25·29 August 2024
inter.noise
NANTES FRANCE

Developing a combined mapping representation of air and noise pollutions

Pierre Jamard[1], Fanny Mietlicki[2], Victor Decourt[3]
Bruitparif, observatoire du bruit en Île-de-France
32 boulevard Ornano, 93200 Saint-Denis, France

Fabrice Joly[4], Fatine Abdoussi[5]
Airparif, observatoire de la qualité de l'air en Île-de-France
7 rue Crillon, 75004 Paris, France

ABSTRACT

Airparif and Bruitparif, observatories for air and noise pollutions in the Ile-de-France region, have worked together to develop a combined mapping representation of air and noise pollutions.
On the one hand, Bruitparif has tested different approaches to propose a noise index considering the various exposures to road, air and traffic noise, according to the strategic noise maps. On the other hand, Airparif and the French regional air quality observatories have developed an air quality index taking into account the main regulated air pollutants. They have finally put together an original method of mapping representation of the double exposure to noise and air pollutions.
Mapping combining air and noise pollutions is an efficient diagnostic tool for municipalities. This makes it possible to identify the areas at stake: those that are preserved from these pollutions and should be protected, and those that are highly exposed and where mitigation measures must be implemented. It offers a wide range of uses, like cross-referencing of air-noise data with the location of establishments receiving vulnerable groups or making comparison with socio-economic data and health indicators.

1. INTRODUCTION

Noise and air pollution are major environmental issues in the Ile-de-France region due to its high population density and its dense transport infrastructure. Ile-de-France is the most populous region of France with 12,2 million inhabitants in a surface area of 12,000 km^2. The Ile-de-France region includes the capital of France, the city of Paris.

The urban environment holds numerous emission sources of air and noise pollution, creating suitable conditions for environmental co-exposure situations. According to the results of one survey on 3074 Ile-de-France residents [1], air pollution and noise are cited by 38% and 36% respectively as the main disadvantages of living in the Ile-de-France region, out of a list of 10 items.

[1] pierre.jamard@bruitparif.fr
[2] fanny.mietlicki@bruitparif.fr
[3] victor.decourt@bruitparif.fr
[4] fabrice.joly@airparif.fr
[5] fatine.abdoussi@airparif.fr

Several epidemiological studies have evaluated the health effects of individual exposure to noise or to air pollution [2] [3] which are now well and truly established. Environmental noise can cause annoyance, sleep disturbance, cardiovascular disease, and diminished learning capacity. Atmospheric pollution encourages the development of cardiovascular disease, respiratory disease, and lung cancer, leading to a loss of life expectancy and increased mortality. Studies have also shown that noise and air pollution are factors that reinforce social inequality, with underprivileged populations also generally being those most exposed. It is only recently that studies have started to take interest in the impacts of co-exposure to noise and air pollution, and there is still a significant lack of knowledge on this subject. Evaluation of the joint-exposure levels is the main obstacle for co-exposure studies.

To start publishing quantitative data on co-exposure to air and noise pollutions and to raise awareness of this major public health issue, Airparif and Bruitparif, the two leading air pollution and noise observatories in the Ile-de-France region, have decided to work together to develop a combined mapping of noise and air pollution issues in the region.

To do this, Airparif and Bruitparif have each developed a global index for air pollution and noise respectively. The two observatories then worked on developing an original method of mapping representation of the co-exposure to noise and air pollutions.

This article presents the methodology used and the results obtained.

2. INPUT DATA AND SCALES FOR PRODUCING THE AIR/NOISE MAP

The two observatories have used the data available to characterise noise and air pollution.

Airparif used the different maps produced to assess annual mean concentrations of three major pollutants (PM_{10}, $PM_{2.5}$, NO_2). These maps are available throughout the Ile-de-France region, with a finer resolution the closer we move to the dense area of the region, particularly in the city of Paris – see https://www.airparif.fr/surveiller-la-pollution/bilans-et-cartes-annuels-de-pollution [4]. Maps for years 2020, 2021 and 2022 have been used.

Bruitparif used the strategic noise maps produced according to the 4th round (2022) of the European Noise Directive (END) 2002/49/EC [5] – see https://carto.bruitparif.fr [6]. These maps take into account noise sources linked to transport (road, rail and air traffic). Within the dense area of the Ile-de-France region which is made up of 14 major agglomerations representing a total of 433 municipalities and 10.5 inhabitants, the maps take account of all transport infrastructures, whereas only the biggest ones are taken into account in the rest of the Ile-de-France region. These maps have been produced according to the common noise assessment method (CNOSSOS-EU) [7], with a 5x5 metre resolution.

Due to the higher resolution for both noise and air quality as we move closer to the dense area, three scales of mapping have been used in the remainder of this article: the Ile-de-France region, the dense area of the Ile-de-France region and the city of Paris (see Figure 1).

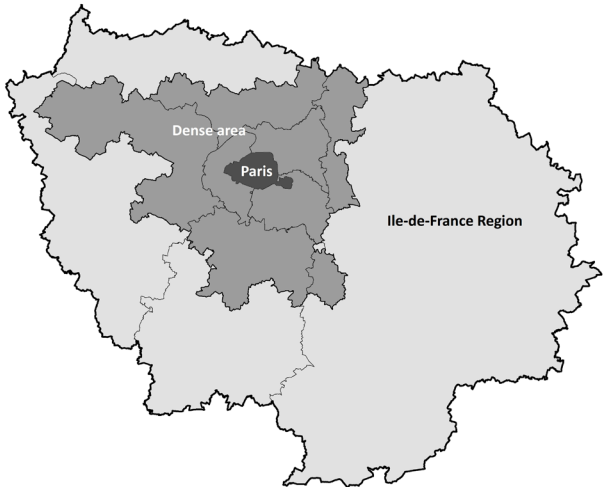

Figure 1: The three scales of mapping within the Ile-de-France region.

3. DETERMINATION OF A GLOBAL INDEX FOR AIR QUALITY

The Strategic Air Quality Maps (SAQMs) were developed[6] as a tool for urban planning. These maps consolidate the impact of three major air pollutants (PM_{10}, $PM_{2.5}$, NO_2) on local air quality. They provide insights into areas with good air quality to be preserved and, conversely, areas where the population is already exposed to exceedances of thresholds. Therefore, they serve as a diagnostic tool for local authorities to evaluate air quality in urban development projects. They facilitate the integration of air pollution exposure concerns into urban planning, aiming to preserve areas with the least pollution, limit the exposure of new populations, or reduce the exposure of populations already exposed to polluted air.

The areas are classified into 7 air quality classes, according to the compliance with health and regulatory thresholds (see Table 1). The reference values retained are:

- The air quality guidelines issued by the WHO, which are health-based recommendations for air quality management [3],
- The limit values defined by the European Ambient Air Quality Directives [8] and transcribed into French law, which are legally binding standards,
- The limit values to not exceed from 2030, proposed in the on-going revision of the European Ambient Air Quality Directives [9], which aims at improving the EU's air quality standards for zero pollution by 2050.

Table 1: The 7 air quality classes, according to the compliance with health and regulatory thresholds.

	NO_2	**PM_{10}**	**PM_{25}**	
	$\mu g/m^3$	*$\mu g/m^3$*	*$\mu g/m^3$*	
A	≤10	≤15	≤ 5	*Compliance with WHO guidelines*
B	]10,16]	]15,16]	]5,8]	*Exceedance of WHO guidelines*
C	]16,20]	]16,20]	]8,10]	*Risk of exceeding the 2030 limit values (> 80% * 2030 limit values)*
D	]20,24]	]20,24]	]10,12]	*Exceedance of 2030 limit values*
E	]24,32]	]24,32]	]12,20]	*Significant exceedance of 2030 limit values (>120% * 2030 limit values)*
F	]32,40]	]32,40]	]20,25]	*Risk of exceeding the EU limit values (>80% * EU limit values)*
G	>40	>40	>25	*Exceedance of EU limit values*

The SAQMs are based on local modelling of annual mean concentrations for NO_2, PM_{10} and $PM_{2.5}$. The data for particulates is collected over 3 years, the median values are retained. Thus, the SAQMs are less influenced by meteorological variations compared to annual air quality maps, and their timeframe is consistent with urban planning. For NO_2, only the last year is considered since this pollutant is mainly emitted by road traffic. Indeed, actions and adjustments to the road network have a direct impact on the concentrations of this pollutant. The multi-pollutant map is formed by the poorest class obtained for each of the three pollutants.

Figure 2 provides the strategic air quality map obtained for year 2022 for the Île-de-France region.

[6] First SAQMs were developed in 2017 by the French regional air quality observatories. The method was updated in 2022 in order to consider the evolution of regulation and health recommendations.

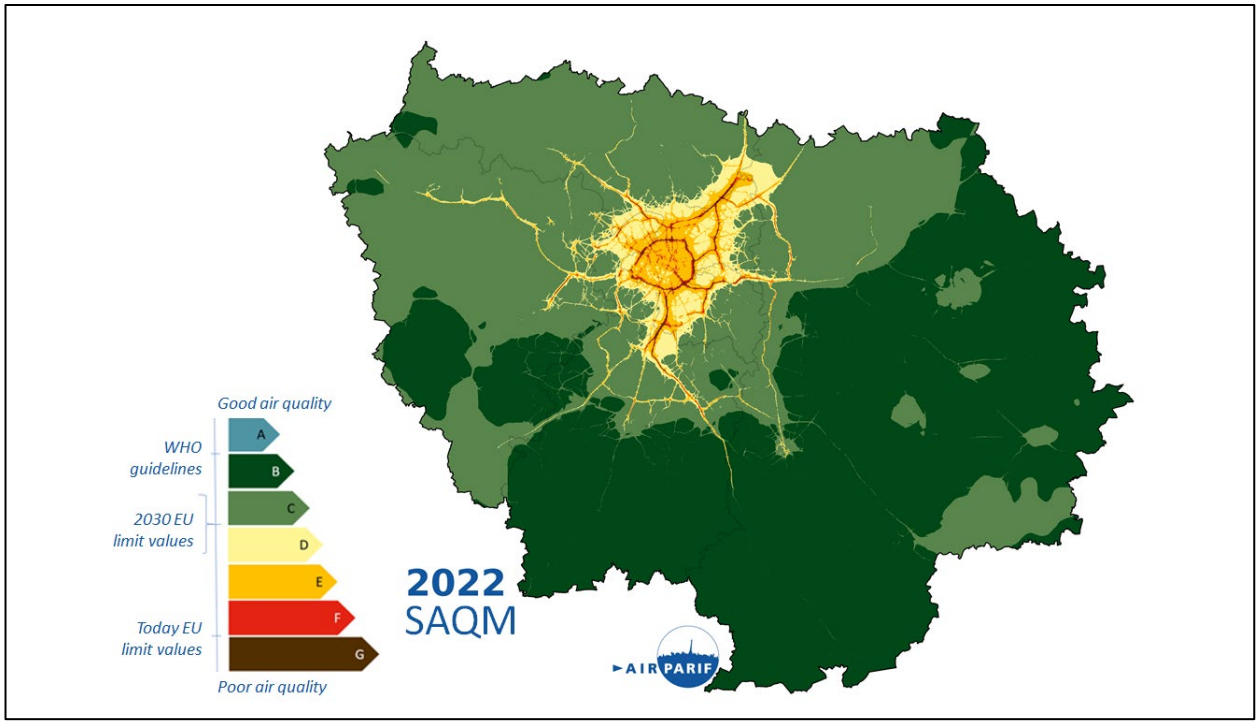

Figure 2: The strategic air quality map obtained for year 2022 for the Île-de-France region.

4. DETERMINATION OF A GLOBAL INDEX FOR TRANSPORT NOISE

Two indicators are used in the strategic noise maps: Level day evening night (Lden) and Level night (Ln). Lden is an indicator of overall noise over 24 hours which takes into account the fact that sensitivity to noise is higher in the evening and at night. It is calculated using equivalent average noise levels (LAeq) during the day, in the evening, and at night applying a weighting of +5 dBA and +10 dBA to noise in the evening and at night. The Ln indicator is the average noise over the night-time period. Both indicators are calculated as an average over the year.

Preliminary tests, carried out by Bruitparif to develop the global index of multi- exposure to noise from the different transport sources, showed that working with the two indicators did not provide any additional information compared to considering only the Lden indicator. This is why we retain the Lden indicator.

Based on the maps for Lden indicator for each transport source, three different approaches were tested and compared to propose an index of multi-exposure to transport noise. These are presented below and illustrated for the dense area of the Ile-de-France region.

4.1. Cumulative noise levels

The first method consists of summing the Lden noise levels of the three noise sources. Although easy to produce (see Figure 3), this cumulative noise map cannot be used to guide public action as there are no reference values for cumulative transport noise. This is why this method has not been selected to deal with multi-exposure to transport noise.

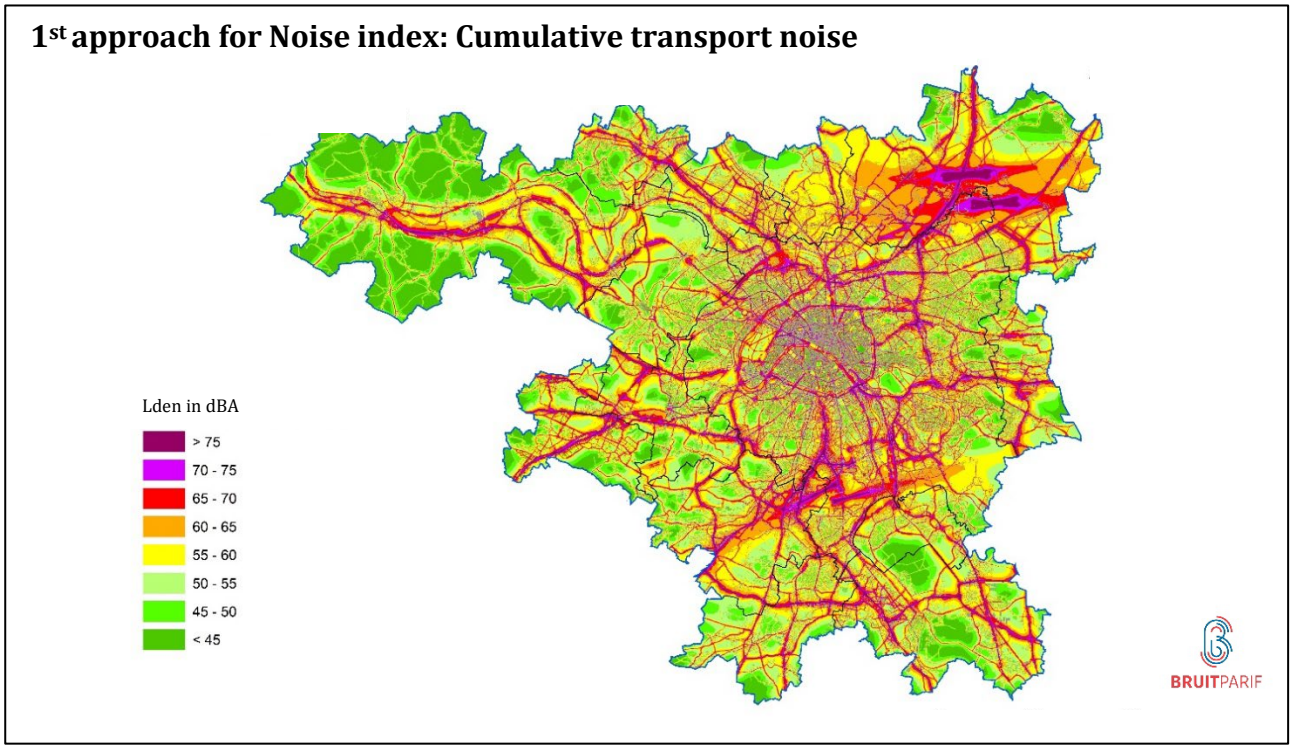

Figure 3: First approach for Noise index: Cumulative noise map for Lden indicator for the dense area of the Ile-de-France region.

4.2. Situation compared to reference values

The second approach is based on a principle similar to that used for the global air quality index. The idea is to determine a noise class for each point in the territory, based on the situation in relation to the reference values available for transport noise. These reference values are, on the one hand, the WHO recommendations [2] to be considered as quality objectives (see Table 2) and, on the other hand, the regulatory limit values (see Table 3) adopted by France in application of European directive 2002/49/EC [5]. Figure 4 provides the noise map resulting from the application of this method.

Table 2: Transport noise recommendations by WHO (2018).

	Lden dBA	Ln dBA
Road	53	45
Rail	54	44
Air	45	40

Table 3: French regulatory limit values for transport noise.

	Lden dBA	Ln dBA
Road	68	62
Rail (conventional)	73	65
Air	55	50

The areas are classified into 7 noise classes, according to the compliance with health recommendations and regulatory thresholds (see Table 4).

Table 4: The 7 noise classes, according to the compliance with health recommendations and regulatory thresholds.

Noise classes	Road noise Lden dBA	Rail noise Lden dBA	Air traffic noise Lden dBA	Significance
1	< 45	< 45	Area not overflown	Compliance with WHO recommendations
2	[45 - 53 [	[45 - 54 [	Area overflown, < 45	
3	[53 - 58 [	[54 - 60 [	[45 - 48 [	Between WHO recommendations and limit values
4	[58 - 63 [	[60 - 67 [	[48 - 52 [	
5	[63 - 68 [	[67 - 73 [	[52 - 55 [	
6	[68 - 75 [	[73 - 80 [	[55 - 60 [	Above at least one limit value
7	≥ 75	≥ 80	≥ 60	

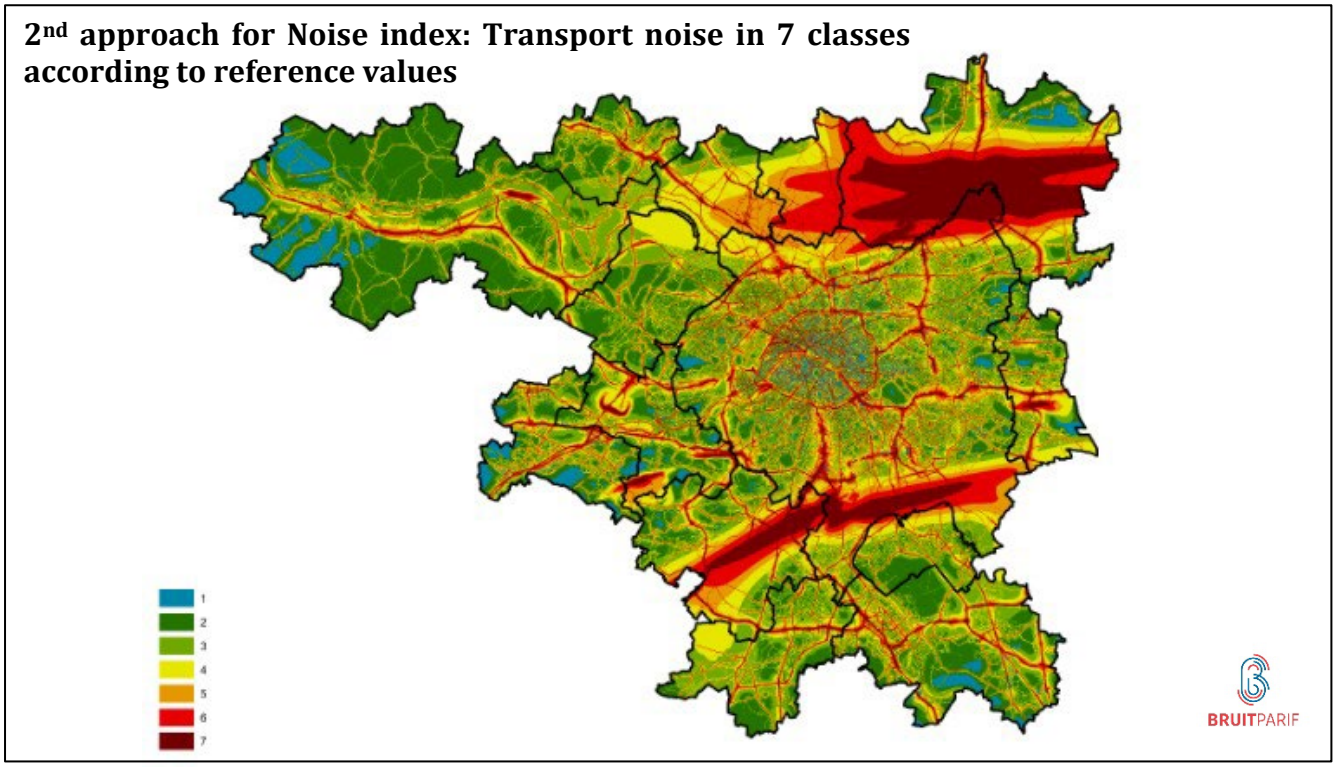

Figure 4: Second approach for Noise index: Transport noise map in 7 classes for the dense area of the Ile-de-France region, according to the compliance with health recommendations and regulatory thresholds.

4.3. Multi-exposure transport noise map based on the annoyance equivalents model

The third tested approach to provide a multi-exposure noise index is based on an annoyance equivalents model. Relationships between exposure to noise (Lden indicator) from a single source (aircraft, road traffic or railways) and annoyance based on a large international dataset have been published by the WHO [2]. The method involves calculating equivalent noise levels in Lden for rail and air traffic noise, which would correspond to the Lden levels of road noise that would be required to generate equivalent rates of highly annoyed people (see the calculation principle in Figure 5).

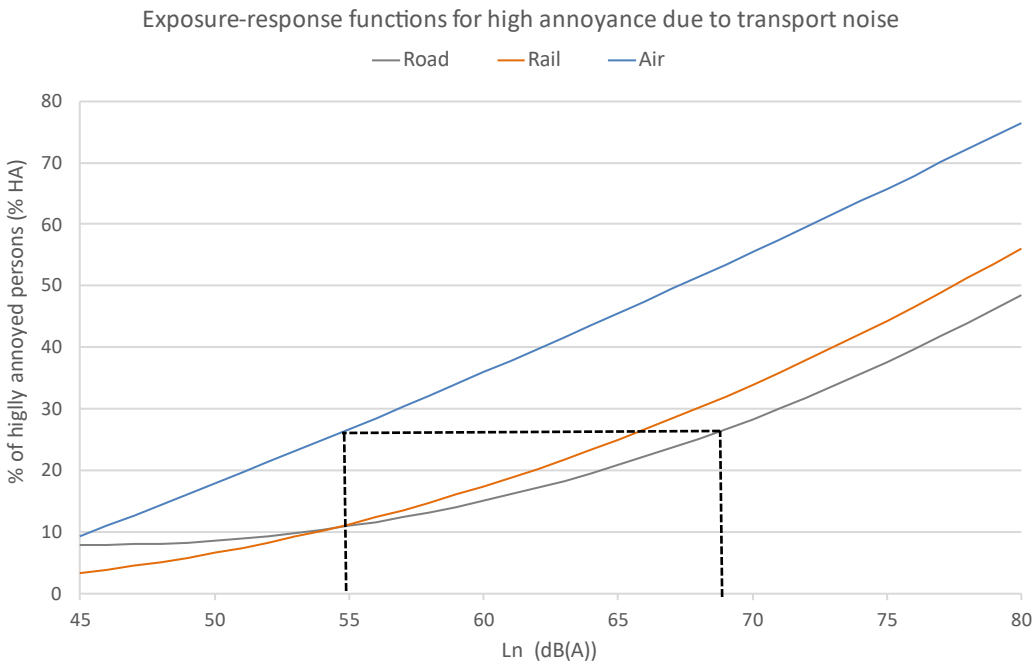

Figure 5: Principle for determining equivalent road noise levels in Lden, based on dose-effects relations for high annoyance due to transport noise. In this example, the Lden air level of 55 dBA is equivalent in terms of annoyance to a road noise level of 69 dBA.

The next step involves summing the road-equivalent rail and air traffic noise levels with the road traffic noise level to obtain the overall road-equivalent Lden noise level. The result of this multi-exposure index is presented in Figure 6.

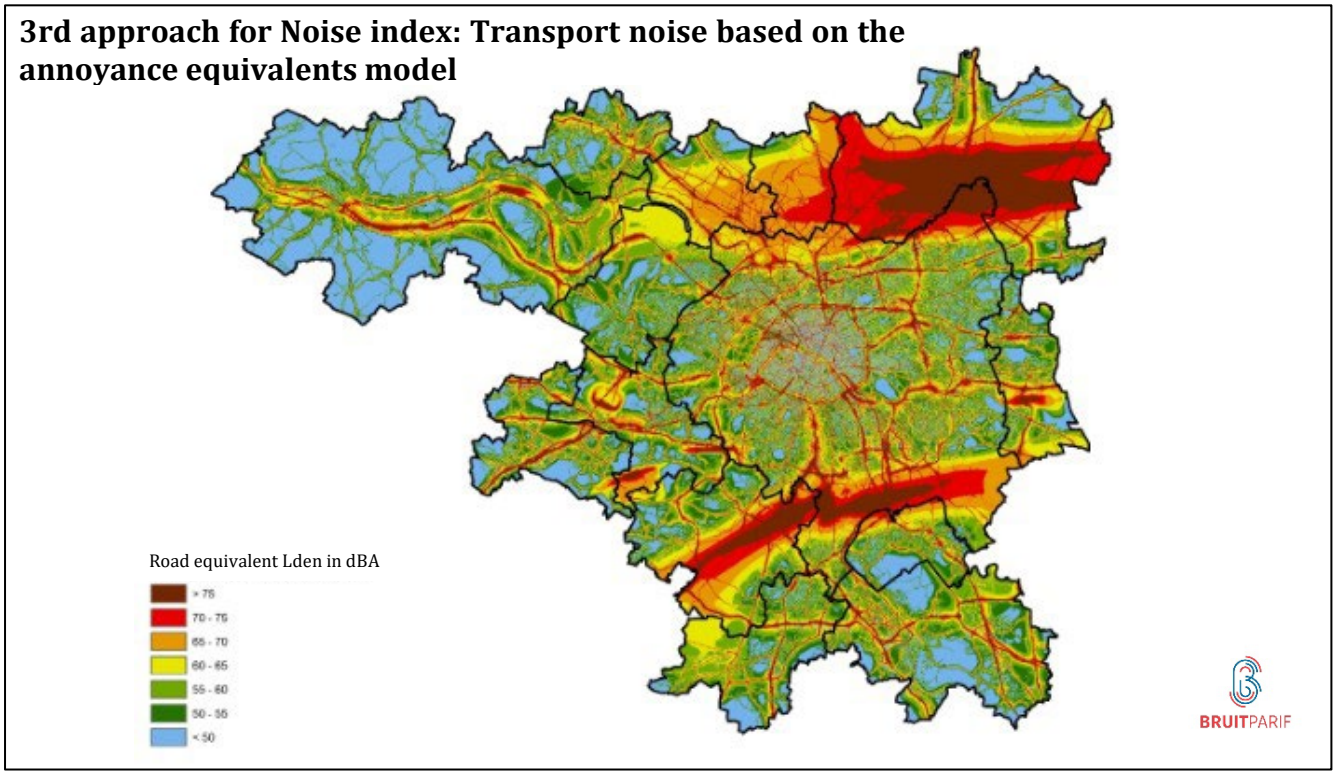

Figure 6: Third approach for Noise index: Multi-exposure transport noise map based on the annoyance equivalents model for the dense area of the Ile-de-France region.

4.4. Discussion on a choice of a multi-exposure index for transport noise

As stated in section 4.1, approach 1 was not adopted due to the lack of reference values for cumulative transport noise. Approaches 2 and 3 each have their advantages and shortcomings.

There are two main advantages to approach 2: first, it can be used directly by public authorities, as it refers to existing reference values for noise abatement. Then, the similarity with the method used for air quality, which ensures methodological consistency in the diagnosis and treatment of the two environmental health issues. On the other hand, noise mapping representation according to approach 2 is dependent on the setting of regulatory limit values, which are not harmonised in Europe and are left to the Member States to decide. The consistency of these limit values with the state of the art of scientific knowledge can sometimes be questioned, as shown for example by the application in France of a "bonus" for rail noise compared with road noise (limit value of 73 dBA for railway noise compared with 68 dBA for road noise) even though the health impacts of rail noise have been shown to be greater than road noise at identical Lden noise levels (see Figure 5).

Approach 3 has the merit of having already been used and tested operationally in France as part of the ORHANE observatory (https://www.orhane.fr) [10], [11]. It is based on scientific principles, with dose-effects relations validated by the WHO. However, it is based on a major assumption, namely that the annoyances associated with the various sources of noise may be cumulative. In its 2018 guidelines [2], the WHO stated that *"Estimated impacts should not be added together without recognizing that addition will, in most practical circumstances, lead to some overestimation of the true impact."*

For these various reasons, we have chosen to retain the two variants (approaches 2 and 3) of the multi-exposure to transport noise index in the context of the coupling work with air pollution presented in the following section.

5. MAPPING REPRESENTATION OF THE CO-EXPOSURE TO NOISE AND AIR POLLUTIONS

Airparif and Bruitparif have worked together on a mapping representation of co-exposure to noise and air pollution that highlights the areas that are the most critical or, conversely, the most protected for both pollutions, as well as the areas where one of the two pollutions is predominant. To do this, it was decided to use an asymmetrical two-dimensional colour scale, as shown in Figure 7.

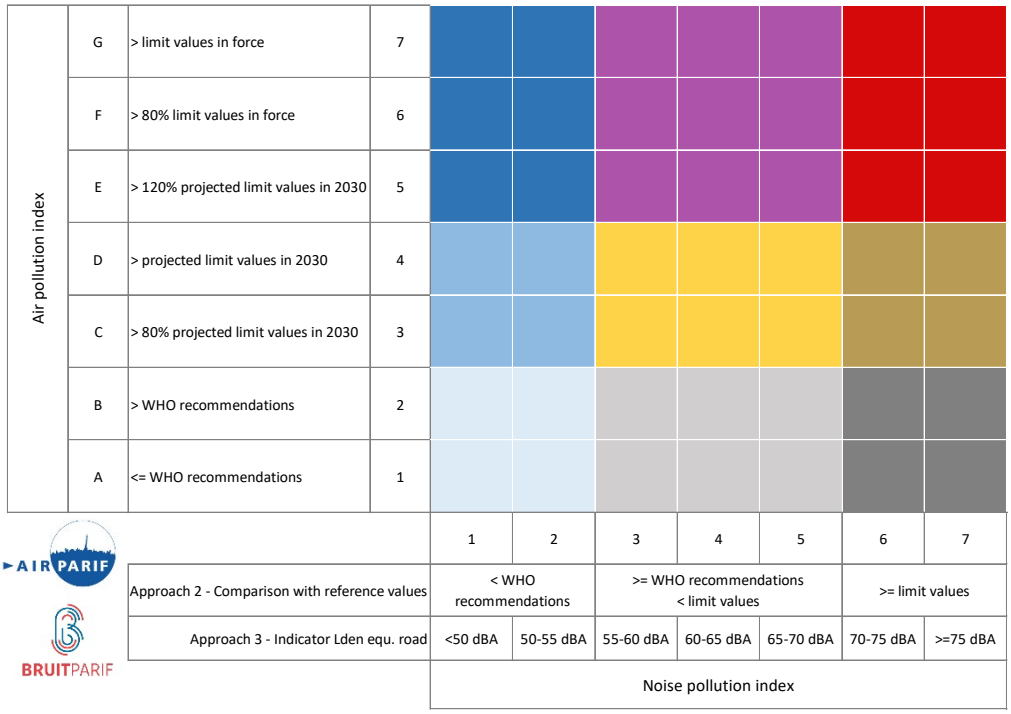

Figure 7: Two-dimensional colour scale for Air-Noise mapping.

The 7 classes corresponding to each index have been grouped into three main categories, each corresponding to a blue (for air pollution) or grey (for noise) colour of increasing intensity depending on the issues at stake. Sectors with both types of pollution are represented by the following four colours: yellow (poor situations for air and noise), red (very poor situations for both air and noise), purple (very poor situation for air and poor situation for noise) and brown (very poor situation for noise and poor situation for air).

Following figures show the Air-Noise maps obtained for the two Noise index variants (approaches 2 and 3) at the scale of the Ile-de-France region (Figure 8).

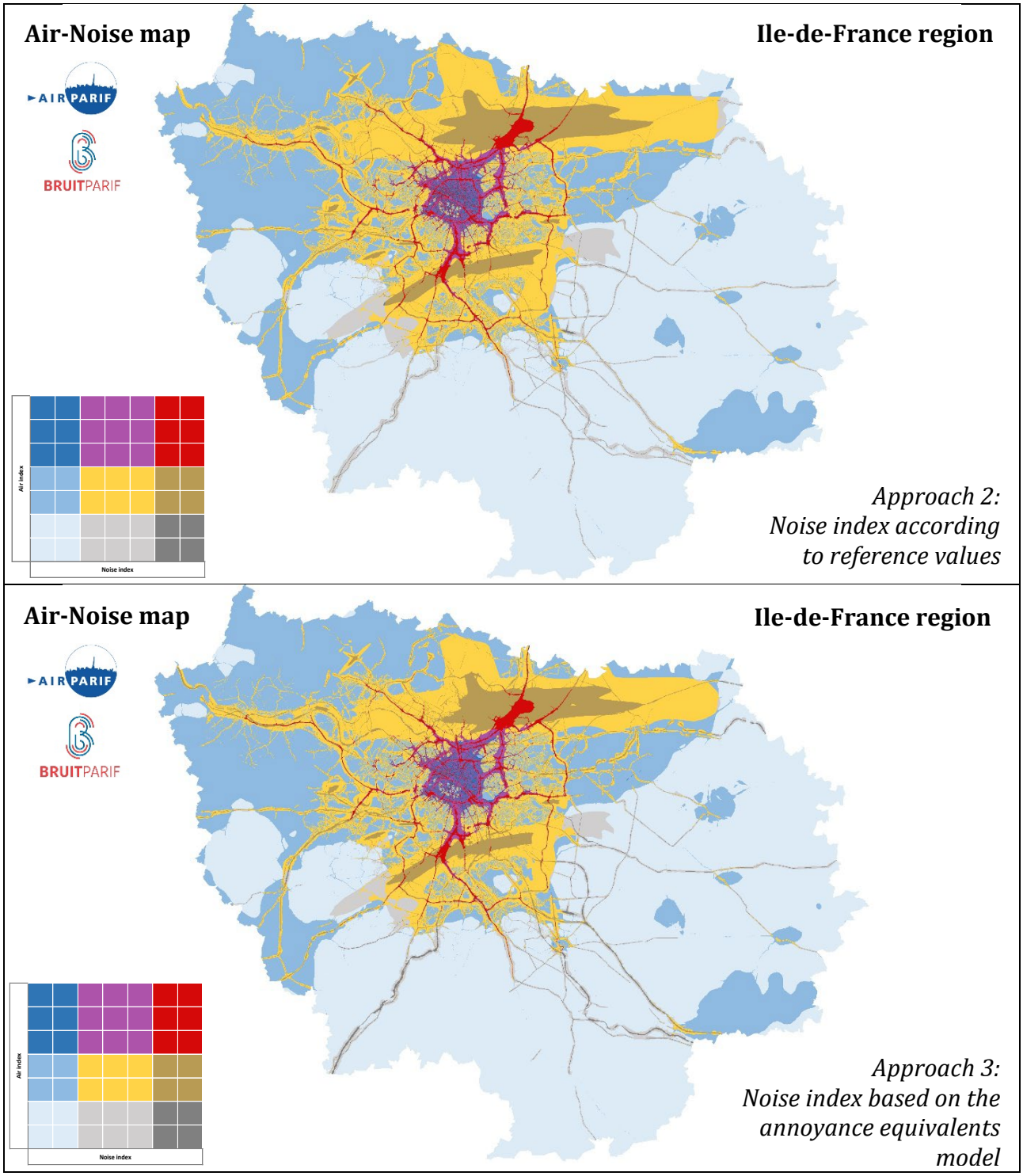

Figure 8: Air-Noise maps for the Ile-de-France region (Noise index approach 2 on the top and Noise index approach 3 on the bottom).

We can note that the Air-Noise maps are quite similar according to the two Noise index variants taken into account. The main differences between the two maps lie in the west area of Paris-CDG airport, with a few small areas changing from brown to yellow. Thus, for the rest of the results, we will only present the Air-Noise maps according to approach 2 (reference values) for the Noise index.

Figures below show the Air-Noise maps obtained at the scale of the dense area of the Ile-de-France region (Figure 9) and at the scale of the city of Paris (Figure 10).

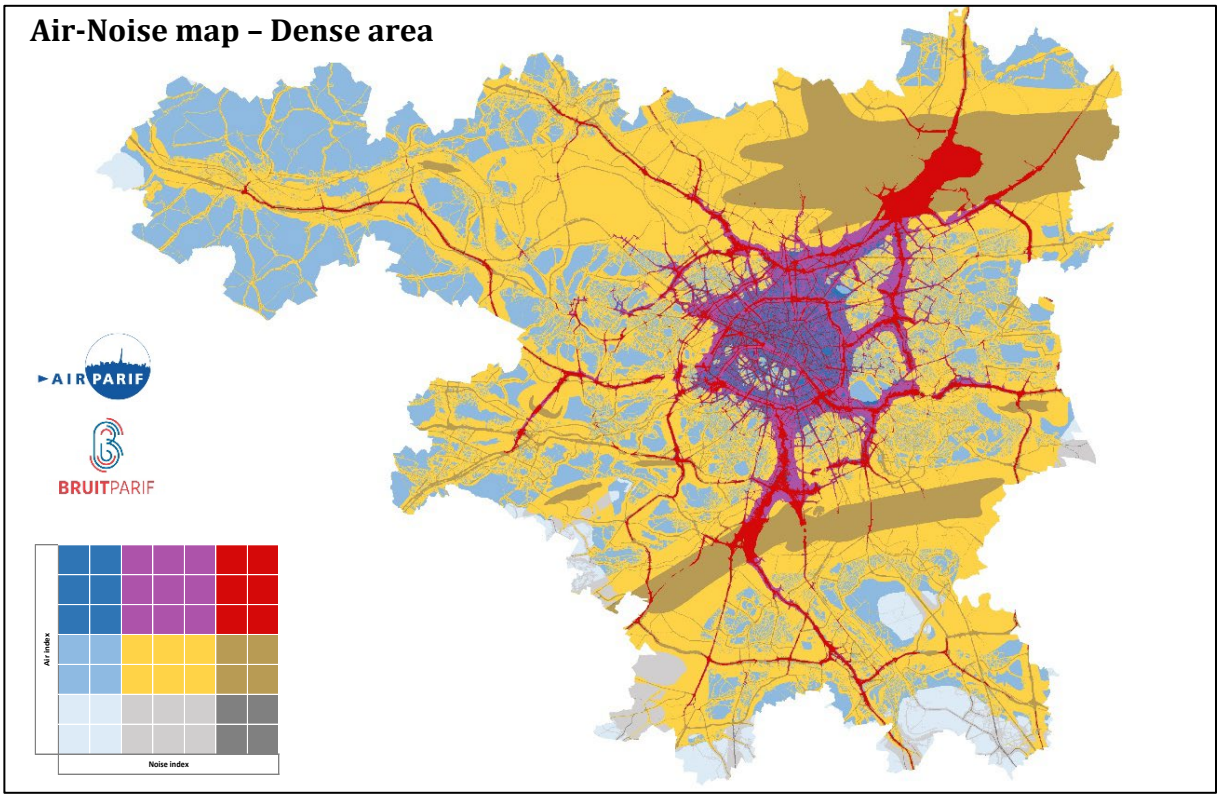

Figure 9: Air-Noise map for the dense area of the Ile-de-France region (Noise index approach 2).

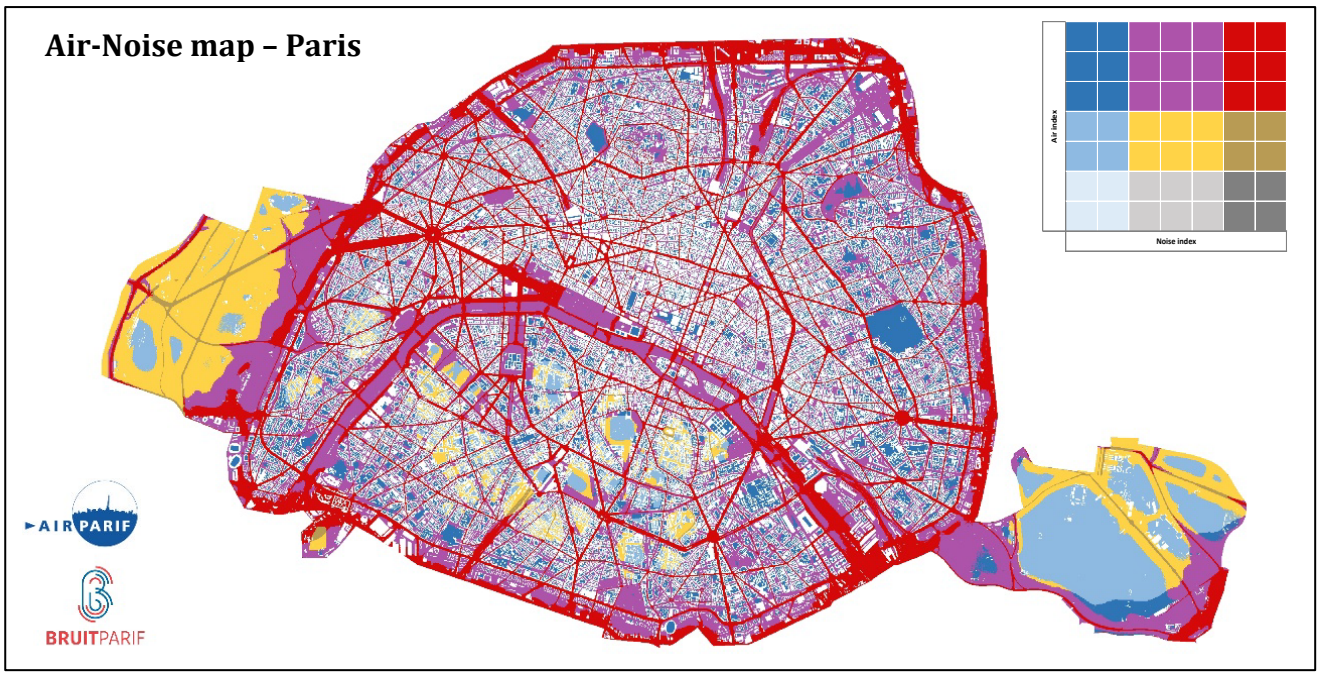

Figure 10: Air-Noise map for the city of Paris (Noise index approach 2).

Then, the Air-Noise maps highlight several major trends:

- Very marked critical air-noise co-exposure issues (areas in red) in the direct vicinity of major roads within the dense area of the Ile-de-France region.
- A large part of the dense area of the region is affected by a poor situation in terms of both noise and air quality (yellow zones), due in particular to airport activity, with a particularly strong issue in terms of noise pollution in the vicinity of airports (brown sectors). It should be noted that the areas around the road access to the airports are areas of very pronounced air-noise co-exposure (areas in red).
- Air pollution increases the closer you get to the dense heart of the conurbation, particularly in Paris and its inner suburbs (dark blue zone).
- In Paris, there is a high degree of air/noise co-exposure in the vicinity of the Paris ring road and major roads. The city experiences, in a large part of the territory, major air quality issues, either combined with a deteriorated quality of the sound environment (purple zones) or relatively free of noise (large urban parks, inner city blocks identified in dark blue). The situation is slightly better in some areas, such as the Bois de Vincennes and Bois de Boulogne, and in some districts of south-west Paris (yellow or medium blue zones).
- Outside the dense area, the south-east of the Ile-de-France region benefits from relatively good air quality (light blue), while the north-west concentrates more air pollution problems (medium blue).
- Specific issues of mono-exposure to noise appear locally in the vicinity of railway lines in the south-eastern half of the Île-de-France region, as well as in sectors outside the dense urban area affected by overflights to and from Paris-Orly airport. Apart from these areas, there is little noise impact further away from the dense area of the Ile-de-France region and the airport zones.

The two-dimensional graphical representation scale was compared with the method used in the Orhane observatory [11]. To cross-reference the air and noise maps, this observatory uses an Air-Noise co-exposure index calculated as the average of the Air index and the Noise index, rounded up to the nearest whole number. We have applied the same method and present the result obtained at the scale of the Ile-de-France region, in comparison with our two-dimensional approach (see Figure 11).

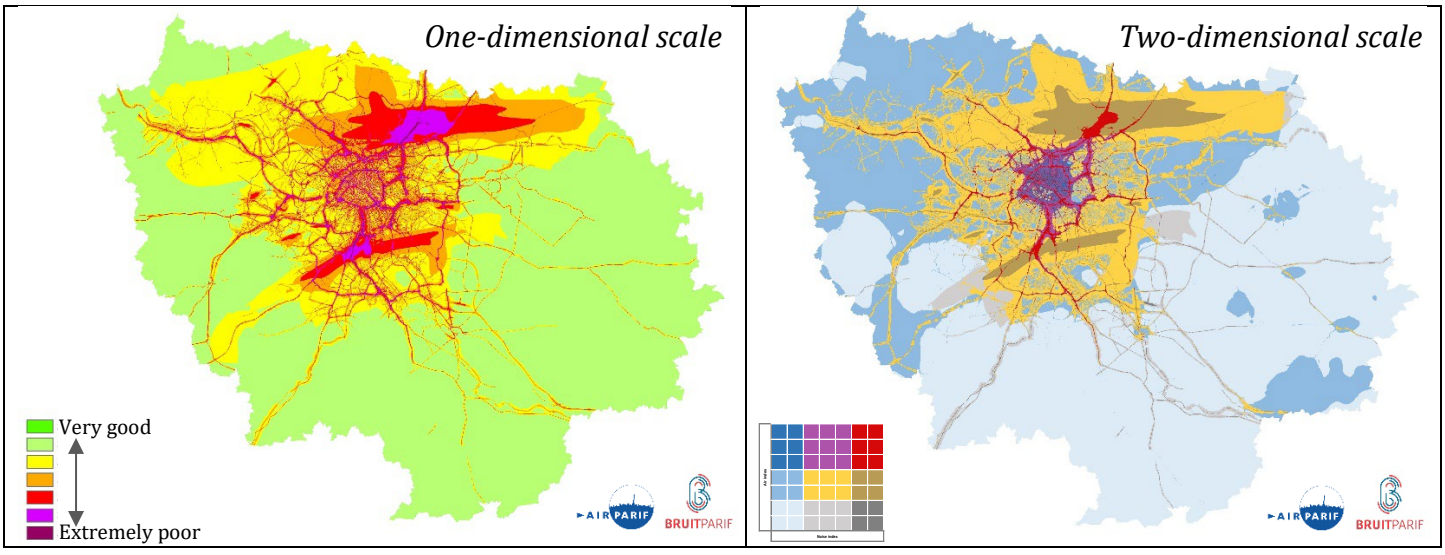

Figure 11: Air-Noise maps produced with a one-dimensional scale according to “Orhane” method (left) or with the two-dimensional scale proposed by Airparif and Bruitparif (right).

Regardless of the different range of colours used in the two graphical representations, we find the same trends in the spatial distribution of exposure to air and noise pollutions. However, the use of a two-dimensional scale makes it easier to highlight the specific issues relating to each of the two types of environmental pollution. The 2D scale distinguishes between areas mainly concerned by air quality issues (in medium and dark blue), areas mainly concerned by noise (in grey), areas where one type of nuisance outweighs the other (brown for noise and purple for air) and, finally, areas of critical co-exposure to the two pollutions (in red).

For these reasons, we believe that it is a mapping representation well suited to providing a meaningful diagnosis of air-noise issues within territories and guiding public action.

6. CONCLUSION

Air-Noise co-exposure is an important issue for local authorities seeking to improve the health and quality of life of their residents. Mapping combining air and noise pollutions is an efficient and operational diagnostic tool for municipalities.

In this article, Airparif and Bruitparif present the method they have jointly developed to provide a meaningful representation of air-noise issues. Applied at different scales in the Île-de-France region, the approach demonstrates its ability to make the various issues of exposure to air and noise pollutions in the region easily understandable.

This makes it possible to identify the areas at stake: those that are preserved from these pollutions and should be protected, and those that are highly exposed and where mitigation measures must be implemented. It offers a wide range of uses, like cross-referencing of air-noise data with the location of establishments receiving vulnerable groups or making comparison with socio-economic data and health indicators.

7. REFERENCES

1. Enquête Crédoc pour Bruitparif : Perception du bruit en Île-de-France fin 2021, Bruitparif, (2022)
2. Environmental Noise Guidelines for the European Region, World Health Organization Regional Office for Europe, (October 2018)
3. World Health Organization. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide: executive summary. World Health Organization. https://iris.who.int/handle/10665/345334. Licence: CC BY-NC-SA 3.0 IGO
4. https://www.airparif.fr/surveiller-la-pollution/bilans-et-cartes-annuels-de-pollution
5. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise", EC, (2002)
6. https://carto.bruitparif.fr
7. Commission Delegated Directive (EU) 2021/1226 of 21 December 2020 amending, for the adapting to scientific and technical progress, Annex II to Directive 2022/49/EC of the European Parliament and of the Council as regards common noise assessment methods, EC, (2021)
8. Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (2008), Official Journal of the European Union. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32008L0050
9. European Commission (2022). Proposal for a Directive of the European Parliament and of the Council on ambient air quality and cleaner air for Europe (recast). COM/2022/542 final. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2022:542:FIN
10. Philippe Olivier, Didier Chapuis, Bruno Vincent, Sebastien Carra, Xavier Olny and Bernard Miege, Air-noise observatory: regional and local scale exposure to air and noise pollution in Rhône-Alpes, Journal of Earth Sciences and Geotechnical Engineering, vol.6, no. 4, 2016, 245-254.
11. https://orhane.fr