Environmental Threats and Childhood Fever during the Rainy Season in Dakar-Senegal: Results from Multilevel Models

Stephanie Dos Santos[1], Iulia Rautu[1], Jean-Yves Le Hesran[2], Mody Diop[3], Abdou Illou Mourtala[4], Alphousseyni Ndonky[5], Richard Lalou[6]

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[1] Institut de Recherche pour le Développement, Laboratoire Population-Environnement-Développement, BP 1386, Dakar, Senegal.
[2] Institut de Recherche pour le Développement, Unité mère et enfant face aux infections tropicales, Faculté de pharmacie, Laboratoire de parasitologie, 4 avenue de l'Observatoire, 75270 Paris cedex 6, France.
[3] Agence Nationale de la Statistique et de la Démographie, BP 116, Point E, Dakar, Senegal.
[4] Ecole Nationale de la Statistique et de l'Analyse Economique, BP 45512, Fann, Dakar, Senegal.
[5] Département de Géographie, Université Cheikh Anta Diop, Fann, Dakar, Senegal.
[6] Institut de Recherche pour le Développement, Laboratoire Population-Environnement-Développement, Université de Provence, 3 place Victor Hugo, 13331 Marseille cedex 03, France.
Corresponding author : Dr Stephanie Dos Santos, Institut de Recherche pour le Développement, Laboratoire Population-Environnement-Développement, BP 1386, Dakar, Senegal. Stephanie.DosSantos@ird.fr

Introduction

In African cities, a major cause of childhood fevers are water-borne diseases, such as typhoid, or water-related diseases, in particular mosquito-borne pathogens such as malaria, dengue and other arbovirus diseases. Such diseases are a major problem in African cities, being the leading cause of child outpatient visits and deaths.

The occurrence of childhood fever is a multifactorial process, related to people, to household and to environmental neighbourhood factors.

As for factors favoring transmission of mosquito-borne fevers in cities of Sub-Saharan Africa, characteristics related to both the household level and the neighborhood level can influence the presence of vectors and therefore the risk of disease.

At the household level, aspects related to house construction quality and condition may favor or impede vector presence. Such aspects as openings, unscreened windows and eaves can facilitate the entering of mosquitoes inside the compound, while cracks and crevices in walls serve as hiding places (S. W. Lindsay et al., 2002; Konradsen et al., 2003; Robert et al., 2003; Yamamoto et al., 2010; Yusuf et al., 2010). Characteristics referring to salubriousness also play an important role, by means of water storage inside the compound (Tsuzuki et al. 2009). The role of protective measures is somewhat disputed. On the one hand, protective measures in general – and long-life treated insecticide nets in particular – have long proven their efficiency (Snow et al. 1988). On the other hand, studies have shown that the use of such measures is highly dependent of mosquito nuisance, which is a function of the vector's density (Thomson et al. 1994; Chavasse et al. 1996; K. Yohannes et al. 2000). Therefore, the use of protective measures is not equally distributed in the whole population.

At the neighborhood level, the presence of wetlands in the area is amount the chief factors which increase the risk of mosquito-borne diseases. Such wetlands may be either natural or man-made, though the former are less prevalent in urban areas. Market-gardens equipped with wells, constitute a favorable environment for mosquito larvae (Pages et al. 2008; Robert et al. 2003). Urban farming can also favour vector reproduction, by means of the man-made water bodies used for irrigation (Ghebreyesus et al. 2000; Matthys et al. 2006; Van Benthem et al. 2005). Mosquitoes have been found to breed successfully in (fish) ponds, flood plains and irrigated fields, since they constitute stagnant waters (Elston 2005; Keiser et al. 2005; Peterson et al. 2009). If present, natural wetlands – such as swamps and streams – also increase the risk of disease (Matthys et al. 2006; Robert et al. 2003; Staedke et al. 2003).

It is thus clear that urban mosquito-borne fevers are highly diverse, both in terms of transmission and prevalence, and cases tend to cluster near mosquito breeding sites (Peterson et al. 2009; Staedke et al. 2003; Sutherst 2004).

Even though previous authors have already shown the theoretical existence of a relationship between environmental threats and child health, the complex processes underlying this association still remain poorly highlight by empirical evidence, in Africa in particular. Apart from the individual and household characteristics, environmental factors at both the household and the neighborhood level can have an influence on those fevers especially during the rainy season The objective of this communication is to identify environmental threats associated with fever occurrence in children in Dakar, the capital-city of Senegal using a multi-level approach.. After presenting the conceptual framework, the contexts are described. We briefly discuss the data and the statistical methods used before presenting the results. Finally, we discuss the limitations of our approach as well as future developments for its improvement.

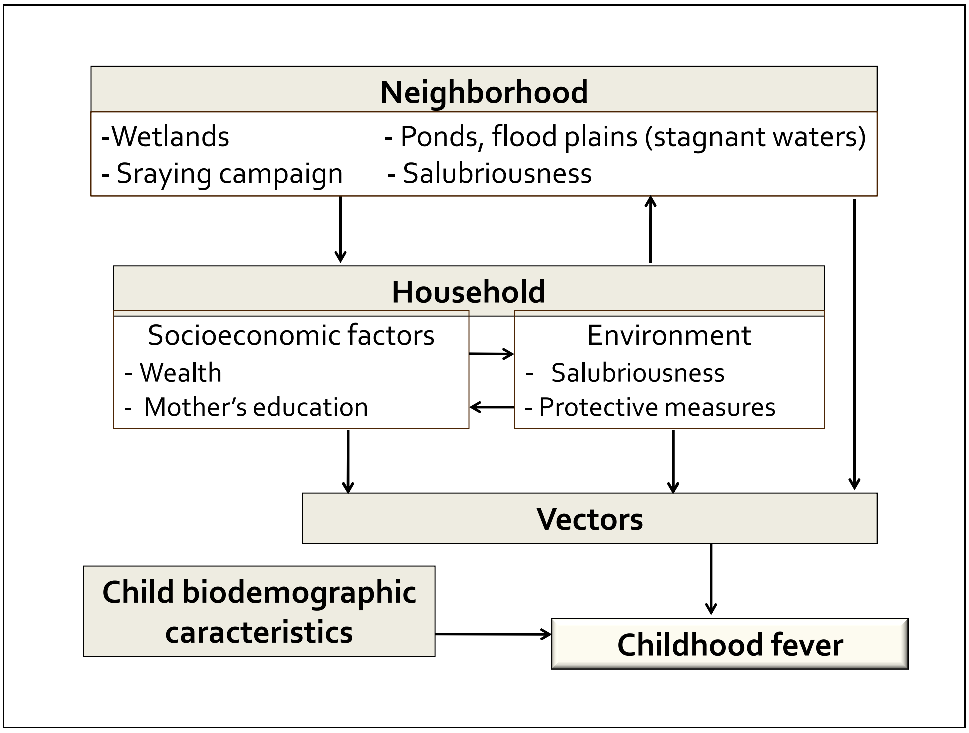
Conceptual framework

Numerous factors play a part in child health differentials. These are manifested at the level of the individual. But other contextual factors should be considered when investigating the associations of disparities with health outcomes (Holmes et al. 2008, Merlo 2003), and neighborhood effects in particular (Subramanian 2004). Long before, Mosley and Chen (1984) were among the first to theorize the environmental factors such as intermediate biomedical factors affecting child mortality, named `proximate determinants'.

In Sub-Saharan Africa, although numerous cases of fever in children during the rainy season are caused by vectors, the web of determinants for those fevers is still a complex one. The relative contribution of each factor varies, as a function of complex interactions between environmental characteristics pertaining to both the household level and the neighborhood level. The figure 1 presents a tentative conceptual framework to understand this complexity.

At the household level, aspects related to house construction quality and salubriousness or protective measures may favor or impede vector presence. At the neighborhood level, the presence of wetlands in the area is among the chief factors which increase the risk of mosquito-borne diseases. Ponds, flood plains can also favor vector reproduction since they constitute stagnant waters.

Figure 1 – The web of factors of the relationship between environmental threats and childhood fever



Studies performed by conventional single level analytical methodologies have been seriously criticized, primarily because they fail to consider the existence of a multilevel structure when analyzing childhood fever in different environment (that is children nested in household, nested in neighborhood. Single level analyses underestimate statistical uncertainty and lead to inappropriate conclusions, providing an unsuitable basis for decision making. A single level analysis is unable to discern whether the observed variation in childhood fever is attributable to individual differences between children, or to the influence of environmental factors related to both the household level and the neighborhood level. Multilevel analysis is today considered a more appropriate way to monitor environmental health, as it allows a less biased estimation of uncertainty, and can also separate and quantify contextual effects (Chaix et al. 2005; Diez-Roux 2001).

Context

Dakar is particularly interesting from this point of view. Capital city of Senegal, Dakar is located on the Western edge of Africa. The climate of Dakar is hot with a short rainy season and annual rainfall very low. In addition, due to both the rapid population growth and the increasing prevalence of individual houses, Dakar experiences a rapid expansion of its urban space, especially in suburban area, leading to a significant social and environmental heterogeneity. This spatial expansion in the suburbs was made and continues to be made in areas that were traditionally wetlands, creating a large heterogeneity in the environment, with green areas or overflows during the rainy season.

Methods

Data collection

Data come from the Actu-Palu project, a cross-sectional study population. Following the model of household surveys using the IRIS (Grouped Islets for statistic indicators) carried out within the SIRS research program (health, inequalities and social breakdown in France) (Parizot et al 2004), almost 3,000 households were surveyed within 50 neighborhoods from the metropolitan area during the 2008 rainy season (from October to December).

The selection of study sites was made to highlight the socio-economic and environmental heterogeneity of the urban zone. The objective was to survey homogeneous zones and the most heterogeneous zones between them. A classification by dynamic clusters (K-means method), using census variables belonging to the same topic (housing, household equipments, sanitation) selected from a principal component analysis, identify 5 types of census area (DR for *district de recensement*) (ANSD 2006). These types ranked DR from high to low living conditions. The most representative type of each neighborhood was chosen. 42 DR were randomly chosen. To reach the number of 50 sites planed for the study, 8 other DR were then added according their proximity to swamp in order to consider the environmental effect. Finally, to avoid the risk of insufficient number of eligible households in one DR, each DR was paired with the nearest same type DR, thereby representing one neighborhood.

To be eligible, a household must contain at least one child less than ten years old. A person responsible for the household answered a standard pre-coded questionnaire based on socioeconomic, housing and close environmental conditions and the occurrence of recent fever for each child of the household. We excluded fevers caused by mumps, cuts or toothaches during the survey. The data covered 7,400 children.

Neighborhood characteristics and potential environmental factors for disease were assessed by a community questionnaire comprises eight sections, out of which physical characteristics, salubriousness and spraying campaigns. As in most community surveys, the respondents were interviewed in groups. This method is recognized to improve data quality (Schoumaker et al, 2006; Frankenberg, 2000).

Groups of discussion were composed by the neighborhood headman (the traditional neighborhood authority), the neighborhood representative (which represents the neighborhood in administrative matters) and a wide range of profiles in terms of sex, age and profession. The choice was largely left to the neighborhood headman who had been briefed by the interviewers about the type of respondent to be selected. On average, the group was constituted by seven respondents per neighborhood, with a minimum of four and a maximum of eleven respondents.

The community questionnaire was composed by a majority of closed questions, recommended for collecting data comparable over district (Bilsborrow, 1984). It comprises eight sections; the first focusing on basic information about the respondents and the other covering several topics such as the history of the settlement, physical characteristics and salubriousness, infrastructures, health and social services, accessibility and transport links, neighborhood groups and associations, spraying campaign. In general, finding respondents posed very few problems, except some intensive discussions for certain questions. The average duration of each interview was a little over one hour and a half.

The household questionnaire and the community questionnaire were conceived to be factored into multilevel analyses since children are nested in households which, in turn, are nested in neighborhoods.

Data analysis

Multilevel modeling has provided attractive solutions, which is still not so common in tropical research on health. The usual analyses of the relationship between environmental factors and fever often treat the former at only one level, the household level or the neighborhood level. However, the exposure to environmental risk varies according to these two competing level.

Since our dependent variable is binary (individual were infected or not), we used the logistic form of the multilevel model. A three-level modeling process is performed. Recent fever incidence is modeled level by level according to individual factors (sex, age), to household factors (socio-economic variables) and to environmental factors at the neighborhood level (floods, shrub lands, water bodies, solid waste and wastewater management facilities). Odds Ratios and their significant level were calculated.

The random effect is also analyzed. These methods allow consideration of within group (household and neighborhood) and between-group relations and integration of household and individual-level variables. The intraclass correlation allows calculation, on an empty model, of the proportion of the total variance explained by the grouping structure, in our case households and neighborhoods.

Results

Environmental heterogeneity

The descriptive results based on the community questionnaire confirm that the agglomeration of Dakar is characterized by a great environmental heterogeneity. The issue of salubriousness is particularly illuminating. Of the 50 neighborhoods surveyed, 39 declare to have problem with salubriousness (Figure 2). This perception varied substantially from one neighborhood to another, but the problem seems to be worst in Pikine.

Figure 2 – Perception about the salubriousness in the neighborhood (Actu-Palu, 2008)

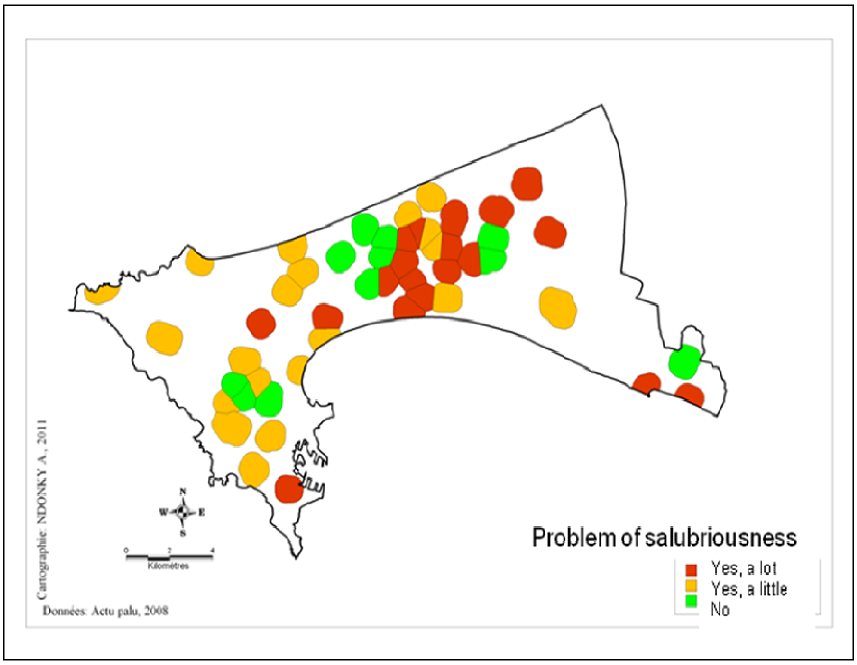
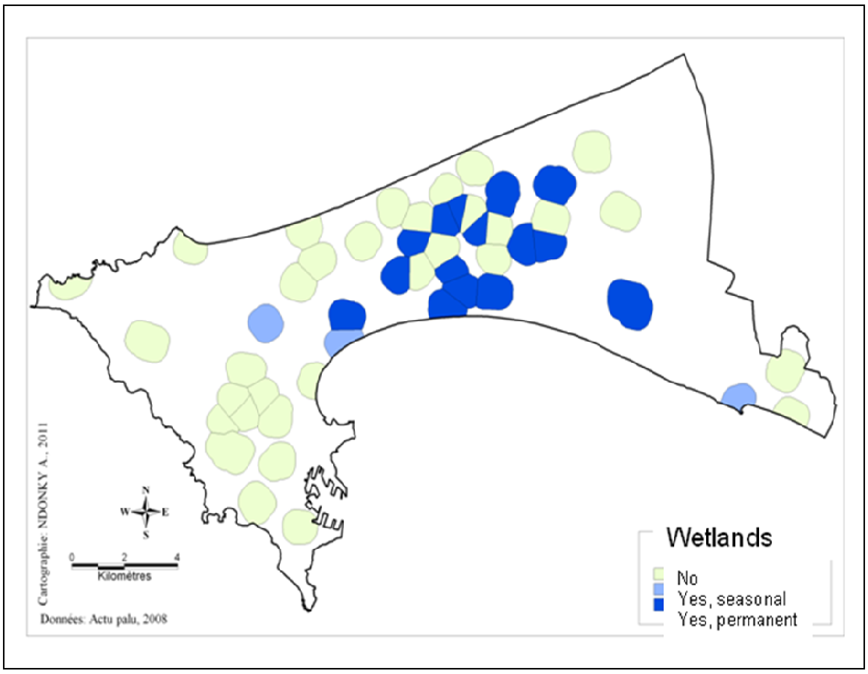


Figure 3 – Presence of water bodies/wetlands (Actu-Palu, 2008)



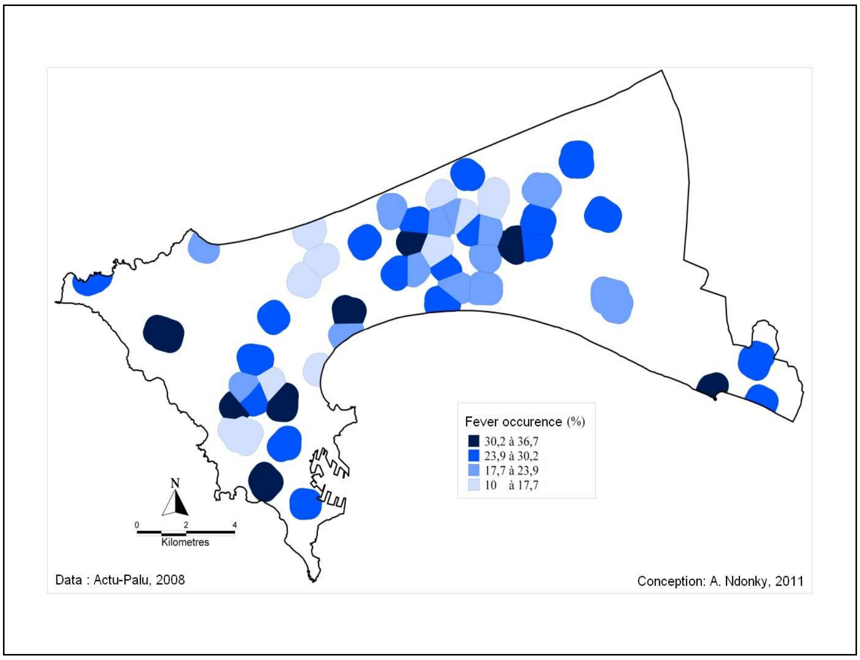
Concerning the wetlands, of the 50 neighborhoods surveyed, 18 have some type of wetland. 32% of the children in our sample live in a neighborhood with a permanent wetland and 6% live in a neighborhood with a seasonal wetland. Practically all of these children reside in the suburbs of Dakar (figure 3).

Fever occurrence

The total population of this study is 7,293 children, nested in 2,948 households, of whom 1,742 (24%) had had a recent fever.

Rates of recent fever varied substantially from one neighborhood to another, ranging between 10 and 37% (figure 4).

Figure 4 – Child fever occurrence in Dakar in 50 neighborhoods (Actu-Palu, 2008)



Multivariate results

The hierarchical organization of the data set in levels, fixed and random effects and cross-level interactions are now considered. The findings (table 1) indicate that the occurrence of fever is influenced by factors from all hierarchical levels.

Table 1 – Odd ratios from hierarchical regressions on the risk factors for child fever

	Model 1 (empty)	**Model 2 (household)**	**Model 3 (complete)**
Constant	0,32	0,31***	0,39***
Child's bio-demographic variables			
Sex (male)			
Female		1.02	1.02
Age – continuous variable		0.90***	0.90***
Household's factors			
Control variables			
Mother's age (< 30)			
30-39		0.99	0.99
40 and over		1.07	1.07
Mother's education (none)			
Primary and over		1.15*	1.16**
Mother's activity (independent)			
Other job		0.76**	0.76**
Housewife		0.84**	0.84**
Other		0.97	0.97
Wealth index – continuous variable		0.99	0.99
Environmental variables			
Drinking water (piped water in the dwelling)			
Other		1.08	1.08
Wastewater management (sewer or septic tank)			
Other (throw outside)		0.85**	0.82**
Garbage (collecting system)			
Other (throw outside)		1.39***	1.39***
Mosquito protective measures (none)			
At least mosquito nets		1.82***	1.71***
Others measures (no mosquito nets)		1.84***	1.76***
Neighboorhood's factors			
Canal (absence)			
Seasonal presence			1.84***
Permanent presence			1.19
Area of floods (absence)			
Presence			0.88
Wetlands - Niaye (absence)			
Seasonal presence			1.30***
Permanent presence			1.18**
Wastewater system (no)			
Yes			0.82
Garbage collecting system (no)			
Yes			0.89
Spraying campaign (no)			
Yes			0.87*

Significance level: *** : p<0.01; ** : p<0.05 ; * : p<0.10.
Reference category in parenthesis.

The majority of environmental risk factors that we included at the household level are associated with recent fever, some in a way we may not expect at a first glance. This is the case for the wastewater management: children, who live in a house not connected to a sewage system, were less at risk of fever than children who live in a house connected to a sewage system. One explanation could be found in the quality of the sewage system. Actually, in many areas in Dakar, the sewage system in general is so deficient, that it poses less risk to simply throw away waste water on the sand where it dries rapidly than to use the sewage system, which will overflow after each rain-shower.

The results obtained concerning the protective measures against mosquitoes may also seem unusual: children who live in a house not using protective measures against mosquitoes were less at risk of fever than children who live in a house using protective. In reality, the use of protective measures is closely correlated with the nuisance of mosquitoes. When this nuisance is high, people use protective measures. This suggests that the variable used here is a proxy for the mosquito nuisance, and hence the mosquito density.

Concerning waste disposal arrangements, the results show that a child who lives in a household where garbage pick-up is managed by a collecting system has less risk of a fever than child who lives in a household where garbage is thrown outside.

As for the environmental factors at the neighborhood level, results highlight the role of the presence in the neighborhood of wetlands and canals in the risk of childhood fever. More precisely, it is the seasonality of the wetlands and the canal which seems to be more strongly associated with the risk of childhood fever than the permanent presence. We see here the impact that the change of the environmental context has on fever in children. This is particularly the case for the presence of the canal. The presence of a canal in the neighborhood can influence mosquito-borne diseases in two ways. The most obvious case is that of permanent canals, which constitute water bodies, thus favoring mosquito breeding. However, there is also another aspect. In Dakar, the role of canals is to evacuate the excess water that accumulates during the rainy season. Therefore, except for the two-three months of abundant rainfall, these canals are dry. Given the absence of public garbage containers, often these canals serve as waste disposal areas. Hence, when the rainy season arrives, they often overflow, due to the presence of garbage. In this sense, it could be argued that the presence of canals constitutes not only a measure of water bodies in the neighborhood, but also a measure of insalubriousness at neighborhood level. In the community dataset, the 12 neighborhoods surveyed that have a canal are in Dakar-city or in Rufisque, at the edge of the metropolitan area.

A spraying campaign in the past seems to have a negative influence on the childhood fever occurrence, but the standard error associated with the odd ratio doesn't allow drawing any conclusions without a statistical error.

The analysis of the random effects shows that, in the empty multilevel model, the intra-household correlation showed that 11 % of the variance of the dependent variable - childhood fever - is related to household factors. The between household variance is also significant.

Table 2 – Random part from hierarchical regressions on the risk factors for child fever

	Model 1 (empty)	**Model 2 (household)**	**Model 3 (complete)**
Inter-household variance	0.428 *(0.300-0.555)*	0.446 *(0.273-0.618)*	0.453 *(0.288-0.618)*
Intra-household variance	11.3 %	11.8%	12.0%
Inter-neighborhood variance	0.061 *(0.017-0.104)*	0.047 *(0.010-0.084)*	0.026 *(-0.003-0.055)*
Intra- neighborhood variance	1.6%	1.2%	1.0%

The intra-neighborhood correlation showed that 1.6 % of the total variance is related to neighborhood factors. The neighborhood variables included in the final model explain 45% of the between neighborhood variance of the risk of fever.

Discussion/Conclusion

Our results suggest that childhood fever occurrence is influenced by factors from all three hierarchical levels. At the household level: solid waste and wastewater management facilities play a significant role in the risk of fevers for children. At the neighborhood level, it is the seasonality of salubriousness and of wetlands which constitute the key risk factors.

However environmental factors at the household and neighborhood levels play a relatively lower role than the individual level. This is not surprising, since the first source of heterogeneity in health is individual (Wagstaff et al., 2001). In addition, the number of neighborhoods included in this study is close to the minimum desirable for such models. A larger study may render these results even weightier than in this present survey.

The authors recommend the combining use of multilevel modeling and spatial data (land cover maps and spatial entomological data), mainly to identify more accurately ecological targets for public health policy (Diez-Roux 2008; Chaix et al., 2005).

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