 2.9 ha), mainly used for cultivation of vegetables and characterized by presence of areas with debris dump. These places

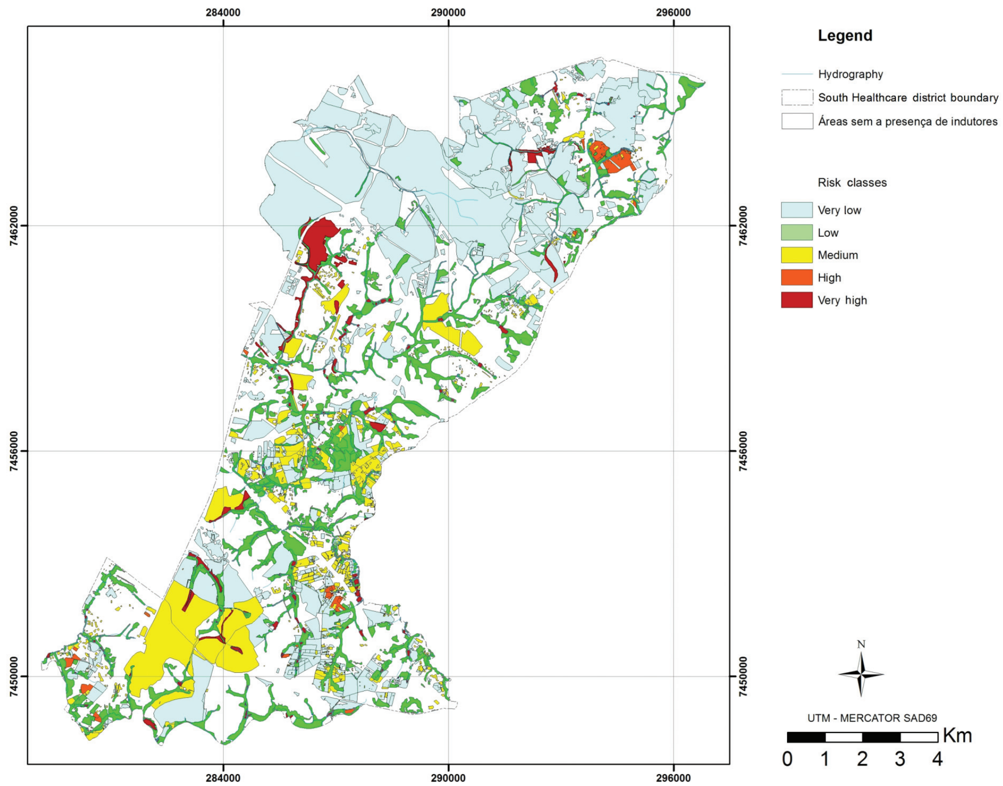

Fig. 4. Map of risk classes of schistosomiasis mansoni foci and *B. glabrata* breeding sites in the Mosaic of the South Healthcare district, Campinas, Sao Pãulo, Brazil.

Table 3. Classes of polygons with regard to risk and corresponding intervals.

Risk classes	Interval	
Very low	>1.0	≤1.2
Low	>1.2	≤1.4
Medium	>1.4	≤1.6
High	>1.6	≤1.8
Very high	>1.8	≤2.0

are predominantly distributed south of the district in Campo Belo, Helvetia, east of the Bandeirantes highway and to the north, close to Jardim Nova Morada representing a total area of 24.6 ha.

According to the strategy adopted in this study, the risk does not proceed directly from land use that may be observed, but from the summation of disease inducers that occur at one point because of the particular characteristics of that place. With the perspective of method application, the proposal to the public institutions is that these patterns need to be monitored throughout the city since they are the variables that generate higher risk. Thus, it is important that any endemic "hotspot" found receives special attention and is immediately addressed by:

(i) execution of a control and monitoring programme;
(ii) intervention with regard to landscape "inducer characteristics"; and
(iii) strengthening of the "primary attention" aspect.

The basic healthcare units close to these locations must be informed and their agents trained for prompt intervention on suspicious schistosomiasis cases. In synthesis, this study suggests that maps of the endemic hotspots could help in the control or elimination of the endemic disease in the city.

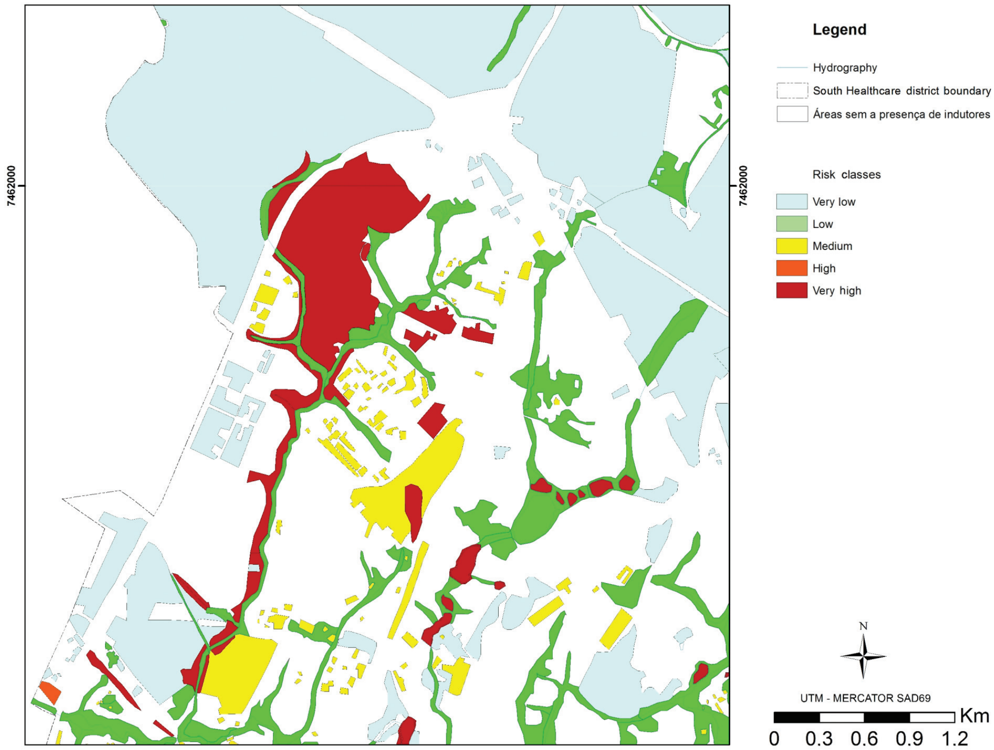

Fig. 5. Map of the South Healthcare district, representing "high" and "very high" hazardousness areas for *B. glabrate* breeding sites or schistosomiasis mansoni foci in Campinas, São Paulo, Brazil. Detail of the Bradesco farm with populous districts close to several water reservoirs.

By using a 5-level classification of disease inducers, we confirmed that the "moderate", "high" and "very high" classes pointed to areas with conditions at particular risk for the occurrence of new schistosomiasis cases. The inducers rated as "low" and "very low" risk, on the other hand, led us to areas with unfavourable conditions for the transmission cycle, thus showing that these locations do not require a high need for immediate public intervention. When overlapping historic information related to the *B. glabrata* collection stations and schistosomiasis foci, as assessed by SUCEN (Fig. 6), was consulted, this study confirmed that, in spite of lack of high accuracy in the localization of these points[1], the risk areas rated as "high" and "very high", most of the time were located within, or very close, to the districts where there was any collection station or a focus. This observation suggest reasonable accuracy in the risk map due to the correlation between the probable occurrence, expressed by the map, and effective occurrence in the field according to the SUCEN data.

[1] The distribution of schistosomiasis cases reports by SINAN cannot be used to check the accuracy of the risk map because the likely place of infection was not reported but only the domicile of the individual infected by the parasite. However, it is evident that the overlapping of reported cases with the areas with favourable conditions for disease results in locations with higher probability of risk since these individuals play the role of infection source. These patients received treatment but there is evidence that many refused taking the drug. Leite and Vasconcellos (2003) argued that the absence of signs and symptoms of disease, such as in the case of schistosomiasis in areas with low endemicity, are factors that lead a great part of the infected individuals to refuse appropriate treatment.

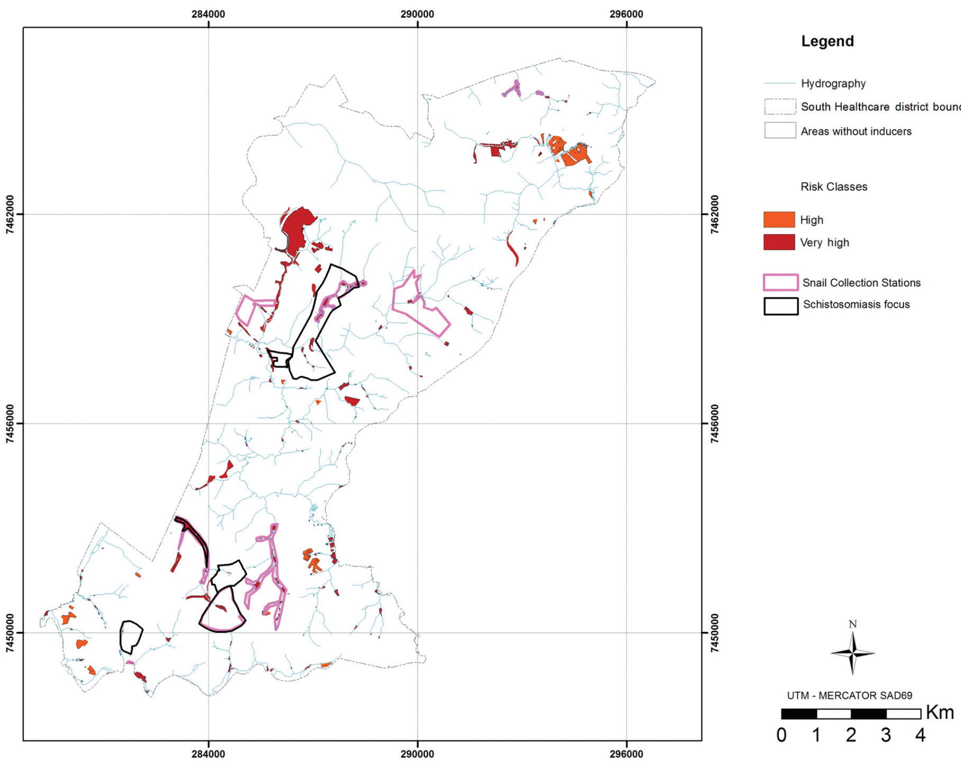

Fig. 6. Snail collection stations and areas with schistosomiasis focus, both surveyed by SUCEN from 1998 to 2005, overlapping with the "high" and "very high" risk classes in the Mosaic of the South Healthcare district in Campinas, São Paulo, Brazil.

Since the risk maps, produced according to the proposed methodology, are capable of pinpointing schistosomiasis "hot spots", they should be useful as guides for public preventive interventions. Thus, the risk-maps facilitate the implementation of simple and cost-effective actions that would effectively hinder completion of the parasite lifecycle, and thus the continuity of the disease, significantly reducing public expenses.

The following conclusions emanate from the present paper:

(i) the methodological proposal was found to be appropriate in the spatial and hierarchical distribution of inducing factors of schistosomiasis mansoni;

(ii) among all the disease inducers evaluated, the ones rated in the "low" and "very low" risk classes might be excluded in future risk mapping in similar studies;

(iii) as a prophylactic measure to combat schistosomiasis in downstream areas, agricultural areas must be frequently monitored in terms of sewage disposal;

(iv) it is proposed that regions with concentration of risk areas rated as "moderate", "high" and "very high" be named *endemic hotspots* and be subjected to control and monitoring and it is suggested that they also receive intervention, whenever required, as guided by the inducing characteristics of the landscape and the local "primary attention" be strengthened; and

(v) it was possible to represent potentialities, weaknesses and risk conditions by overlapping an extensive dataset using GIS, which could help controlling schistosomiasis in Brazil.

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