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## **SURVOL part 3: Environmental pollution (air, noise) exposure and social deprivation around the major Ile-de-France airports**

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### **ABSTRACT**

The SURVOL project, led by the Ile-de-France Region Prefecture and the Ile-de-France Regional Health Agency, aims to strengthen environmental monitoring around the three major Ile-de-France airports: Paris – Charles de Gaulle, Paris - Orly, and Paris-Le Bourget. Bruitparif - a noise observatory in the Ile-de-France Region - has been in charge of implementing the Geographical Information System (GIS), in order to analyse and follow the changes over time of the relationships between the environmental variables related to noise and air pollution and the socio-economic characteristics of the population living in the SURVOL study areas. The GIS integrates data taken from the strategic noise maps created by Bruitparif, air quality data provided by air quality monitoring network Airparif, and socio-economic data from INSEE (French National Institute for Statistics and Economic Studies). The cross-tabulation of this information has highlighted the first elements on the potential links that exist between social inequalities and exposure to noise and/or pollution. Statistical analysis highlights that a relationship exists between exposure to environmental pollution and social deprivation. This article presents the areas where social and environmental inequalities are highest in the Ile-de-France region and the results of the third part of the SURVOL project.

Keywords: environmental noise, deprivation, GIS

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# 1. INTRODUCTION

## 1.1 Context

The Ile de France region has two international airports, Paris-Charles de Gaulle and Paris-Orly; and one business airport, Paris-Le Bourget. These airports are among the biggest in their category at European level and are responsible for a significant amount of air traffic over the region.

Despite measures to protect locals (Plan de Gêne Sonore – Noise Pollution Map, Plan d'Exposition au Bruit – Noise Exposure Plan), inhabitants are strongly challenging the disturbance created by air traffic and are concerned about the impact that exposure to the noise and atmospheric pollution generated by planes and the airport hubs will have on their health.

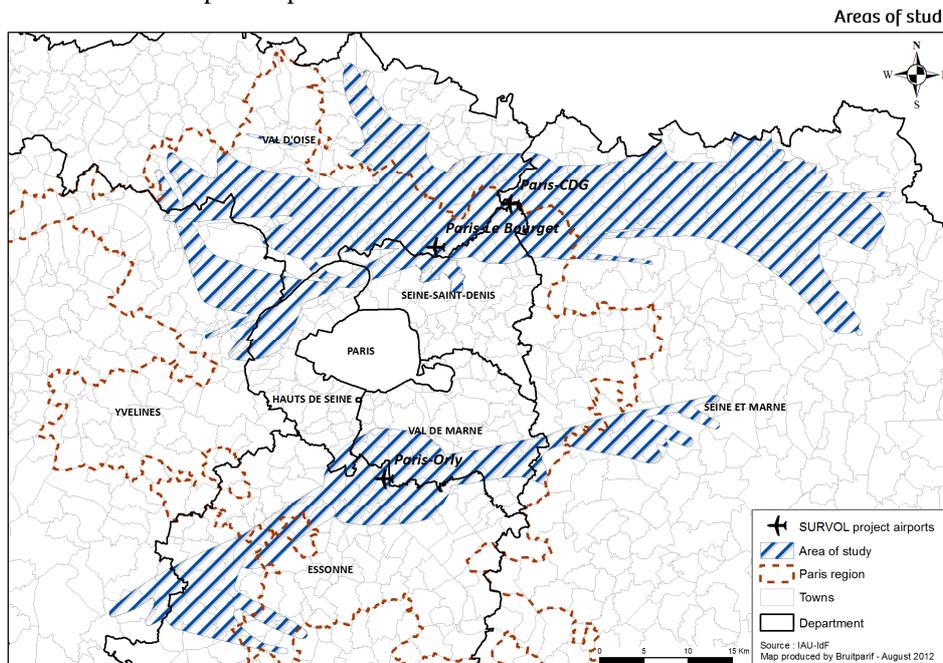
It is in this context that the Prefect of the region included actions concerning the disturbances generated by the region's airports in the first Regional Health Environment Programme (PRSE1). This initiative aims, firstly, to produce a summary of the knowledge of the health impact of planes and, secondly, to set up a health and environmental monitoring system around the region's airports. At the end of 2008, the Prefect of the region tasked the Inter-regional Unit of Ile de France (InVS-Drass) to set up the monitoring system that constitutes the SURVOL project (SURVOL stands for "SURveillance sanitaiRe et enVironnementale des plate-formes aéroportuaires de rOissy, orLy, le bourget" or "Health and environmental monitoring of the airport hubs of Roissy, Orly, and Le Bourget"). This system relies on help from bodies that aim to protect the health of locals (ARS, Cire) and monitor pollution (Airparif and Bruitparif).

During the first phase of the project (2008-2011), Bruitparif, which is responsible for the "noise" aspect, set up a GIS that delimited the areas of study then mapped the noise levels by source of noise and the number of people exposed. The association also set up ten measurement stations.

The SURVOL project is also part of the second Regional Health and Environment Plan for Ile de France (PRSE 2). For the second phase of the project (2012-2013), Bruitparif is continuing to reinforce the monitoring system by setting up new stations and it has been tasked with characterising the populations of the area of study in relation to exposure to noise and atmospheric pollution.

## 1.2 Area of study

The area of study chosen for the first phase of the project covers 299 towns, divided into a northern zone (Paris-Charles de Gaulle and Paris-Le Bourget) and a southern zone (Paris-Orly). The population exposed to noise and atmospheric pollution within this area is around 2.17 million inhabitants.



Map 1 – SURVOL's areas of study

These zones were defined based on flight paths, noise environment curves, and delimitations of the Noise Pollution Map and the Noise Exposure Plan.

### **1.3 Issue**

These defined areas are potentially subjected to noise and atmospheric pollution linked to air traffic.

The following hypothesis can be made: depending on income, environmental disturbances can strongly influence the socio-professional make-up of these areas' populations. Indeed, income plays a key role in the choice of one's place of residence. These disturbances can therefore prevent new, better-off inhabitants from moving to the area, and can constitute a reason for moving. Conversely, people with more modest incomes may find it more difficult to move out, so they, therefore, have no choice but to suffer environmental disturbances. New underprivileged populations may even see this as an opportunity to acquire cheap housing close to their place of work.

This hypothesis is particularly relevant in Ile-de-France, where there is both very strong pressure on the property market and pre-dominant economic activity in Paris and its immediate vicinity. This special context attracts populations to these areas, despite the environmental disturbances.

The aim of this study is, therefore, to answer the following question: Are there social inequalities concerning exposure to noise and atmospheric pollution in the areas studied as part of SURVOL?

### **1.4 Geographical unit and socio-economic data**

In order to guarantee coherence between the different variables that must be cross-tabulated, it was decided that data from 2006 would be used, as this is when the data used for modelling the noise maps was entered. The two social deprivation indices were therefore created using data from the 2006 population census, supplied by INSEE (the French National Institute for Statistics and Economic Studies) at IRIS level. The IRIS (Ilots Regroupés pour l'Information Statistique - Zones Grouped for Statistical Information) is the most precise geographical unit for which census data is supplied.

## **2. SELECTION AND REPRESENTATION OF SOCIAL DEPRIVATION INDICES**

### **2.1 Socio-economic characterisation of the population**

In order to characterise a region in terms of the socio-economic characteristics of its population, different aspects must be taken into account: the breakdown of the population by age, education, activity, housing, and material conditions. Studying all the variables of these different socio-economic aspects can, however, be very time consuming and can adversely affect the clarity of the analysis. A reduced choice of variables and the creation of an index allows a more precise analysis of the populations' characteristics. The use of an index summarises the socio-economic situation of a population while translating its multiplicity. The initial question being whether it is the most underprivileged populations that are most exposed to disturbances, it was important to find indices that translate this socio-economic disadvantage.

In the literature, there are several indices that seek to translate the socio-economic context, and social and material disadvantage: the inequalities index [1-2], the social and materials deprivation index [3], the EPICES index, [4], and the human development index (HDI) [5]. The majority of these indices can be divided into two groups, depending on whether the creation protocol used a multidimensional or an additive method.

### **2.2 Social deprivation indices tested in the study**

Two indices, each using one of these two methods, were chosen in order to compare their results: the Townsend index [6] (additive method) and the contextual deprivation index (or SES, for Socioeconomic status - a multidimensional method) [7].

#### **2.2.1 The Townsend index**

The additive method consists in calculating an index with a reduced sum of normalised variables. The two most commonly cited indices in scientific publications, in particular for the analysis of health inequalities, are the social deprivation indices created by British sociologists Townsend and Carstairs [8]. For Peter Townsend, there are two forms of deprivation: material deprivation and social deprivation. These are two components can be found in all four variables that make up his index: the proportion of unemployed people in the active population, the proportion of main homes with more than one person per room, the proportion of main homes for which the occupier is not the owner, and the proportion of households without a car.

## 2.2.2 The SES index

Multidimensional methods use a large number of socio-economic and/or socio-demographic variables that are reduced by multi-level factor analysis. The choice of variables is determined by the statistical relationships between these variables. The definitive index, therefore, takes socio-economic and geographical contexts into account.

In the protocol for creating the SES index, the group of variables selected at the start of the procedure includes information on activity and education, and the breakdown of the population, households, and accommodation. Whereas the Townsend index only includes variables that translate social "underprivilege", the SES index also features variables that correspond to social "privilege" (main homes measuring over 100 m<sup>2</sup>, persons on open-ended contracts/civil servants, households with two cars, etc.).

The preparation of the SES index requires several successive PCAs (Principal Component Analyses) in order to, initially, reduce the number of variables while retaining the most relevant ones (variables providing the largest possible variance in the data), and then to calculate the index. The statistical computing was carried out using the programming language R.

## 2.3 Socio-economic characterisation of IRIS's using social deprivation indices

For the two indices, the higher the value of the index, the higher the area's level of (social and material) deprivation is compared to others. The results obtained through the two approaches were first analysed separately, then compared. The two indices being highly correlated and, therefore, having very similar results, only the SES index is presented in this article.

### 2.3.1 Statistical correlation of the indices

In order to compare the two indices, we calculated the Bravais-Pearson correlation coefficient, using Matlab®, removing the ten IRIS's with missing values. The point cloud showing the results of the Townsend index as a function of the SES, shows a positive linear correlation between the two indices. With correlation coefficient of 0.97, the Townsend index and the SES index are highly correlated. They therefore show the same type of social and material deprivation, although they use different methods.

### 2.3.2 The results of the SES index

The creation of the SES index enabled the selection of relevant variables for characterising the populations of the IRIS's in the area of study. 21 variables were selected to create the index, projected on the correlation circle below:

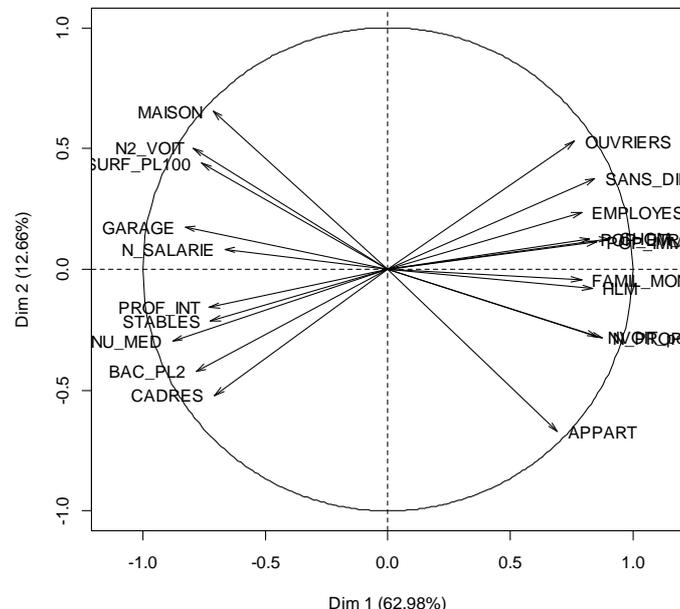
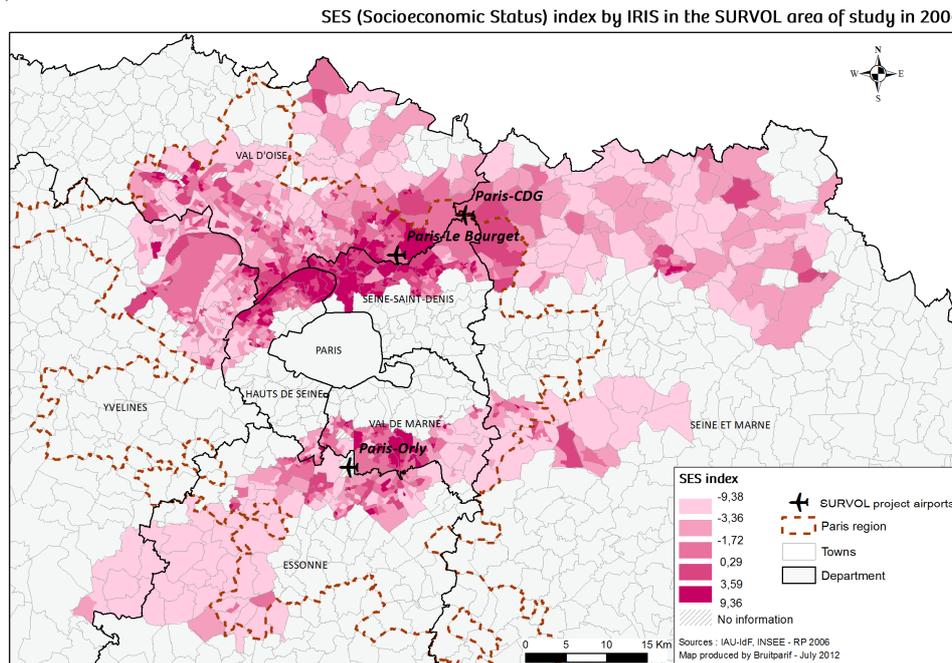


Figure 1 – Correlation circle for the variables of the final PCA (axes 1 and 2)

The first axis explains a significant proportion of the total variance (62.98 %). The correlation circle is a good illustration of the opposition between variables of social and material "deprivation" (proportion of unemployed people, proportion of non-home owners, households without a car, immigrants, unqualified, foreigners, employees, single-parent families, unskilled workers) with

"privilege" (median income, proportion of households with a parking space, households with two cars, higher education, main homes measuring over 100 m<sup>2</sup>, middle management, stable income, houses, executives).



The most "underprivileged" populations (IRIS's with values above the 95<sup>th</sup> percentile), using the SES index, are concentrated in the northern areas of study. These are highly built-up IRIS's, mostly located in the Seine-Saint-Denis and Val d'Oise departments. The town of Meaux, which has several IRIS's with high values, also stands out in the Seine-et-Marne department. In the southern area of study, the IRIS's located near and north-east of Paris-Orly airport stand out as being the most underprivileged.

While the most underprivileged populations seem to be concentrated in IRIS's in very built-up towns, the most "privileged" populations are found in peri-urban and more rural zones, mostly in the departments of Seine-et-Marne or Essonne, and some of them outside of the Paris region. The privileged IRIS's are mostly whole towns, contrary to underprivileged IRIS's, which are neighbourhoods in towns.

### 3. CHARACTERISATION OF THE EXPOSURE OF POPULATIONS TO NOISE AND ATMOSPHERIC POLLUTION

#### 3.1 Available data for noise

The noise indicators chosen to build the GIS are noise related to road traffic, noise related to rail traffic, and noise related to air traffic. The noise data used comes from strategic noise maps produced by the relevant authorities in application of European directive 2002/49/EC.

To characterise exposure to multiple sources of transport noise in the areas of study, Bruitparif used work in progress at national level. The national multi-exposure work group is coordinated by the LRPC (Laboratoire Régional des Ponts et Chaussées) of Strasbourg, and IFSTTAR, ENTPE, CETE Lyons, Acoucity and Bruitparif are partners. A multi-exposure noise indicator called "Miedema" has been developed [9]. It is based on the "dose-response" curves defined by Miedema [10] to express the annoyance felt by populations for each source of transport noise, in mono-exposure situations. It is based on an extrapolation of the "Miedema mono-exposure" indicator to multi-exposure situations. It is currently being approved.

In the absence of one model for calculating noise annoyance related to multiple-exposure to transport noise that is scientifically more valid than another at this point in time [11], we have chosen to use the model suggested by the national work group to evaluate multi-exposure in the SURVOL area of study.

### 3.2 Data on environmental exposure evaluated at IRIS level

The environmental data comes from models with a high resolution: an irregular grid to provide a high resolution for each building for the noise and a regular grid of 50 m x 50 m for air quality. Environmental data is, therefore, available at a much more precise level than by IRIS. Whether it be for noise levels or NO<sub>2</sub> concentrations, it is not adequate to average values at IRIS level to evaluate the exposure of the population. Indeed, the level of exposure to pollution is highly linked to the distribution of sources within the IRIS. For example, as pollution sources linked to land transport are essentially linear (roads, railways, etc.), two people living in different parts of the same IRIS are not necessarily exposed to the same levels of pollution.

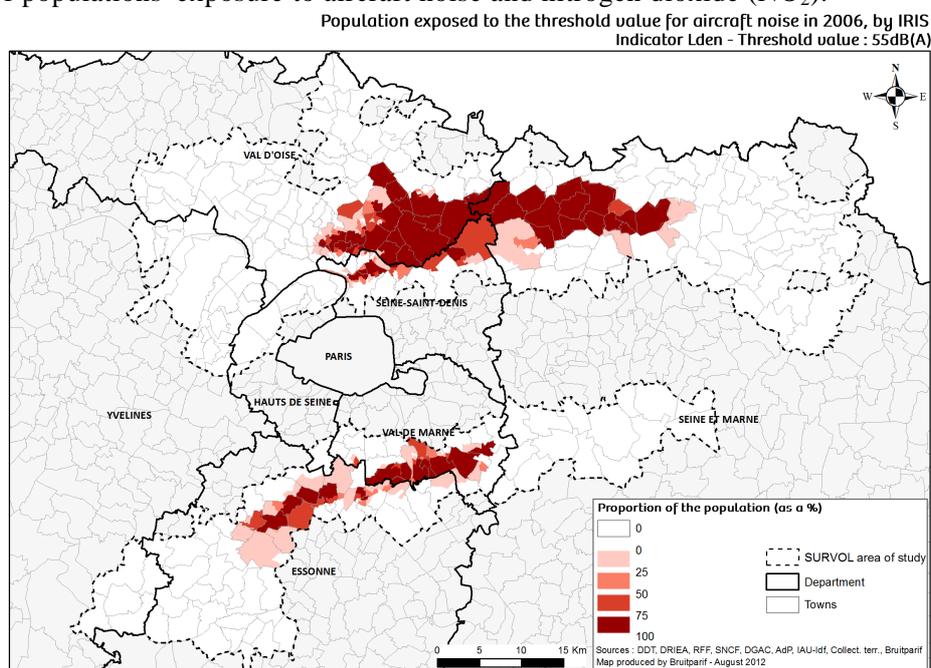
To get over this problem of scale and take this variation into account, exposure to noise and atmospheric pollution has been estimated not in terms of decibels (dB(A)) or micrograms per cubic metre of air (µg/m<sup>3</sup>), but rather by the proportion of the population in each IRIS exposed to levels that exceed a certain threshold.

The threshold values chosen are the regulatory limits in Lden, as defined in article 7 of the order of 4 April 2006 for the noise produced by different sources of transport (aerial noise = 55 dB(A), road noise = 68 dB(A), rail noise = 73 dB(A)) and by decree no. 2010-1250 of 21 October 2010 for the average level of nitrogen dioxide per calendar year (NO<sub>2</sub> = 40 µg/m<sup>3</sup>). For the multi-exposure noise indicator called "Miedema" (cf. 3.1), the threshold value chosen for this indicator makes a road equivalent Lden of 68 dB(A).

In order to know the number of people per IRIS exposed to values that exceed the threshold, for each source of pollution, two layers of data have been cross-tabulated: the IRIS buildings, which has been previously attributed a population by the IAU-îdF (Densimos), and the level of noise or atmospheric pollution from the models and evaluated on the façade of every building. This calculation was made using the highest noise level recorded on the façade of each building, in accordance with the method recommended by directive 2002/49/EC.

The data concerning the number of people exposed to NO<sub>2</sub> levels that exceed the threshold value was provided by Airparif directly.

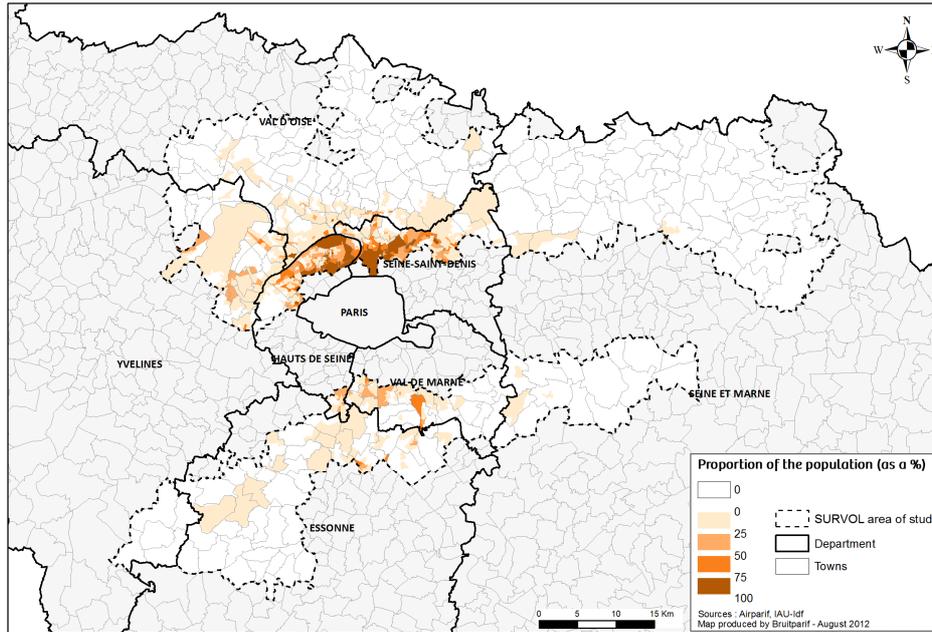
The maps below (Maps 3 and 4) show, as an example, the results obtained at IRIS level for the indicators of populations' exposure to aircraft noise and nitrogen dioxide (NO<sub>2</sub>).



Map 3 - Population overexposed to aircraft noise by IRIS (2006)

The IRIS's where a high proportion of the population is very exposed (over 75 %) is naturally concentrated below the three airports' air traffic lanes. We observe an "all or nothing" phenomenon: The IRIS's that suffer from over-exposure to aircraft noise (based on the threshold value of 55 dB(A) in Lden) can be found in only half of the area of study, but for the majority of these IRIS's a very high proportion of the population is concerned (> 75 % for most of them).

Population exposed to a nitrogen dioxide (NO<sub>2</sub>) level above 40µg/m<sup>3</sup> (quality objective) in 2006, by IRIS



Map 4 - Population overexposed to nitrogen dioxide (NO<sub>2</sub>) by IRIS (2006)

Within the areas of study, a very high percentage of the population (over 75 %) is over-exposed to atmospheric pollution (NO<sub>2</sub> above 40 µg/m<sup>3</sup>) in certain IRIS's in towns in the north-west of Seine-Saint-Denis and the north of Hauts-de-Seine.

## 4. CROSS-TABULATION OF ENVIRONMENTAL DATA WITH SOCIO-ECONOMIC VARIABLES

### 4.1 Statistical analyses

Among all the socio-economic variables and the variables linked to environmental pollution, a reduced number was selected in order to concentrate on the most relevant cross-tabulations for our study. The following variables were cross-tabulated: socio-economic data (SES or Townsend index); exposure to noise (proportion of the population exposed to values that exceed the threshold value for aircraft noise of 55 dB(A) in Lden; proportion of the population multi-exposed (according to the "Miedema multi-exposure indicator") to a road noise equivalent level that exceeds the threshold; exposure to NO<sub>2</sub> (proportion of the population exposed to an average annual NO<sub>2</sub> level above 40µg/m<sup>3</sup>).

We are interested in a possible causal relationship between the variations in social deprivation indices (Y) and environmental variables (X), according to a linear function:  $Y \approx aX + b$ .

The statistical analyses were carried out using the Townsend index and the SES index. However, only the cross-tabulation carried out with the SES index will be presented as an example in this article.

### 4.2 Bivariate analysis

Tukey's box-and-whisker plots (also known as boxplots) allow a graphical depiction of the cross-tabulation of the social deprivation index (SES or Townsend) and environmental variables. For this type of representation, we have split the indices into deciles. Class 1 corresponds to the 10% of the "least underprivileged" IRIS's and class 10 represents the 10% of the "most underprivileged" IRIS's.

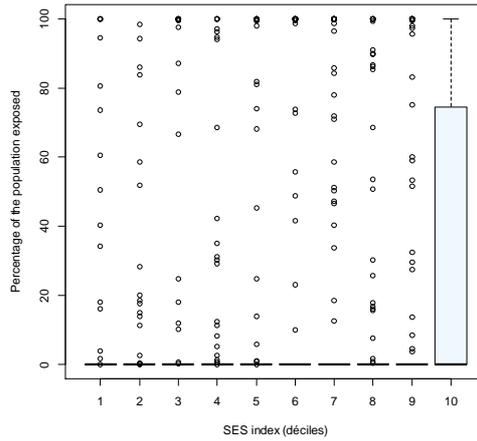


Figure 2 - SES index and proportion of the population overexposed to aircraft noise

The proportion of the population exposed to values that exceed the threshold values for aircraft noise jumps dramatically from very low values to very high values when we reach the most underprivileged IRIS's (10<sup>th</sup> decile).

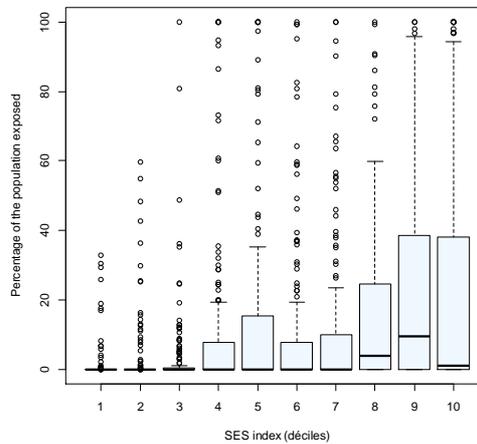


Figure 3 - SES index and proportion of the population overexposed to NO<sub>2</sub>

The increase of the proportion of the population exposed to values that exceed the threshold limits for atmospheric pollution by IRIS as a function of the SES or Townsend indices is very marked. In the area of study, the higher the level of "deprivation" by IRIS is, the more people are exposed to levels of NO<sub>2</sub> exceeding 40 µg/m<sup>3</sup>.

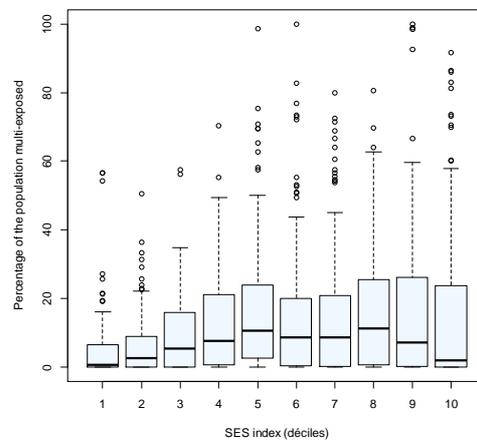


Figure 4 - SES index and proportion of the multi-exposed population (road equivalent)

The proportion of the population exposed by IRIS tends to increase as the level of "deprivation" rises.

### 4.3 Analysis of correlations

The bivariate boxplot representations seem to indicate that the relationship between the variable couples studied is not coincidental. The analysis of correlation coefficients, determination coefficients, and p-value statistics in combination with a significance test of the slope allowed an evaluation of the nature of the relationship between the environmental variables studied and the social deprivation index.

Table 1 - Analysis of correlations for the SES index

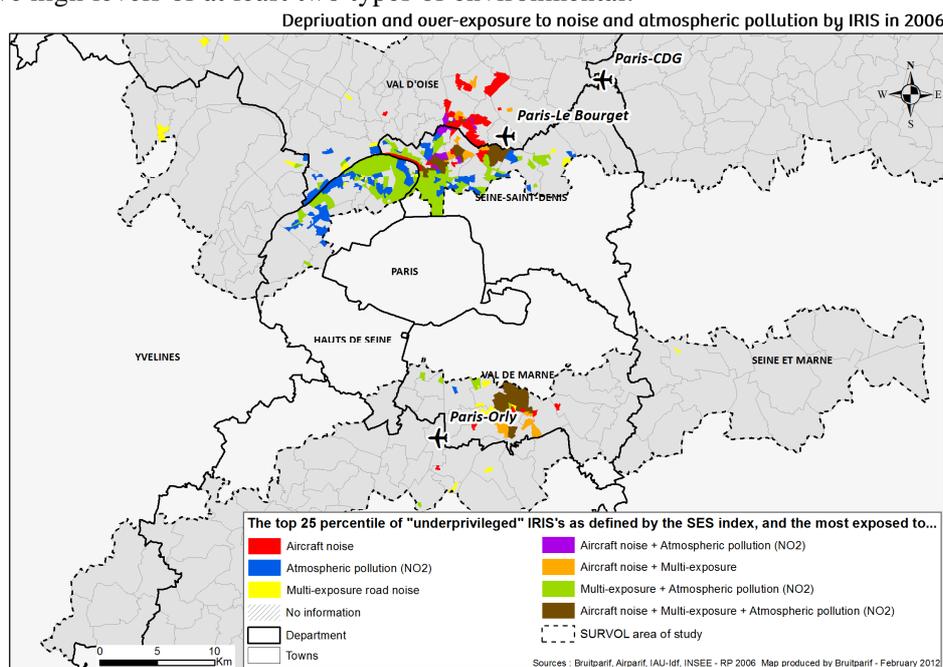
	Pearson correlation coefficient (R)	Slope significance test (P-value)	Determination coefficient (R <sup>2</sup> )
% of the population exposed to more than 55dB(A) for aircraft noise	0.18	6.129e-13	0.03278
% of the population multi-exposed (road equivalent)	0.18	6.297e-13	0.03274
% of the population exposed to more than 40µg/m <sup>3</sup> for the level of NO <sub>2</sub>	0.28	2.2e-16	0.08094

While the Bravais-Pearson linear correlation and determination coefficients are low, the p-value values are all below 5 %, which allows us to reject the hypothesis that the variables are not correlated. Consequently, the relationship between people that are over-exposed to noise and/or atmospheric pollution, and the level of social deprivation, as defined by the SES index, cannot be coincidental.

### 4.4 Cartographic representations

Maps were produced to highlight the IRIS's with high levels of socio-economic deprivation (either according to the SES index, or the Townsend index, or both) and a significant proportion of the population over-exposed to environmental pollution. For each of these variables, the IRIS's in the top 25 percentile in terms of both social deprivation and exposure to noise nuisance or atmospheric pollution were chosen. The use of the Townsend index or the SES index has little effect on the results, only a few IRIS's stand out. All the maps are presented in the full study report written by Bruitparif [12].

The map below (Map 5) summarises all the possible combinations of social deprivation and exposure to environmental disturbances. For the most socially underprivileged IRIS's, we observe that there is an accumulation of several types of pollution: indeed, the great majority of IRIS's identified on the map have high levels of at least two types of environmental.



Map 5 - Type of cross-tabulation between the SES index and environmental pollution (2006)

## 5. CONCLUSION

The statistical analyses have highlighted relationships that cannot be coincidental, between socially underprivileged populations and exposure to noise and atmospheric pollution within the areas of study. The most underprivileged IRIS's have a higher concentration of people exposed to air or road traffic noise and/or atmospheric pollution.

A detailed study of the location of the most critical IRIS's (those that are in the top 25 percentile of the most underprivileged from a socio-economic point of view and in the top 25 percentile of those most exposed to noise and/or atmospheric pollution) has highlighted a great diversity of situations with the areas of study combining social inequality and environmental inequalities.

By highlighting the sectors within the areas of study that are both significantly socially and environmentally underprivileged, the study identifies which zones should be considered as priority zones for public health policies. This information can also help the local authorities concerned to prioritise their actions in terms of fighting noise and atmospheric pollution and protecting exposed populations.

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