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1 **Spatialized composite indices to evaluate environmental health**
2 **inequalities: meeting the challenge of selecting relevant variables**

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24

25 **Abstract**

26 The wide range of factors involved in environmental health and the complexity of interactions
27 between all environmental determinants require the validation of multidimensional approaches.
28 While the development of composite indices is receiving growing attention by scientists and public
29 authorities, the concept continues to lack transposability and robustness partly due to varying
30 conceptualizations and/or methodologies.

31 This review aims to promote harmonizing practices governing the first step of development of
32 composite index, namely identification and characterization of the dimensions and variables that are
33 included in environmental health indices. A review of available literature (more than 1,500 studies)
34 was conducted to identify the composite indices developed to assess territorial determinants from
35 an environmental health perspective. This process made it possible to identify 23 spatialized
36 composite indices and to assess a total of 329 variables. This diversity highlights that the absence of a
37 common framework can lead to a strong subjectivity and limit comparisons between different
38 environmental health indices. The specificity and the availability of certain variables would limit the
39 transposability of indices.

40 In light of current knowledge, this review proposes a consolidated methodological framework based
41 on a categorization of variables into dimensions and sub-dimensions related to health, environment,
42 social, economics, services and policy. To characterize the sub-dimensions, several variables are
43 possible and can be chosen according to the availability and/or accessibility of the data. The
44 adaptation of a composite index to a specific territory or to a specific issue would then be effective
45 through the included variables. This also aims to be transposable to any spatial unit (country, region,
46 census tract).

47 This work is a first step towards a proposal of guidelines designed to provide a consensual framework
48 that could facilitate the exploitation of environmental health indices. This transparency could also
49 increase the understanding and adoption of these tools by public authorities and general public.

50 **Keywords**

51 combined environmental pressure ; indicators ; health determinants ; overlapping inequalities ;
52 interterritorial comparisons

53

54 **Highlights**

- 55 • Composite indices contain many variables and selection methods for specific needs
- 56 • The absence of a common framework leads to strong subjectivity
- 57 • It is possible to harmonize dimension characterization practices
- 58 • A framework is provided for selection of relevant variables for composite indices
- 59 • An increase in methodological transparency will improve interterritorial comparison

60 **1. Introduction**

61 The WHO first tackled the environmental health issue in 1994 by defining the concept as follows:
62 “Environmental health comprises those aspects of human health, including quality of life, that are
63 determined by physical, chemical, biological, social, psychosocial and aesthetic factors in the
64 environment”. In its definition, WHO considers any health problems that are not caused by genetic
65 factors or due to individual choices. The idea of the environment therefore reflects the different
66 neighborhoods of populations and excludes the effect of individual behaviour and voluntary
67 exposition to factors such as alcohol consumption, smoking or unhealthy dietary habits. Although
68 these behavioural and individual factors are socially distributed, many studies suggest that other
69 factors could also contribute to explaining observed health inequalities (Saib, 2015). The health
70 status of populations is thus strongly influenced by complex interactions between all environmental
71 determinants, which are interconnected and evolve over time and space (Sarkar and Webster, 2017).
72 The environment, considered in this context to be the outdoor living environment, is characterised
73 by a number of determinants such as environmental quality (water, air and ground) and living
74 conditions (*e.g.* surroundings, access to healthcare) and by socio-economic parameters such as local
75 economic drive, social disadvantage and education. These different environmental determinants can
76 influence the health status of the population in a combined or sequential way. The environment is
77 currently the subject of increasing apprehension and concern (Scarwell et al., 2013), with a particular
78 emphasis on the possible impacts of environmental quality on health. These consequences are
79 difficult to characterize due to the many aspects that can be harmful or beneficial.

80 The wide range of factors involved in environmental health, the complexity of interactions and their
81 spatio-temporal variabilities all require the validation of multidimensional approaches that would
82 provide more than a simple aggregation of health determinants. One of the recognized methods to
83 explain a complex research problem and follow the evolution of a given phenomenon is based on the
84 creation of composite indices. A composite index is a mathematical combination of variables
85 reflecting one or more selected dimensions that are usually evaluated separately (Nardo et al., 2005;
86 Nascimento and Carrage, 2007). It derived from quantitative or qualitative measurements obtained
87 from field observations (Freudenberg, 2003). In light of the wide range of methodological
88 approaches, the OECD has developed a guidance manual for evaluators, non-specific to
89 environmental health issues (European Commission et al., 2008). This manual confirms the interest
90 of grouping together different variables that measure the multiple facets of the phenomenon and
91 provide a picture of it. A spatial approach, that is the calculation of the composite index for each
92 spatial unit, can be added to provide a further level of information (Beale et al., 2008; Flacke, 2015).
93 A wider availability of spatialized data for the environment, health and population has led to an

94 increase in the number of spatialized epidemiological studies. Composite indices are increasingly
95 recognized as a useful measurement tool for not only etiological approaches but also strategy and
96 policy development, and public communication by institutions (Cutter et al., 2010; Saib et al., 2015;
97 Saisana and Cartwright, 2007).

98 Although an increasing number of studies in the literature show interest in composite indices and
99 report on the growing demand for environmental health variables, a number of questions remain to
100 be answered, particularly with respect to methodological issues (WHO, 1999). Informative reviews
101 have been published on specific aspects of methodological constructions and concentrate on
102 mathematical aspects. The findings of these reviews provide guidelines for future environmental
103 composite indices, mainly in terms of the overall uncertainties linked to each step of the
104 methodology. Many focused on weighting and/or aggregation (Becker et al., 2017; Gan et al., 2017;
105 Greco et al., 2018; Wiréhn et al., 2015). Becker et al. (2017) highlighted the complexity of including
106 weighting in composite indices and presented tools to help developers investigate the effects of
107 weights. The main aim of these works was to propose a methodological framework or a means to
108 evaluate the qualitative aspects of the methodology used to develop composite indices. However, no
109 studies to date have considered the potential inclusion of data, as a carrier of information, for use in
110 composite environmental health indices. There is no recognized standard or internationally
111 recognized rule to determine the number and type of variables to be included in the quantification of
112 environmental health (He et al., 2018). The design of composite indices in environmental health has
113 to be optimized and induced variability must be mastered (Burgass et al., 2017).

114 To this end, this study analyses the literature to identify and characterize the dimensions and
115 variables that are included in environmental health indices. Our analysis will highlight (i) the diversity
116 of the published composite indices, but also (ii) the diversity of variables used in these composite
117 indices. For this purpose, a literature review on the 23 main papers dealing with composite indices in
118 environmental health was conducted. This work is a first step towards a proposal of guidelines
119 designed to provide a consensual framework that facilitates the exploitation of environmental health
120 indices. Their transposability and comparability regardless of the spatial scale were considered as
121 mandatory criteria. The availability or accessibility of data have also been given a special attention.

122

123 **2. Materials and methods**

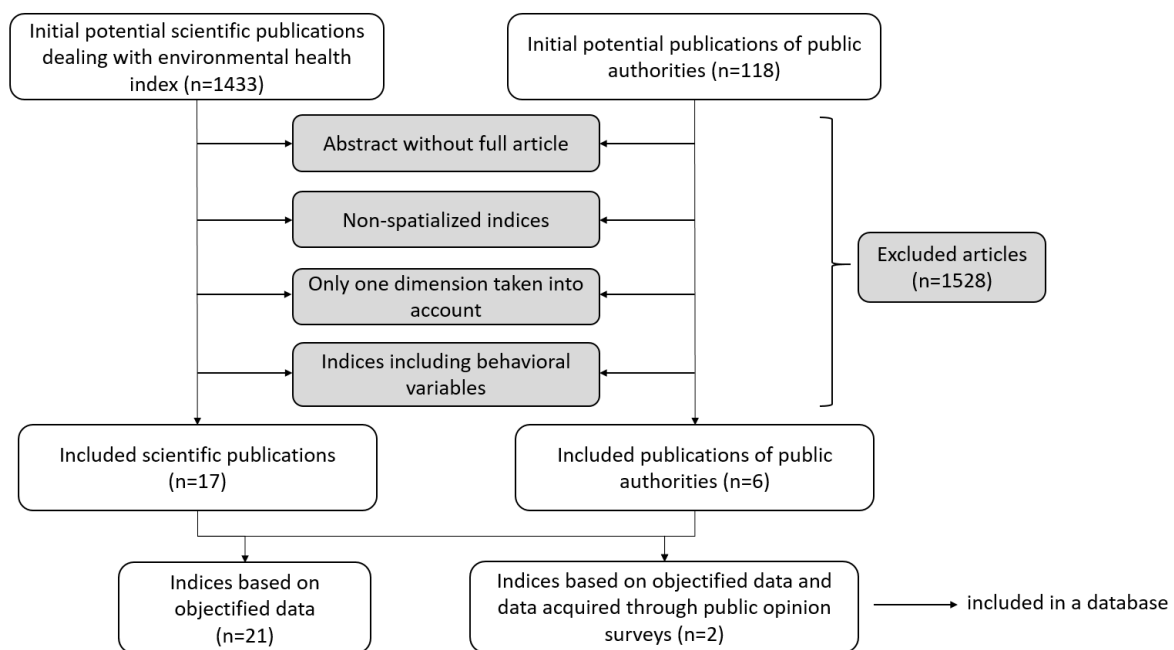
124 **2.1. Methodology for the selection of publications**

125 An analytical framework was developed to ensure the exhaustive nature of this review. The article
126 selection methodology took place in two stages (Figure 1). First, a search with the keywords

127 “environmental health” and “composite indices” was conducted on scientific databases (Wiley,
 128 ScienceDirect, Google Scholar, Web of Science). In a second step, non-academic searches were
 129 carried out on the Google search engine to find methodologies proposed by public authorities, which
 130 were not indexed in the scientific databases. The present review summarizes the data published
 131 before December 2018. Special attention has been given to the use of composite indices to assess
 132 the possible spatial heterogeneity of exposure to the beneficial and harmful aspects of the
 133 environment (Figure 1).

134 At the time this paper was written, a meticulous screening of the 1,551 initial studies was carried out.
 135 The exclusion criteria were (i) studies with an abstract but no provision of the full article, (ii) studies
 136 that developed non-spatialized indices, (iii) composite indices that do not include both health and
 137 environmental data and (iv) composite indices that included behavioural variables.

138



139

140 Fig 1. Results of the article search and outline of the entire article searching process for this systematic review

141 23 spatialized composite indices tested on different geographical perimeters or specific countries
 142 met the inclusion criteria for our analysis. 73.9 % of composite indices were originating from
 143 scientific teams, and 26.1 % from public authorities. 91.3 % were constructed using objectified data
 144 from scientific measurements, 8.7 % based on objectified data and from public opinion data
 145 collected through questionnaire surveys.

146

147 **2.2. Classification of variables within dimensions**

148 A variable, which can also refer to an indicator in some studies although these two terms do not
149 overlap (Maggino, 2017), is linked to an observable phenomenon to which different measured values
150 can be attributed. A variable is a basic element permitting the understanding of a dimension. Several
151 variables may be needed to obtain a complete characterization of a dimension.

152 The dimensions partly reflect the determinants of health presented by Dahlgren and Whitehead
153 (1991), namely environmental, social, economic, housing and educational conditions, all recognized
154 as playing a role in health inequalities. These dimensions are not all systematically found within the
155 composite indices. The authors generally present a classification of variables within each dimension
156 before building the composite index. We observed that a given variable may be classified in different
157 dimensions by different authors, because of a possible overlapping between dimensions.

158 In order to provide an unambiguous reading of the distribution of variables within composite index
159 dimensions, an iterative process was used to categorize variables, based on the principle of greater
160 proximity between the information provided. Thus, the variables that are thematically related have
161 been grouped together within the same dimension and the analysis led to a six-dimensional
162 organization. The dimensions names (health, environment, social determinants, economics, services
163 and policy) are the most frequently mentioned in the literature and are in accordance with the work
164 of (i) Dahlgren and Whitehead (1991) on the determinants of health and (ii) Stiglitz et al. (2009) on
165 the quality of life.

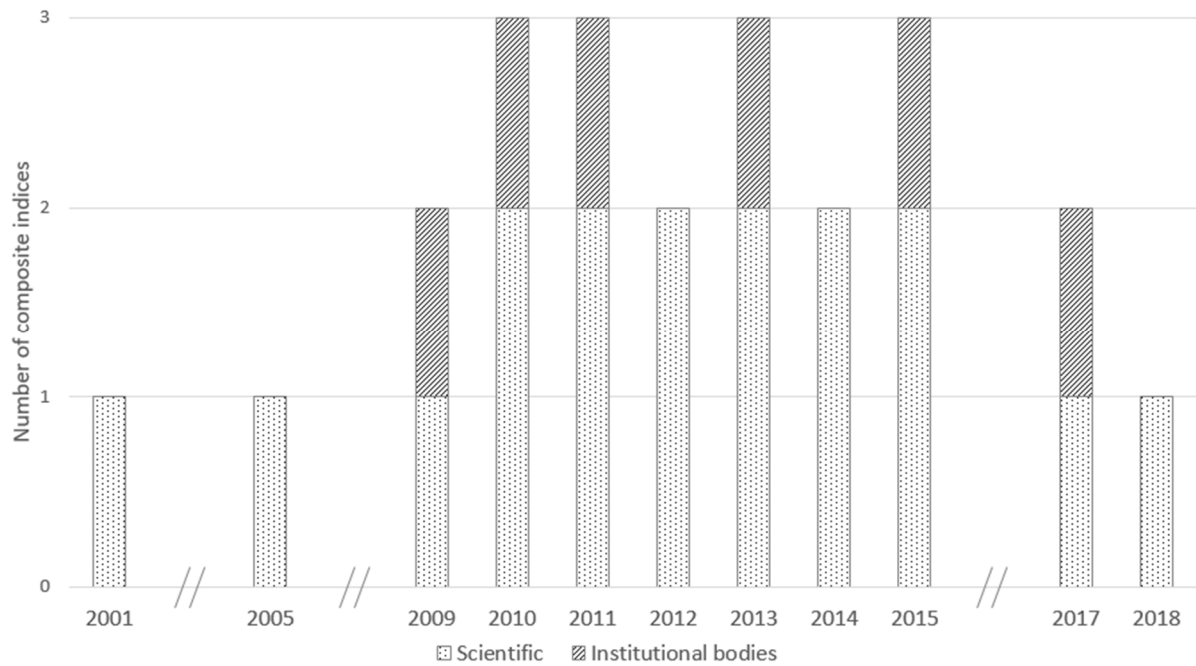
166 The *health* dimension will include all variables related to health in general, but will also incorporate
167 information about resources that can be used to solve public health events in the study area. The
168 *environment* dimension will group together all aspects of environmental quality, the natural
169 characteristics of the spatial unit in question or the environmental hazards to which the populations
170 may be exposed. The *social factors* dimension will include any variable that characterizes the
171 population in terms of its integration, structure, sensitivity and social network, but will also consider
172 educational variables, as education is important for the quality of life regardless of its effects on
173 income (Stiglitz et al., 2009). The *economics* dimension contains any variable that characterizes
174 employability, economic drive and influence, and also the incomes and inequalities of populations in
175 the geographic area considered. The *services* dimension will include all variables that are linked to
176 regional development, population mobility and access to basic necessities and will also incorporate
177 variables for accommodation, a key factor in quality of life for populations (Lejeune et al., 2012).
178 Finally, the *policy* dimension will group together any measures concerning the civil rights and
179 liberties, environmental governance and investments made in the spatial units considered in these
180 studies.

181 **3. Overview of the spatialized composite indices in environmental health**

182 **3.1. Temporal dynamics**

183 The use of spatialized composite indices is relatively recent. The first index to be recognized was the
184 Human Development Index (HDI) (UNDP, 1990), which was developed in order to “direct the
185 developmental economy through policies that are based on human capital rather than an evaluation
186 of national revenue” (WHO, 2012). It is one of the most widely used composite indices (Biggeri and
187 Mauro, 2018) and aims to measure the level of development of countries by considering: 1) health,
188 measured in terms of life expectancy at birth, 2) education, evaluated with the average duration of
189 scolarity, and 3) lifestyle, as proxied by the average gross income per capita. However, the use of this
190 index is considered to be questionable for the management of natural resources and insufficient for
191 human needs (Lasso de la Vega and Urrutia, 2001).

192 Environmental concerns progressively became a central element of socio-economic conditions,
193 leading to suggest that different environmental variables such as pollution or energy consumption
194 should be added to the HDI in order to improve it with a dimension for sustainable development
195 (Lasso de la Vega and Urrutia, 2001; Togtokh and Gaffney, 2010). In environmental health, interest
196 began in 2001 and the vast majority of composite indices which took both health and environment
197 into account were developed after 2009. One or more indices are repeatedly observed in the
198 literature every year. On how the harmful and beneficial impacts are taking into account, two types
199 of index construction are revealed: (i) unique indices that combine variables of negative impact and
200 environmental benefits (Braconnier et al., 2011; Kerényi, 2011; Pearce et al., 2010; Pearson et al.,
201 2013; Stewart et al., 2014; Zuideau and Lipovac, 2009), or (ii) two independently constructed sub-
202 indices that permit the comparison of beneficial or harmful environmental issues (Estoque and
203 Murayama, 2014) or more generally any determinants that have a positive or negative impact on
204 territorial inequalities (Miller et al., 2017). Figure 2 shows the dynamics of publications based on
205 environmental health composite indices.



206
207

Fig 2. Composite indices in environmental health, scientific vs institutional bodies, published since 2001

208 **3.2. Structuration, aim and exploitability of composite indices**

209 Since 2001, environmental health composite indices have been developed by either the scientific
 210 community or by institutional bodies, and have been improved with the addition of different
 211 variables that make it possible to consider (i) the main criticisms of the HDI, and (ii) the multiple
 212 factors that play a role in environmental health. Figure 3 illustrates this diversity of information,
 213 showing the number of variables included in each dimension, as indicated by numbers in each line on
 214 the graph. It does not take into account the effect of a possible weighting (between the variables
 215 within a dimension) in the methodologies developed by the authors.

216

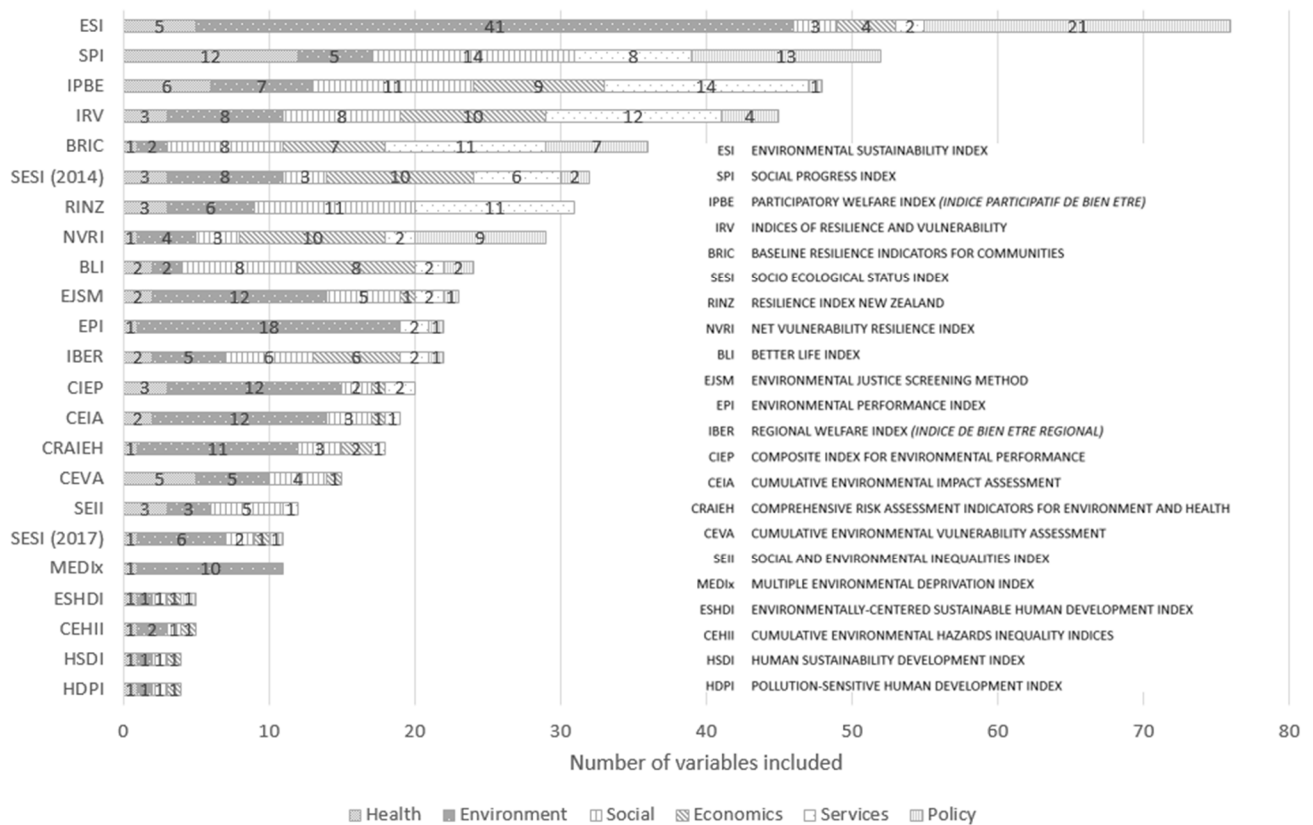


Fig 3. Representativeness of the number of variables within dimensions

217
 218
 219 5 of the 7 indices that are composed of more than 30 variables describe all six dimensions. The RINZ
 220 does not account for economic and political variables (Pearson et al., 2013), and the SPI does not
 221 include economic variables (Porter et al., 2013).

222 The “health” and “environment” dimensions are systematically present, as required by the perimeter
 223 of this literature review. The “social” dimension, including educational data, was found in over 90 %
 224 of all the indices studied, while the “economics” or “services” dimensions that included
 225 accommodation-linked data were found in 78 and 70 % of all the indices studied, respectively. The
 226 “policy” dimension was only found in 56 % of all the indices analysed. The number of variables used
 227 to describe a given dimension differs from one study to another and the conclusions of the authors
 228 did not find this number to be related to the importance of the dimension within the index.

229 The variables that authors include in these dimensions are generally selected to solve the specific
 230 research problematic for which the index was designed, without the use of specific methodological
 231 framework that is reliable or recognized for the creation of composite indices for use in
 232 environmental health. Consequently, each of these indices is situation specific and is difficult to
 233 transpose and/or generalize.

234 Table 1 summarizes the dimensions of each of the 23 composite indices, and specifies the number of
235 variables for each dimension concerned. The table also specifies the country where each index was
236 created, the spatial unit concerned, the aim of the study and the exploitability of the results. The
237 indices marked with an asterisk were developed by agencies or institutional bodies, the others were
238 described in the scientific literature.

Table 1. Synthesis of studied indices

Indices	Identified dimension	Number of variables	Country of origin-spatial unit of study	Weighting of dimensions within index	Aim Exploitability	Reference
Pollution-sensitive Human Development Index (HDPI)	Health	1	Spain. 165 countries	None	Evaluation and ranking of countries. The HDPI penalizes countries that achieved strong economic growth to the detriment of the environment.	Lasso de la Vega and Urrutia (2001)
	Environment	1				
	Social	1				
	Economics	1				
Environmental Sustainability Index (ESI)	Health	5	USA, Switzerland. 146 countries	None	Evaluation of a country's capacity to efficiently preserve its environmental resources over several decades and rank countries. A low score results from low performances for a high number of variables. A decision-making tool.	Etsy et al. (2005)
	Environment	41				
	Social	3				
	Economics	4				
	Services	2				
	Policy	21				
Cumulative Environmental Hazards Inequality Indices (CEHII)	Health	1	USA. Census tract (Los Angeles county)	Population weighted	Comparison of additive and multiplicative methods to characterize inequalities and cumulative environmental hazards.	Su et al. (2009)
	Environment	2				
	Social	1				
	Economics	1				
Indice Participatif de Bien Être (IPBE)* <i>Participatory welfare index</i>	Health	6	France. Three spatial units (France, Nord Pas de Calais region, agglomeration)	Budget Allocation Process (<i>dimension with the strongest weighting: employment or economy</i>)	Spatial comparison and positioning of the results for evaluation of well-being in the three spatial units. Possibility to monitor over time. Also designed to improve communication and alert local authorities.	Zuindeau and Lipovac (2009)
	Environment	7				
	Social	11				
	Economics	9				
	Services	14				
	Policy	1				
Human Sustainability Development Index (HSDI)*	Health	1	Mongolia, Sweden. 169 countries	None	Evaluation and ranking of countries. Like the HDPI, the HSDI penalizes countries that achieved strong environmental growth to the detriment of the environment. Strongly correlated with the HDI (Bravo, 2014).	Togtokh and Gaffney (2010)
	Environment	1				
	Social	1				
	Economics	1				
Baseline Resilience Indicators for Communities (BRIC)	Health	1	USA. 736 counties (Federal Emergency Management Agency IV)	None	Monitoring through time and comparison of the different entities. An increase in the index corresponds to a higher resistance to disasters through individual resources (resilience). Definition of priorities, measurement of progress, help in decision-making processes.	Cutter et al. (2010)
	Environment	2				
	Social	8				
	Economics	7				
	Services	11				
	Policy	7				
Multiple Environmental Deprivation Index (MEDix)	Health	1	United Kingdom. 10,654 census area statistics wards (United Kingdom)	Population weighted	Study of how multiple environmental disadvantages impact health inequality. The index, and thus the inequalities, increase with the north/south gradient.	Pearce et al. (2010)
	Environment	10				

Table 1. Synthesis of studied indices (cont.)

Indices	Identified dimension	Number of variables	Country of origin – spatial unit of the study	Weighting of dimensions within index	Aim Exploitability	Reference
Indice de Bien Être Régionale (IBER) <i>Regional welfare index</i>	Health	2	France. 22 regions	None	Evaluation and ranking of regions. Identification of the dimensions with the weakest results. Comparison of the IBER with other indices (HDI, SHI et GDP per capita). IBER penalizes the regions with contradictory results between dimensions.	Braconnier et al. (2011)
	Environment	5				
	Social	6				
	Economics	6				
	Services	2				
	Policy	1				
Environmental Justice Screening Method (EJSM)	Health	2	USA. Census tracts (Southern California)	None	Evaluation of the cumulative effects of social and environmental stress factors, shown by a high score; ranking of spatial units to enable decision-makers to find more efficient solutions for cumulative negative impacts.	Sadd et al. (2011)
	Environment	12				
	Social	5				
	Economics	1				
	Services	2				
	Policy	1				
Better Life Index (BLI)*	Health	2	34 countries	None	Comparison of the performances of the different countries after adding further variables linked to well-being.	Kerényi (2011)
	Environment	2				
	Social	8				
	Economics	8				
	Services	2				
	Policy	2				
Cumulative Environmental Vulnerability Assessment (CEVA)	Health	5	USA. Census block group (California's San Joaquin Valley)	None	Study of cumulative impacts designed to help authorities by concentrating on units that have a high index, <i>i.e.</i> those with the highest levels of vulnerability (in terms of environmental hazards and social vulnerability as a whole).	Huang and London (2012)
	Environment	5				
	Social	4				
	Economics	1				
Social and Environmental Inequalities Index (SEII)	Health	3	Portugal. 15 neighbourhoods (Porto)	Analytic Hierarchy Process (<i>heaviest weighting: health</i>)	Study of the relations between urban conditions, lifestyles and health events designed to identify the priorities for a strategy to improve the quality of urban life. A high index indicates high inequalities.	Monteiro et al. (2012)
	Environment	3				
	Social	5				
	Services	1				
Resilience Index New Zealand (RINZ)	Health	3	New Zealand, United Kingdom. 1,919 census area units (New Zealand)	None	Identification and quantification for each spatial unit of the characteristics that are linked to resilience, which is strongly associated with the accessibility of certain structures. Can be used by authorities to improve living conditions.	Pearson et al. (2013)
	Environment	6				
	Social	11				
	Services	11				
Environmental Performance Index (EPI)	Health	1	USA, Abu Dabi. 132 countries	Experts adjust according to the relative importance of certain dimensions (<i>heaviest weighting: ecosystem vitality</i>).	Ranking of countries according to performance variables for all categories; and the performances of a given country are measured in relation to the goals.	Hsu et al. (2013)
	Environment	18				
	Services	2				
	Policy	1				

Table 1. Synthesis of studied indices (cont.)

Indices	Identified dimension	Number of variables	Country of origin-spatial unit of study	Weighting of dimensions within index	Aim Exploitability	Reference
Social Progress Index (SPI)*	Health	12	USA. 50 countries	None	Measure performance, facilitate improvement, and seek similarities and differences between countries. Compared with other indices, compensation between dimensions changes the ranking. It seeks to prioritize investments and strengthen the ability to implement life improvement strategies.	Porter et al. (2013)
	Environment	5				
	Social	14				
	Services	8				
	Policy	13				
Socio-Ecological Status Index (SESI)	Health	3	Japan. 81 provinces (Philippines)	None	Ranking and comparison of provinces according to a socio-ecological variable that considers the interactions between humans and the environment without favouring either of these dimensions (low correlation with HDI and HSDI). Ranking of the provinces for all dimensions and sub-dimensions.	Estoque and Murayama (2014)
	Environment	8				
	Social	3				
	Economics	10				
	Services	6				
	Policy	2				
Cumulative Environmental Impact Assessment (CEIA)	Health	2	USA. 372 census tracts (Santa Clara County)	None	Evaluation of the links between social vulnerability, exposition to environmental hazards and access to amenities. A high index indicates areas of high environmental hazards associated with low access to amenities. The results can be used to reform public health policies.	Stewart et al. (2014)
	Environment	12				
	Social	3				
	Economics	1				
	Services	1				
Composite Index for Environmental Performance (CIEP)	Health	3	Spain. 152 countries	Criteria Importance Through Inter-Criteria Correlation (<i>highest weighting: environment</i>).	Ranking of countries and analysis of their performances. A high index indicates better environmental quality (influenced by growth and population density). Monitoring over time is possible. Facilitates decision-making for environmental policies.	García-Sánchez et al. (2015)
	Environment	12				
	Social	2				
	Economics	1				
	Services	2				
Comprehensive Risk Assessment Indicators for Environment and Health (CRAIEH)*	Health	1	China. 58 counties (Jiangsu province, Eastern China)	Multi-Criteria-Decision-Analysis (<i>highest weighting: pressure and state indices</i>)	Evaluation of the risks linked to health and the environment across a wide geographical area. A high index indicates high-risk zones that are affected by industrialization and population density. Facilitates the creation of environmental and public health policies.	Zhang et al. (2015)
	Environment	11				
	Social	3				
	Economics	2				
	Services	1				
Net Vulnerability Resilience Index (NVRI)	Health	1	France. 95 countries	None	Comparison of countries and identification of their individual strengths and weaknesses. The final index combines all the information that reveals a country's ability to create resilience. A tool to provide advice for policy needs.	Angeon and Bates (2015)
	Environment	4				
	Social	3				
	Economics	10				
	Services	2				
	Policy	9				

247

248

Table 1. Synthesis of studied indices (final section)

Indices	Identified dimension	Number of variables	Country of origin – spatial unit of study	Weighting of dimensions within index	Aim Exploitability	Reference
Socio-Ecological Status Index (SESI)	Health	1	Japan. 144 countries	None	Ranking and comparison of counties according to a socio-ecological variable that considers the interactions between humans and the environment. An increase in the index indicates a higher status. Applicable and adaptable on a scale from a province/region to an entire country.	Estoque and Murayama (2017)
	Environment	6				
	Social	2				
	Economics	1				
	Policy	1				
Index of Resilience and Vulnerability*	Health	3	USA. 3,077 counties	None	Identification, measurement and comparison through the use of a resilience / vulnerability quadrant. The spatial units are attributed to one of the four quadrants according to their resilience and vulnerability scores. Facilitates the elaboration of programmes to manage human and natural threats.	Miller et al. (2017)
	Environment	8				
	Social	8				
	Economics	10				
	Services	12				
	Policy	4				
Environmentally-centered Sustainable Human Development Index (ESHDI)	Health	1	Italy. 50 countries	None	Ranking of countries. Results are similar for homogenous countries (the countries with the highest CO ₂ emissions are the most penalized); comparison of this index with the HDI and comparison of the new construction method that penalize heterogeneity with other aggregation methods.	Biggeri and Mauro (2018)
	Environment	1				
	Social	1				
	Economics	1				
	Policy	1				

249

250

251 These 23 composite indices can be differentiated in several ways, thus shedding light on their main
252 strengths and limitations.

253 First, the number of variables included impacts the complexity of the composite indices. By providing
254 an additional environmental dimension to the three initial dimensions of the HDI, Biggeri and Mauro
255 (2018), Lasso de la Vega and Urrutia (2001) and Togtokh and Gaffney (2010) developed an index
256 construction methodology that is close to the reasoning behind the HDI, *i.e.* one variable per
257 dimension. This “minimalism” makes it possible to (i) improve the accessibility and/or availability of
258 variables that give opportunity of comparability across spatial units and across years, and (ii) simplify
259 the reading and understanding of measured phenomena. Etsy et al. (2005), Miller et al. (2017),
260 Porter et al. (2013) and Zuideau and Lipovac (2009) integrated more than 40 variables within their
261 composite index. Their general objective was therefore to improve the representativeness of the
262 index by including a maximum of variables in order to characterize each dimension as well as
263 possible. These authors incorporated issues that were local in scope as well as those that were global
264 in scale. However, a large number of variables increases the probability that variables will not be
265 available for all the spatial units of the study area and the risk of strong inter-variable correlation
266 (Miller et al., 2017), which can complicate the development and interpretation of an index.

267 The authors’ choice of construction methodology varies according to the spatial unit that is being
268 considered. 10 indices were created on a nationwide scale, while 13 others considered a smaller
269 spatial unit. Of these 13, 4 considered an intermediate spatial unit (county, province, region). The 9
270 other composite indices were created for “small” spatial scales, *i.e.* census tracts or neighborhoods.
271 It has been shown that the use of a composite index must provide relevant information, regardless of
272 spatial granularity (Zuideau and Lipovac, 2009).

273 The assignment of weights is not systematic. In the case where each dimension is weighted equally
274 and the number of variables is different within these dimensions, the integrated variables do not
275 necessarily have the same importance in the final composite index (Greco et al., 2018). In addition, if
276 two colinear variables are integrated within the same dimension, this dimension will therefore have a
277 greater weight due to the phenomenon of “double counting” (Greco et al., 2018). Becker et al. (2017)
278 underlined the importance of correlation phenomena on the assignment of weights, which can be
279 optimized to reflect the desired importance of a dimension. 16 of the 23 indices did not assign
280 weights during the aggregation process. This lack of weighting is justified in two ways: (i) this method
281 is transparent and easy to understand for potential users, and (ii) there is no adequate scientific
282 justification for a dimension having more weight than another (Cutter et al., 2010; Estoque and
283 Murayama, 2014; Porter et al., 2013). For Burgass et al. (2017), this lack of knowledge concerning the

284 importance of one dimension with regard to another, or the reticence to prioritize one dimension
285 over another, even if the former is considered neutral, are in themselves a weighting decision.

286 The composite indices analysed could also be distinguished according to the authors'
287 recommendations as for the exploitation of their research results. In 13 of the 23 composite indices,
288 the authors consider that the results could be used for the development of public health or
289 environmental policies. They also underline that their indices are developed to meet the needs of
290 decision makers in terms of tools to identify, understand and monitor the phenomena occurring in
291 their territory, but also to allocate investments (Etsy et al., 2005). Of the 13 indices, 4 were
292 developed by agencies or institutions, of which only 2 mention a possible direct exploitation of
293 results (Miller et al., 2017; Zhang et al., 2015). This low number can be explained in two ways: either
294 the composite index developed was more an "experiment" requiring further improvement in the
295 light of identified limitations, or the index was developed by an agency that was not in a position to
296 implement new public and/or environmental health policies.

297

298 **3.3. Identification of dimensions and associated variables**

299 The analysis of the 23 indices made it possible to highlight the existence of sub-dimensions. Each
300 sub-dimension aims to bring an additional level in the description of a dimension. The variables used
301 to characterize each sub-dimension were justified by the spatial scale of the study, the level of
302 development, the availability or the accessibility of data. Table 2 presents examples of variables from
303 the 23 studied articles, these have been classified in the appropriate sub-dimensions.

Table 2. Characterization of sub-dimensions and distribution of variables within dimensions.

Dimension	Sub-dimensions	Number of identified variables	Examples of variables	References
Health	General population health	9	Life expectancy at birth, at 60 and at 65 years of age	Biggeri and Mauro (2018), Braconnier et al. (2011), Estoque and Murayama (2014, 2017), García-Sánchez et al. (2015), Kerényi (2011), Lasso de la Vega and Urrutia (2001), Miller et al. (2017), Porter et al. (2013), Togtokh and Gaffney (2010), Zuideau and Lipovac (2009)
			General death rate	Pearce et al. (2010), García-Sánchez et al. (2015)
			Children death rate	Hsu et al. (2013), Etsy et al. (2005), García-Sánchez et al. (2015), Porter et al. (2013)
			Birth rate	Zuideau and Lipovac (2009)
			Fertility rate	Etsy et al. (2005)
	Environmental health indicators or complementary indicators of general public health	18	Rate of low weight at birth	Estoque and Murayama (2014), Huang and London (2012), Miller et al. (2017), Sadd et al. (2011), Stewart et al. (2014), Su et al. (2009)
			Rates of obesity	Porter et al. (2013)
			Death due to cardiovascular disease	Porter et al. (2013)
			Death due to HIV	Porter et al. (2013)
			Chronic Obstructive Pulmonary Disease rate	Monteiro et al. (2012)
	Health care facilities	8	Rate of hospitalisation for asthma for 0-19 year-olds	Huang and London (2012), Estoque and Murayama (2014)
			Number of hospital beds or General Practitioners	Braconnier et al. (2011), Cutter et al. (2010), Miller et al. (2017), Pearson et al. (2013), Zhang et al. (2015), Zuideau and Lipovac (2009)
			Access to pharmacies	Pearson et al. (2013)
			Accessibility of all possible medical specialities	Estoque and Murayama (2014), Huang and London (2012), Miller et al. (2017), Pearson et al. (2013), Porter et al. (2013)
Accessibility of health care specialities			Angeon and Bates (2015), Estoque and Murayama (2014), Porter et al. (2013)	
Environment	Anthropogenic pressure	16	Accessibility of emergency services	Pearson et al. (2013)
			Greenhouse gas emissions	Angeon and Bates (2015), Biggeri and Mauro (2018), Estoque and Murayama (2017), Etsy et al. (2005), García-Sánchez et al. (2015), Hsu et al. (2013), Lasso de la Vega and Urrutia (2001), Porter et al. (2013), Togtokh and Gaffney (2010)
			Ecological footprint	Estoque and Murayama (2017), Etsy et al. (2005), Porter et al. (2013)
	Natural resources	23	Use of fertilizers and pesticides per hectare of arable land	Etsy et al. (2005), García-Sánchez et al. (2015), Huang and London (2012), Stewart et al. (2014)
			Fresh and/or underground water resources	Etsy et al. (2005), Zhang et al. (2015)
			Closeness to green spaces, parks and open spaces	Monteiro et al. (2012), Pearce et al. (2010), Pearson et al. (2013), Stewart et al. (2014)
			Access to energy or the production	Angeon and Bates (2015), Etsy et al. (2005), García-Sánchez et al. (2015), Hsu et al. (2013), Porter et al. (2013)
Area of agricultural land	García-Sánchez et al. (2015), Zuideau and Lipovac (2009)			

Table 2. Characterization of sub-dimensions and distribution of variables within dimensions (cont.).

Dimension	Sub-dimensions	Number of identified variables	Examples of variables	References
Environment	Biodiversity	10	Number of endangered species (amphibians, birds and mammals)	Etsy et al. (2005)
			Monetary value for ecosystem services	Estoque and Murayama (2014)
			Proportion or density, of the area that included protected zones	Angeon and bates (2015), Estoque and Murayama (2014, 2017), Etsy et al. (2005), García-Sánchez et al. (2015), Hsu et al. (2013), Zuideau and Lipovac (2009)
			Natura 2000 classified land, total area of ecologically rich land	Braconnier et al. (2011), Zuideau and Lipovac (2009)
			Total land artificialisation	Braconnier et al. (2011)
	Water quality	10	Concentration of dissolved oxygen	Etsy et al. (2005)
			Electric conductivity	Etsy et al. (2005)
			Phosphorus concentration	Etsy et al. (2005)
			concentration of suspended solids	Etsy et al. (2005)
			Average nitrate concentration	Zuideau and Lipovac (2009)
			Proportion of good quality water	Braconnier et al. (2011), Kerényi (2011), Pearson et al. (2013)
			Percentage of the population that had access to a water network served by water systems with at least one health-based violation	Miller et al. (2017)
			Data pertaining to the organic water pollutants	Etsy et al. (2005), Porter et al. (2013)
			Areas that suffer from water scarcity	Hsu et al. (2013)
	Air quality	26	NO _x , NO ₂ : emissions and/or concentrations, population-weighted, per unit of area, per populated land area	Etsy et al. (2005), Pearce et al. (2010), Su et al. (2009), Zhang et al. (2015)
			SO ₂ : emissions and/or concentrations, population weighted, per unit of area, exportations	Etsy et al. (2005), Hsu et al. (2013), Zhang et al. (2015)
			PM _{2.5} , PM ₁₀ , TSP : average annual concentration, population weighted or not	Etsy et al. (2005), Hsu et al. (2013), Kerényi (2011), Pearce et al. (2010), Pearson et al. (2013), Sadd et al. (2011), Su et al. (2009)
			Weighted annual average of the ATMO index	Zuideau and Lipovac (2009)
			Average number of days per year in areas where ozone exceeds the safe threshold for human health	Braconnier et al. (2011), Sadd et al. (2011)
			Indoor air pollution	Etsy et al. (2005), Hsu et al. (2013)
			Carbon monoxide CO	Pearce et al. (2010)
			Volatil Organic Compounds (VOC)	Etsy et al. (2005)

Table 2. Characterization of sub-dimensions and distribution of variables within dimensions (cont.).

Dimension	Sub-dimensions	Number of identified variables	Examples of variables	References
Environment	Environmental safety or environmental risks	21	Percentage of the population living less than 10 miles from a nuclear plant	Miller et al. (2017)
			Proximity measures for different pollution sources (industries, hazardous waste sites, transport infrastructures, etc.)	Braconnier et al. (2011), Huang and London (2012), Miller et al. (2017), Monteiro et al. (2012), Pearce et al. (2010), Sadd et al. (2011), Stewart et al. (2014), Zuideau and Lipovac (2009)
			Models of noise from different sources (road traffic, industry, ...)	Zuideau and Lipovac (2009)
			Natural risks (flooding and earthquakes, amongst others)	Cutter et al. (2010), Estoque and Murayama (2014), García-Sánchez et al. (2015), Miller et al. (2017)
Social	Social network	5	Number of associations or the proportion of the population involved in these associations, social defense organizations	Braconnier et al. (2011), Cutter et al. (2010), Miller et al. (2017), Zuideau and Lipovac (2009)
	Integration and anomie	21	Percentage of households that are considered linguistically isolated	Cutter et al. (2010), Huang and London (2012), Miller et al. (2017), Sadd et al. (2011), Stewart et al. (2014)
			Suicide rates, comparative suicide mortality index	Braconnier et al. (2011), Zuideau and Lipovac (2009)
			Violent crimes rates, homicide or criminality rate, number of police officers per 10,000 inhabitants	Braconnier et al. (2011), Estoque and Murayama (2014), Kerényi (2011), Miller et al. (2017), Porter et al. (2013), Zuideau and Lipovac (2009)
			Data related to ethnicity	Huang and London (2012), Pearson et al. (2013), Sadd et al. (2011), Su et al. (2009), Zuideau and Lipovac (2009)
	Population sensitivity	6	Age-related data	Cutter et al. (2010), Huang and London (2012), Miller et al. (2017), Monteiro et al. (2012), Sadd et al. (2011), Stewart et al. (2014), Zhang et al. (2015)
			Part of the population with and without disabilities	Cutter et al. (2010), Miller et al. (2017)
	Education level	18	Literacy or scolarity rate	Biggeri and Mauro (2018), Cutter et al. (2010), Lasso de la Vega and Urrutia (2001), Porter et al. (2013), Sadd et al. (2011), Togtokh and Gaffney (2010)
			Number of individuals that have continued to higher education and/or obtained further qualifications	Braconnier et al. (2011), Cutter et al. (2010), Huang and London (2012), Kerényi (2011), Zuideau and Lipovac (2009)
			Presence or distance to childcare facilities	Cutter et al. (2010), Estoque and Murayama (2014), Pearson et al. (2013), Zuideau and Lipovac (2009)
			Presence or distance to schools, state schools and /or higher education establishments	Pearson et al. (2013), Porter et al. (2013)
PISA score (Programme for International Student Assessment)			Kerényi (2011)	

Table 2. Characterization of sub-dimensions and distribution of variables within dimensions (cont.).

Dimension	Sub-dimensions	Number of identified variables	Examples of variables	References
Social	Social resources	3	Access to contraception, childcare	Pearson et al. (2013), Porter et al. (2013)
			Proportion of the population that received public aid	Braconnier et al. (2011), Monteiro et al. (2012)
	Urbanization	4	Rural / urban status	Pearson et al. (2013), Zhang et al. (2015)
			Population density	Estoque and Murayama (2014, 2017), García-Sánchez et al. (2015), Monteiro et al. (2012), Pearson et al. (2013)
			Number of accidents or victims of road accidents	Braconnier et al. (2011), Zuideau and Lipovac (2009)
		Urban population growth	Etsy et al. (2005), García-Sánchez et al. (2015), Pearson et al. (2013)	
Economics	Employability	8	Employment and/or unemployment rate	Angeon and Bates (2015), Braconnier et al. (2011), Cutter et al. (2010), Estoque and Murayama (2014), Kerényi (2011), Miller et al. (2017), Zuideau and Lipovac (2009)
			Proportion of unstable contracts, insecurity rate of labour market	Estoque and Murayama (2014), Kerényi (2011), Zuideau and Lipovac (2009)
	Diversity and/or economic drive	15	Rate of job creation over three years and the company deregistration rate	Braconnier et al. (2011)
			Part of the population employed in different sectors	Etsy et al. (2005), Braconnier et al. (2011), Estoque and Murayama (2014), Miller et al. (2017), Zuideau and Lipovac (2009)
			Company creation rate, delisting of companies	Braconnier et al. (2011), Miller et al. (2017), Zuideau and Lipovac (2009)
			Training offer for the unemployed	Zuideau and Lipovac (2009)
			Diversity of job sectors	Miller et al. (2017)
	Equality of sexes	2	Rate of childcare for children under the age of three	Braconnier et al. (2011)
			Proportion of women in the labour market	Cutter et al. (2010)
	Incomes	8	Income per capita, gross available household revenue, median income per consumption unit	Angeon and Bates (2015), Biggeri and Mauro (2018), Braconnier et al. (2011), Estoque and Murayama (2014, 2017), García-Sánchez et al. (2015), Kerényi (2011), Lasso de la Vega and Urrutia (2001), Togtokh and Gaffney (2010), Zhang et al. (2015), Zuideau and Lipovac (2009)
			D9/D1 ratio of income distribution, Gini Index	Braconnier et al. (2011), Cutter et al. (2010), Miller et al. (2017)
Household savings			Kerényi (2011), Miller et al. (2017), Zhang et al. (2015)	
Proportion of the population below the poverty threshold, or more than twice below the poverty threshold			Estoque and Murayama (2014), Huang and London (2012), Miller et al. (2017), Sadd et al. (2011), Stewart et al. (2014), Su et al. (2009)	

Table 2. Characterization of sub-dimensions and distribution of variables within dimensions (cont.).

Dimension	Sub-dimensions	Number of identified variables	Examples of variables	References
Economics	Economic influence	7	Proportion of polluting goods and raw materials that had been imported and the ratio of gasoline price compared to the world average	Etsy et al. (2005)
		2	Sums invested in private investments	Angeon and Bates (2015)
			Current transfers and transport costs	Angeon and Bates (2015)
Services	Access to the homeownership market	3	Proportion of home owners who occupy their main dwelling address	Braconnier et al. (2011), Cutter et al. (2010), Miller et al. (2017), Sadd et al. (2011), Stewart et al. (2014), Zuideau and Lipovac (2009)
			Accessibility to affordable accommodation	Porter et al. (2013)
	Habitat characteristics	8	Age of the dwelling	Cutter et al. (2010), Miller et al. (2017), Monteiro et al. (2012)
			Proportion of the population that lived in an uncomfortable and/or overpopulated dwelling with the number of rooms per capita	Kerényi (2011), Zhang et al. (2015), Zuideau and Lipovac (2009)
			Median value of the dwelling	Sadd et al. (2011)
	Access to basic needs	7	Percentage of the population with or without access to fresh water, electricity or sanitation facilities	Angeon and Bates (2015), Etsy et al. (2005), García-Sánchez et al. (2015), Hsu et al. (2013), Kerényi (2011), Miller et al. (2017), Porter et al. (2013)
			Distance from ambulance and fire services	Pearson et al. (2013)
			Proportion of the population with or without covered by medical insurance	Cutter et al. (2010), Miller et al. (2017)
	Access to public services	1	Number of places for seniors citizens in residential homes	Zuideau and Lipovac (2009)
	Access to information and communication	2	Number of mobile telephone or internet contracts, digital access index	Angeon and Bates (2015), Estoque and Murayama (2014), Etsy et al. (2005), Cutter et al. (2010), Porter et al. (2013)
			Proportion of population that had a telephone, number of people with landline telephones	Estoque and Murayama (2014)
	Mobility	8	Number of kilometres of the public transport network per citizen and the proportion of the road network that includes cycle paths	Zuideau and Lipovac (2009)
			Length of main and secondary roads per unit of area	Cutter et al. (2010), Estoque and Murayama (2014), Miller et al. (2017)
			Proportion of the population that worked in the same employment area	Zuideau and Lipovac (2009)
			Proportion of the population that owned a vehicle	Cutter et al. (2010), Miller et al. (2017), Zuideau and Lipovac (2009)
Proportion of the population who still reside in the state where they were born			Cutter et al. (2010), Miller et al. (2017), Pearson et al. (2013), Zuideau and Lipovac (2009)	

Table 2. Characterization of sub-dimensions and distribution of variables within dimensions (final section)

Dimension	Sub-dimensions	Number of identified variables	Examples of variables	References
Services	Land use planning	14	Presence or proximity of different infrastructures that had a positive or negative effect on the phenomena studied (cinemas, sports and leisure facilities, healthy and unhealthy living infrastructures)	Braconnier et al. (2011), Cutter et al. (2010), Miller et al. (2017), Pearson et al. (2013), Zuindeau and Lipovac (2009)
Policy	Political commitment	1	Voting rate	Cutter et al. (2010), Estoque and Murayama (2014), Kerényi (2011), Miller et al. (2017), Sadd et al. (2011), Zuindeau and Lipovac (2009)
	Civil and political rights	15	Individual liberties (speech, assembly rights, religion, ...) and tolerance	Angeon and Bates (2015), Biggeri and Mauro (2018), Etsy et al. (2005), Miller et al. (2017), Porter et al. (2013)
			Individual property rights	Porter et al. (2013)
	Integrity	2	Corruption, democracy or civil and political liberties	Angeon and Bates (2015), Estoque and Murayama (2017), Etsy et al. (2005)
			Government efficiency (defined as the quality of public services)	Angeon and Bates (2015), Etsy et al. (2005)
	Environmental governance	7	Effectiveness of environmental governance, knowledge creation in environmental, technological and political sciences	Etsy et al. (2005)
			Local Agenda 21 initiatives	Angeon and Bates (2015), Etsy et al. (2005)
			Number of environmental treaties	Angeon and bates (2015)
	Political fragmentation	1	Jurisdictional overlap	Cutter et al. (2010), Miller et al. (2017)
	Anticipate and plan	5	Proportion of the population covered by protection programs	Cutter et al. (2010)
			Country's ability to cope with any kind of threat	Angeon and Bates (2015)
	Budget	5	Share of expenditures for local services	Angeon and Bates (2015), Cutter et al. (2010), Estoque and Murayama (2014), Miller et al. (2017)
			Subsidies, including those for agriculture	Etsy et al. (2005), Hsu et al. (2013)
Regional public spending			Braconnier et al. (2011)	
General government final consumption			Angeon and Bates (2015)	

318 **3.3.1. The “health” dimension**

319 The number of variables included in the “health” dimension of the composite indices studied varies
320 from 1 for Angeon and Bates (2015), Biggeri and Mauro (2018), Hsu et al. (2013), Lasso de la Vega
321 and Urrutia (2001), Pearce et al. (2010), Pearson et al. (2013), Su et al. (2009), Togtokh and Gaffney
322 (2010) and Zhang et al. (2015) to 12 for Porter et al. (2013). The contribution of these variables to the
323 final index varies from 3 % (Angeon and Bates, 2015; Cutter et al., 2010) to 33 % (Huang and London,
324 2012).

325 For the measurement of **general population health**, the most frequently observed health variable is
326 life expectancy at birth, at 60 or at 65 years of age (47.8 % of studies). Death rate is also found in
327 works by Pearce et al. (2010) and Pearson et al. (2013). Hsu et al. (2013) used the child death rate to
328 develop the EPI while Etsy et al. (2005) used the death rates for infectious intestinal disease, for
329 deaths of children due to respiratory disease and the death rate for children under the age of five per
330 1,000 births in the “reducing human vulnerability” component. Mortality variables for children
331 and/or children under the age of five are sensitive variables that reflect recent changes in
332 environmental and economic conditions, and unlike adult deaths are less reliant upon the time
333 between exposure and the declaration of the illness (Sherrieb et al., 2010). Finally, some authors
334 mention the fertility rate (Etsy et al., 2005), to indicate social evolution when socio-economic,
335 political or health conditions improve (Fekete, 2018).

336 More specific public health events are sometimes mentioned as either **environmental health**
337 **variables** or **complementary general variables of general public health**. The Chronic Obstructive
338 Pulmonary Disease (COPD) rate was for example used as a health variable (Monteiro et al., 2012), as
339 the appearance and aggravation of this disease is affected by individual lifestyle, gene pool, general
340 state of health but also socio-economic or environmental factors.

341 Variables that give an idea of **health care facilities** can be used to complete the “health” component.
342 This information about resources can be used to meet the daily needs of the population or solve
343 public health events such as epidemics or terrorist attacks (Braconnier et al., 2011; Cutter et al.,
344 2010; Estoque and Murayama, 2014; Huang and London, 2012; Miller et al., 2017; Pearson et al.,
345 2013; Sadd et al., 2011; Zuideau and Lipovac, 2009).

346 **3.3.2. The “environment” dimension**

347 The number of variables in the “environment” dimension ranges from 1 for Biggeri and Mauro
348 (2018), Lasso de la Vega and Urrutia (2001) and Togtokh and Gaffney (2010) to 41 for Etsy et al.
349 (2005). The contribution of these variables to the final index varies from 6 % (Cutter et al., 2010) to

350 91 % (Pearce et al., 2010). The low availability of certain variables in some countries appears to be an
351 obstacle to obtaining relevant information (Braconnier et al., 2011). This may explain the imbalance
352 of representation and precision for this dimension in the indices studied.

353 In cases where just one environmental variable is considered, the variable that is used reflects
354 greenhouse gas emissions (Biggeri and Mauro, 2018; Lasso de la Vega and Urrutia, 2001; Togtokh and
355 Gaffney, 2010). This variable is one of the most representative variables of environmental damage,
356 and this data is already available for most countries (Lasso de la Vega and Urrutia, 2001). Angeon and
357 Bates (2015), Estoque and Murayama (2017), Etsy et al. (2005), García-Sánchez et al. (2015), Hsu et
358 al. (2013) and Porter et al. (2013) also used this variable to complement other environmental
359 variables. Estoque and Murayama (2017), Etsy et al. (2005) and Porter et al. (2013) also integrated
360 the ecological footprint within the composite indices they developed. The ecological footprint
361 monitors the combined impact of **anthropogenic pressures** that are more typically evaluated
362 independently (Galli et al., 2012) and tracks humanity's demands on the biosphere (Estoque and
363 Murayama, 2017).

364 Regarding to **natural resources**, works by Pearce et al. (2010) established a link between the
365 presence of green spaces and beneficial effects on blood pressure, excess weight, obesity and self-
366 perceived health. Closeness to green spaces, parks and open spaces is also mentioned in a number of
367 studies (Monteiro et al., 2012; Pearson et al., 2013; Stewart et al., 2014). Access to green spaces
368 encourages physical activity (Humpel, 2002), provides psycho-social benefits (Pretty et al., 2005) and
369 communities with little access to green areas tended to be more socially disadvantaged (Comber et
370 al., 2008; Estabrooks et al., 2003). Zuindeau and Lipovac (2009) and García-Sánchez et al. (2015)
371 considered the area of agricultural land in the environment dimension in order to evaluate the
372 negative effect of agriculture on natural resources.

373 The variables mentioned for the measurement of **biodiversity** are varied, although few indices
374 consider this issue. In their study, Estoque and Murayama (2014) used methods produced by
375 Costanza et al. (1998) and de Groot et al. (2012) to calculate the sub-index of biological integrity. A
376 monetary value for ecosystem services was attributed to each spatial unit studied, and this value
377 increased with the diversity and richness of the biome and ecosystem in question. The term
378 "ecosystem services" describes all direct or indirect benefits and services that ecosystems generate
379 or provide to individuals (Estoque and Murayama, 2013).

380 Other variables can be considered to provide information about the quality of the environments
381 within the area where the studied population live. Data for **water quality** were included by
382 Braconnier et al. (2011), Etsy et al. (2005), Kerényi (2011), Miller et al. (2017), Pearson et al. (2013),

383 Porter et al. (2013) and Zuideau and Lipovac (2009). To account for the possible evolution of
384 pressure on water bearing resources, data pertaining to the organic water pollutants or linked to
385 agriculture are sometimes mentioned (Etsy et al., 2005; García-Sánchez et al., 2015; Huang and
386 London, 2012; Porter et al., 2013; Stewart et al., 2014; Zhang et al., 2015). The data used to
387 characterize **air quality** concern emissions and/or concentrations of different pollutants (SO₂, NO₂,
388 NO_x, PM, CO, O₃, VOC) (Etsy et al., 2005; Hsu et al., 2013; Kerényi, 2011; Pearce et al., 2010; Pearson
389 et al., 2013; Sadd et al., 2011; Su et al., 2009; Zhang et al., 2015).

390 Information about **environmental safety** or **environmental risk** were also used for the development
391 of a composite indice (Braconnier et al., 2011; Huang and London, 2012; Miller et al., 2017; Pearce et
392 al., 2010; Sadd et al., 2011; Stewart et al., 2014; Zuideau and Lipovac, 2009). For example, density of
393 sources of burdens in each spatial unit studied, distance to industrial facilities or percentage of
394 population living in an “at-risk” area were included. Cutter et al. (2010), Estoque and Murayama
395 (2014) and Miller et al. (2017) also included **natural risks** in the “environment” dimension (flooding
396 and earthquakes, amongst others).

397 **3.3.3. The “social” dimension**

398 In order to interpret the interactions between variables and possible aggregations thereof, social
399 factors should be considered when studying the link between health and environment as variables
400 that are related to environmental exposure and play an important role in health inequalities (WHO,
401 2012). The number of variables integrated within the “social” dimension of the composite indices
402 studied varies from 1 for Lasso de la Vega and Urrutia (2001), Su et al. (2009), Togtokh and Gaffney
403 (2010) and Biggeri and Mauro (2018) to 14 for Porter et al. (2013). The contribution of these
404 variables to the final index varies from 4 % (Etsy et al., 2005) to 42 % (Monteiro at al., 2013). Angeon
405 and Bates (2015) state that many variables can be selected to characterize human capital, and for
406 Braconnier et al. (2011), this dimension has very varied and complex aspects which can lead us to
407 consider increasing numbers of variables. However, Angeon and Bates (2015) recommend the use of
408 data that can be interpreted without ambiguity.

409 To characterise the **social network** of the area studied, Cutter et al. (2010) state that the number of
410 associations or the proportion of the population involved in these associations should be included as
411 they make it possible to identify the relationships between individuals, neighbourhoods and
412 communities. Variables, defined in different ways (e.g. the percentage of households that are
413 considered linguistically isolated), were integrated to determine the social fragmentation that can
414 result from the population structure that can lead to a form of isolation (Huang and London, 2012;
415 Miller et al., 2017; Sadd et al., 2011).

416 To account for **social integration difficulties and anomie**, suicide rates and violent crimes rates are
417 included as variables of community deterioration (Braconnier et al., 2011; Miller et al., 2017). Age-
418 related data are used to characterize **population sensitivity** in the studied area (Cutter et al., 2010;
419 Huang and London, 2012; Miller et al., 2017; Monteiro et al., 2012; Sadd et al., 2011; Stewart et al.,
420 2014). Social capital is also characterized by the **education level** of the population. An other aspect of
421 this “social” dimension concerns **social resources** related to population structure.

422 Several studies include data about the **level of urbanization** in their composite indices. Indeed, high
423 population density makes it possible to reduce transaction costs, improves the profitability of public
424 spending on infrastructure and services, and facilitates the production and dissemination of
425 information, all of which lead to economic growth (WHO, 2010). Rural / urban status, population
426 density, urbanisation ratio have therefore been used by Estoque and Murayama (2017), García-
427 Sánchez et al. (2015), Monteiro et al. (2012), Pearson et al. (2013) and Zhang et al. (2015). However,
428 for Estoque and Murayama (2017), this variable was used as a proxy measure for vulnerability to risk.
429 García-Sánchez et al. (2015) supplemented the information provided by population density by adding
430 urban population growth and Etsy et al. (2005) added the percentage difference in population
431 change between 2004 and the projection for 2050.

432 **3.3.4. The “economics” dimension**

433 The number of variables included in the “economy” dimension on the composite indices studied here
434 varies from 1 for Biggeri and Mauro (2018), García-Sánchez et al. (2015), Huang and London (2012),
435 Lasso de la Vega and Urrutia (2001), Pearce et al. (2010), Sadd et al. (2011), Su et al. (2009) and
436 Togtokh and Gaffney (2010), to 10 for Angeon and Bates (2015), Estoque and Murayama (2014), and
437 Miller et al. (2017). The contribution of these variables to the final index varies from 4 % (Sadd et al.,
438 2011) to 34 % (Angeon and Bates, 2015). This dimension was not considered for 26.1 % of the
439 studied indices (Hsu et al. (2013), Monteiro et al. (2012), Pearce et al. (2010), Pearson et al. (2013),
440 Porter et al. (2013) and Stewart et al. (2014)).

441 Within this dimension, the sub-dimensions of **employability, diversity and/or economic drive** of the
442 study area and the **equality of sexes** were characterized by different items. Amongst the variables
443 used in this dimension, incomes (income per capita, gross available household revenue, median
444 income per consumption unit) are mentioned. According to the spatial scale studied, the measure of
445 the statistical dispersion of income distribution (the Gini index) makes it possible to measure **income**
446 **inequalities**. To highlight this sub-dimension, Braconnier et al. (2011) use the inter-decile ratio
447 (D9/D1) of income distribution. Kerényi (2011), Miller et al. (2017) and Zhang et al. (2015) also
448 consider household savings in their indices in order to reflect living standards.

449 To characterize the **economic influence** of the studied area, Etsy et al. (2005) included the proportion
450 of polluting goods and raw materials that had been imported and also the ratio of gasoline price
451 compared to the world average. Indices created by Angeon and Bates (2015) incorporated sums
452 invested in private investments and current transfers as well as transport costs to account for
453 inefficient logistics.

454 **3.3.5. The “services” dimension**

455 The number of variables included in the “services” dimension of composite variables varies from 1
456 for Monteiro et al. (2012), Stewart et al. (2014) and Zhang et al. (2015) to 14 for Zuideau and
457 Lipovac (2009). The contribution of these variables to the final index varies from 3 % (Etsy et al.,
458 2005) to 35 % (Pearson et al., 2013). Biggeri and Mauro (2018), Estoque and Murayama (2017),
459 Huang and London (2012), Lasso de la Vega and Urrutia (2001), Pearce et al. (2010), Su et al. (2009)
460 and Togtokh and Gaffney (2010) did not use any data that can be considered to be part of the
461 “services” dimension.

462 To provide information about **access to the homeownership market**, Braconnier et al. (2011), Cutter
463 et al. (2010), Miller et al. (2017), Sadd et al. (2011) and Zuideau and Lipovac (2009) included the
464 proportion of home owners who occupy their main dwelling address, while Porter et al. (2013) used
465 accessibility to affordable accommodation within the studied area. In addition to these variables,
466 data is also provided about the **habitat characteristics**: the age of the dwelling (Cutter et al., 2010;
467 Miller et al., 2017; Monteiro et al., 2012), the median value of the dwelling (Sadd et al., 2011) or the
468 proportion of the population that lived in an uncomfortable dwelling (Kerényi, 2011; Zhang et al.,
469 2015; Zuideau and Lipovac, 2009). **Access to basic needs** and public services is characterized by
470 variables that indicates the percentage of the population that had access to fresh water, electricity or
471 sanitation facilities (Angeon and Bates, 2015; Etsy et al., 2005; García-Sánchez et al., 2015; Hsu et al.,
472 2013; Kerényi, 2011; Miller et al., 2017; Porter et al., 2013), by the number of places for seniors
473 citizens in residential homes (Zuideau and Lipovac, 2009).

474 **Access to information and communication** was included in composite indices *via* the number of
475 mobile telephone or internet contracts (Angeon and Bates, 2015; Porter et al., 2013), while Etsy et al.
476 (2005) included digital access index. Cutter et al. (2010) considered the proportion of the population
477 that had a telephone, and Estoque and Murayama (2014) included data for the number of people
478 with landline telephones.

479 The **mobility** and the **land use planning** were also considered as sub-dimensions that should be
480 included in this dimension. Several studies include: the number of kilometres of the public transport
481 network per citizen and/or the proportion of the road network that includes cycle paths (Zuideau

482 and Lipovac, 2009), the length of main and secondary roads per capita (Miller et al., 2017), the
483 proportion of the population that owned a vehicle and the proportion who still reside in the state
484 where they were born (Cutter et al., 2010; Miller et al., 2017). The presence or proximity of different
485 infrastructures that had a positive or negative effect on the phenomena studied (cinemas, sports and
486 leisure facilities, healthy and unhealthy living infrastructures) have been also considered (Cutter et
487 al., 2010; Miller et al., 2017; Pearson et al., 2013; Zuideau and Lipovac, 2009).

488 **3.3.6. The “policy” dimension**

489 The “policy” dimension was only found in 56 % of the studied indices. The number of variables
490 included in the “policy” dimension varies from 1 for Biggeri and Mauro (2018), Braconnier et al.
491 (2011), Estoque and Murayama (2017), Hsu et al. (2013), Sadd et al. (2011) and Zuideau and Lipovac
492 (2009) to 21 for Etsy et al. (2005). The contribution of these variables to the final index varies from 2
493 % (Zuideau and Lipovac, 2009) to 28 % (Etsy et al., 2005).

494 For several years now, the emphasis has been placed on the policy dimension (or governance), which
495 is considered to be an essential factor for environmental improvement (Etsy et al., 2005). When
496 building the SESI, Estoque and Murayama (2014) considered the governance dimension to be as
497 important as the environmental, social and economic dimensions. Angeon and Bates (2015)
498 considered this dimension to represent both the institutional framework and the institutional
499 capacity on a national level. However, the governance or policy is the least integrated aspect in the
500 studies considered. For Modica and Reggiani (2015), this dimension could show the ability of the
501 areas studied to implement operational plans or public investments.

502 Voter turnout can be seen as a proxy variable of **political commitment**, and may also indicate a
503 tendency to lose trust in the political regime and thus lead to instability (Fekete, 2018). A voting rate
504 was incorporated into many composite indices. However, the use of this type of variable as a variable
505 of voter turnout and commitment to political life should be adjusted according to each case. Indeed,
506 some countries such as Australia, Belgium, Brazil, Costa Rica, Greece or Turkey have a mandatory
507 vote that imposes fines on those who abstain for voting. In these countries, low abstention in the
508 vote does not necessarily show a greater commitment or participation in political life. Variables of
509 **integrity** and **civil and political rights** were also used. Porter et al. (2013) included variables for
510 individual liberties (speech and assembly rights) and tolerance, while Biggeri and Mauro (2018)
511 incorporated the composite indicator for civil and political rights developed by Freedom House.
512 Angeon and Bates (2015) and Miller et al. (2017) also used a variable of freedom.

513 In order to identify and quantify **environmental governance**, Etsy et al. (2005) incorporated variables
514 for the effectiveness of environmental governance, knowledge creation in environmental,

515 technological and political sciences, or for local Agenda 21 initiatives in which governmental
516 competence strengthens the ability to monitor and respond to environmental challenges. Angeon
517 and Bates (2015) used the number of environmental treaties in their index. Cutter et al. (2010) and
518 Miller et al. (2017) incorporated variables to specify the **political fragmentation** of the geographical
519 areas studied, which was considered a source of vulnerability. Indeed, although jurisdictional overlap
520 may be a positive attribute in terms of the plurality of potential resources, the multitude of
521 jurisdictions raises the question how these entities can collaborate to attain their targets (Miller et
522 al., 2017).

523 Variables to measure the ability to **anticipate** and plan for certain hazards had been integrated in
524 some indices, and/or the proportion of the population covered by protection programs or the
525 country's ability to cope with any kind of threat.

526 Angeon and Bates (2015), Cutter et al. (2010), Estoque and Murayama (2014) and Miller et al. (2017)
527 incorporated a **budget** sub-dimension with the share of expenditures for emergency medical
528 services, social services, schools, firefighters or the police, whose efficiency depends on several
529 factors including communication, organization or their resources (Miller et al., 2017).

530

531 For each dimension, Table 2 shows that several sub-dimensions exist and can be integrated in the
532 index. To characterize these sub-dimensions, several variables are possible and can be chosen
533 according to the availability and/or the accessibility of the data. Consequently, it may be considered
534 to implement this structuring in dimensions and sub-dimensions as a transposable framework to
535 constitute a dataset. The adaptation of the index to a specific territory or to a local issue would then
536 be effective through the included variables.

537

538 **4. Discussion**

539 **4.1. The subjective perception of certain concepts**

540 Different appraisals can be observed concerning the definition of the variable or the impact (positive
541 or negative) of the variable on environmental health issues (Pearce et al., 2010; Pearson et al., 2013).
542 In the area of environmental health where there is an acute need of assessment method, certain
543 aspects as the complexities of human activities, environmental processes and human well-being
544 come together (Briggs, 2008). Since well-being values are not universal, it would be inappropriate to
545 include solely subjective variables. Each variable should be objective. However, as mentioned by

546 Nascimento and Carrage (2007) and Stiglitz et al. (2009), it is acceptable for a life quality index to
547 incorporate both objective and subjective variables.

548 When the sensitive population group is used in environmental health studies, it is sometimes defined
549 as a group of individuals at an “extreme” age. Subjectivity here is thus dependent on the definition of
550 these age limits. Indeed, Huang and London (2012) and Sadd et al. (2011) considered the population
551 aged below 5 or over 60, whilst Stewart et al. (2014) defined them to be under 14 and over 65,
552 Shrestha et al. (2016) considered a population aged 6 to 11, and Miller et al. (2017) considered
553 sensitive populations to be those under 18 years of age or over 65 years of age. The conclusions of
554 these studies are difficult to compare because the populations concerned have different
555 characteristics (physiology, behaviour, exposure profile).

556 The impact of population migration on quality of life can be negative or positive. Cutter et al. (2010)
557 considered that net international migration had a negative impact on well-being, while Zuideau and
558 Lipovac (2009) mention that the impact of the foreign population on well-being is perceived in
559 different ways according to the population concerned. For Sherrieb et al. (2010), demographic
560 changes or migration could indicate a stress on resources or a loss of human capital.

561 The effects of urbanization are equivocal in studies, and can be positive (access to infrastructure) or
562 negative (chronic stress caused by noise and respiratory problems related to road traffic) for human
563 health (Pearson et al., 2013). Cutter et al. (2010), Estoque and Murayama (2014) and Miller et al.
564 (2017) considered access to a road network to be beneficial for well-being through the connectivity
565 between territories, which provides easier access to services and infrastructures. However, road
566 traffic-related atmospheric pollution and exposition to noise may negatively affect the health of
567 populations living close to roads, although there is some uncertainty regarding the estimation of
568 population exposure (Host, 2013). Monteiro et al. (2012) included the density of the road network in
569 their study, as they considered this variable to be a factor that was at the origin of, or aggravated,
570 the public health event studied (COPD).

571 Population density is sometimes considered as an explanatory factor of the result, and sometimes as
572 a factor that directly impacts environmental health. Thus, Cutter et al. (2010) did not use population
573 density in the BRIC and the analysis of their results showed a bias that revealed an urban/rural
574 divide. Pearson et al. (2013) revealed unexpected results for regions that were characterized by a
575 high population density close to downtown areas, linking a good state of health with a higher social
576 deprivation index. The lower mortality rates could however be artificially low in these
577 neighbourhoods, as their inhabitants live there for shorter periods of time.

578 The potential environmental benefits on health are widely accepted, especially in connection with
579 the presence of green spaces. However, characterizing the association between green spaces and
580 public health events seems to be complicated because it can vary considerably according to the
581 definitions used for “green spaces” (Klomp maker et al., 2018). There is also no consensus in the
582 literature regarding the measurement of access to green spaces when different distances are
583 involved (Stewart et al., 2014), with availability also playing a possible role in the notion of access
584 (Flacke et al., 2016; Kruize et al., 2014; Yao et al., 2014). Pearce et al. (2010) use the proportion of
585 the smallest area classified as green space and Monteiro et al. (2012) use the percentage of green
586 spaces in neighbourhoods. To elaborate their composite index, Pearson et al. (2013) mainly
587 considered the means of accessibility and distances to different types of structures and amenities,
588 which explains their inclusion of the distance to parks. However, none of these three studies specifies
589 the characteristics of these green spaces in terms of (i) size, (ii) availability or (iii) accessibility, which
590 could raise the question of the comparability of these variables. Stewart et al. (2014) chose to use
591 buffer zones, with different weighting according to the type of park: urban parks, which generally
592 had areas 0.05 miles², had a lower weighting and a smaller buffer zone, whilst the county parks and
593 open spaces, which had areas of approximately 3 miles², had twice the weighting of urban parks and
594 a buffer zone that was twice as large. These different interpretations of the “green spaces” variable
595 emphasize the importance of defining the subject of the evaluation precisely.

596 Within the “environment” dimension, certain authors also seek to evaluate the quality of the
597 environments in which the populations live, mainly using data related to air and/or water quality
598 (Braconnier et al., 2011; Etsy et al., 2005; Hsu et al., 2013; Kerényi, 2011; Miller et al., 2017; Pearce et
599 al., 2010; Pearson et al., 2013; Sadd et al., 2011; Su et al., 2009; Zhang et al., 2015; Zuideau and
600 Lipovac, 2009). The ground is a support for human activity and absorbs types of pollution that can
601 expose human populations to health risks in more long-term manner than *via* occasional water and
602 air pollution. However, soil quality is only mentioned in composite indices in data for polluting /
603 polluted sites listed by Huang and London (2012), Stewart et al. (2014) and Zuideau and Lipovac
604 (2009). A study by Panagos et al. (2012) notes the rarity of soil data, and states that any such data
605 were difficult or impossible to access, especially at the scales needed by policy makers.

606 **4.2. Transposability and influence of the spatial unit studied**

607 In our context, transposability can be defined as the possibility to successfully implement an index
608 outside the framework of study for which it was originally developed, for a different geographical
609 location (other territory), spatial unit (smaller or larger) and research question (*i.e.* different from the
610 initial question for which the index was developed). There are two possible principles of

611 transposability. First of all, transposability can be considered *stricto sensu*, *i.e.* whatever the spatial
612 unit considered, it should be possible to calculate the composite index by using all the defined
613 variables and the chosen methodology (imputation of missing data, normalization, weighting,
614 aggregation). The use of transposability in this strict sense is rare because of the compatibility of the
615 index with the research question (Lasso de la Vega and Urrutia, 2001; Togtokh and Gaffney, 2010).
616 An alternative method would be to transpose the initial developed reasoning and the published
617 overall methodology to develop a new composite index in environmental health. The dimensions and
618 calculation methods are identical to the initial method used, and the variables are adapted to the
619 context of the geographical study area. Although less conservative, this method has less constraints
620 than the first and could thus be more widely accepted and used. The reflection conducted by each
621 author is then perceived as a support for a possible optimization.

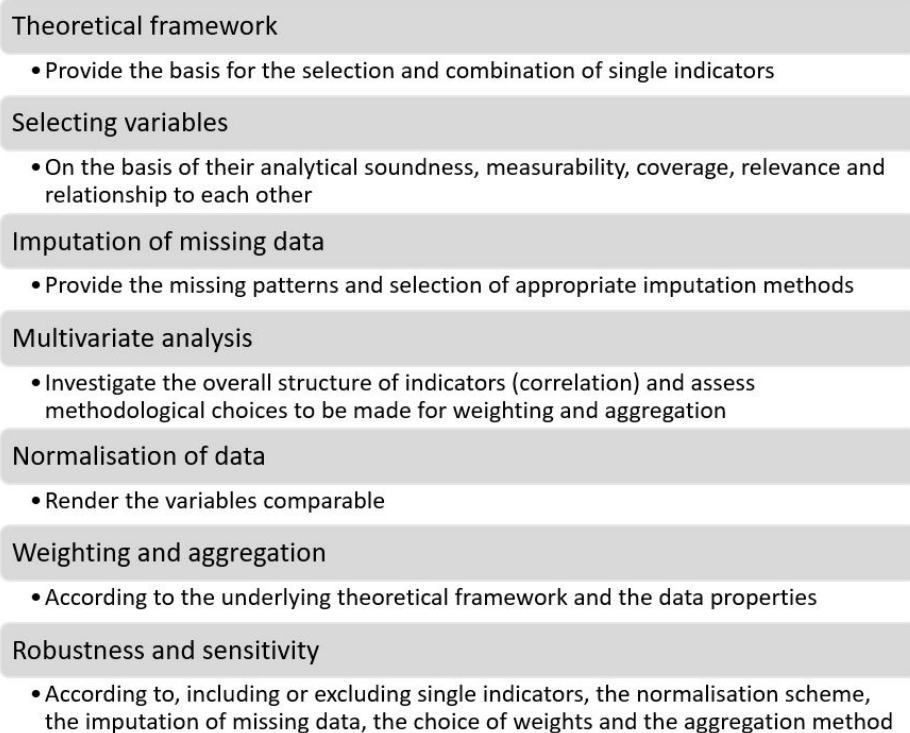
622 The first limitation of transposability is the contextualization of the variables integrated into the
623 composite indices that were developed within a given territory. For example, some authors
624 examined the degree of telecommunications development, with Estoque and Murayama (2014)
625 using the number of land lines per 1,000 inhabitants in the Philippine administrative governance sub-
626 index. While this type of variable would be suitable for countries with the same level of technological
627 development, it would be more relevant to identify Internet access for other countries (Etsy et al.,
628 2005). In addition, certain representative national data (percentage of marae for Pearson et al.
629 (2013) or data relating to ethnicity for studies conducted in the United States) would only be suitable
630 in the context for which they were used.

631 A second limitation is the lack of accessible variables at the appropriate spatial scale (Maantay, 2007;
632 Rothenberg et al., 2015). Certain facets are characterized only at a global scale (*i.e.* national), and
633 not defined on a local scale. The use of a macroscopic index that was designed for use on a
634 nationwide scale for a smaller spatial unit is made difficult by the lack of data measured on a fine
635 scale (Cutter et al., 2010; Estoque and Murayama, 2014). For example, the PISA scores of 15-year-old
636 students in reading, mathematics and science are not available at the local town area scale.
637 Moreover, moving from a large unit to a more discriminating spatial unit may lead to the existing
638 data being subject to statistical secrecy for some data in examples such as the proportion of
639 agricultural area in organic farming in the total agricultural area on the municipal scale. Aggregating
640 these data at a higher level may resolve this problem and make it possible to disseminate
641 information at the smallest possible scale that respects the threshold of statistical confidentiality
642 (Branchu et al., 2018). Another phenomenon to consider is that what appears on one scale may
643 disappear on another (Hamman, 2011). So, it is important to assess how far the choice of spatial
644 scale can influence the research question for which it is being used (Rey et al., 2009). The first step

645 when defining the geographical space to be considered is to choose the most suitable investigation
646 scale, giving it an operational socio-political dimension (Salem, 1995).

647 **4.3. Recommendations and good practices**

648 This review provide a complete overview of the variables included in environmental health indices
649 and consolidate the approach leading to the selection of variables. This proposal complements the
650 OECD's thinking on composite indices construction (European Commission et al., 2008). The OECD
651 handbook provides comprehensive advices about how to design and develop a composite index,
652 without application domain specificity (Figure 4). This guide is mentioned as a reference by Angeon
653 and Bates (2015) and García-Sánchez et al. (2015), Etsy et al. (2005) for their part refer to a version
654 published before 2008. Hsu et al. (2013) detail the entire methodology used to develop their
655 composite index, and their method is very close to that proposed in the OECD guide.



656

657 Fig 4. Good practice for developing composite indices (inspired by (European Commission et al., 2008))

658 Authors must commit to a strict and explicit methodological framework that defines the criteria for
659 the inclusion of variables and spatial units. The challenge is to limit the impact of missing data on the
660 quality of the database used for the development of the composite index. This framework can also
661 be used as a basic structure to identify the most appropriate weighting and aggregation methods for
662 the research question concerned.

663 The missing data profile must be specified in order to determine the most appropriate imputation
664 methods. Missing data can be a challenge when analyzing and interpreting the results, thus
665 weakening the final conclusions (Pedersen et al., 2017). Our analysis shows that within the 23
666 studies, 22 % of composite indices reported a problem of missing data in the development of their
667 database. The percentages attributed to the acceptability of missing data range from 0 to 41 %, and
668 there is no consensus on an acceptable percentage. The imputation methods are mentioned and/or
669 described in the publications. However, only one study mentions a “reliability/robustness” analysis
670 that also considered the results with and without the imputed data (Etsy et al., 2005).

671 70 % of the studied indices did not use any weighting scheme. For the remaining 30 %, the
672 employed methods were the Analytic Hierarchy Process (AHP), the Budget Allocation Process (BAP),
673 the Multi-Criteria-Decision-Analysis (MCDA), the Criteria Importance Through Inter-Criteria
674 Correlation (CRITIC) or population weighted index. The recent review of Becker et al. (2017) showed
675 that there are problems with understanding and appropriating this step. The main difficulty of
676 weighting lies in the choice of the authors to give greater weight to variables considered important
677 regarding the question research, which can be in contradiction with more statistical approaches
678 (Burgass et al., 2017).

679 A sensitivity and robustness analysis is necessary in order to (i) identify the type of variation of the
680 composite index, and (ii) quantify the overall uncertainty that is inherent to the choices made during
681 the development of the methodology. This sensitivity analysis was performed for just over 13 % of
682 the indices (*i.e.*, 3 indices), and only Cutter et al. (2010) considers the impact of missing data on the
683 results. According to European Commission et al. (2008), the development of composite indices
684 involves subjective evaluations of the selection of individual variables, the attitude towards missing
685 data, and the choice of weighting or aggregation models.

686 The selection of the variables must be made in the light of (i) their relevance in the literature, (ii)
687 their availability, and (iii) the robustness of the association of the data with health. The selection
688 criteria for the selection of the variables to be included are mentioned in 20 out of the 23 indices: the
689 selection of the variables reflecting the multiple facets of the environmental health was generally
690 based on an analysis of the literature. Beccari (2016) state that the availability of variables on the
691 desired geographic scale could even be the main selection factor as it is a major problem when
692 developing sub-national methodologies to measure and compare territories.

693

694 **5. Conclusion**

695 This review aimed to identify and characterize the dimensions and variables that are included in
696 environmental health indices. This analysis led to the identification of 23 spatialized composite
697 indices that each answered a specific research question. A great diversity in the design of the indices
698 was highlighted: these composite indices could be included from 2 to 6 dimensions and from 4 to 76
699 variables. In this review, a total of 329 variables was assessed in a systematic way: this multitude of
700 variables demonstrates the need for classification and ordering of concepts. These indices had been
701 developed by scientific or institutional bodies, and the diversity of information used by these two
702 actors highlights the lack of consensus for an index that would be acceptable to both parties (Strezov
703 et al., 2017). The 23 composite indices were developed with the aim of characterizing the territorial
704 inequalities in health environment. The results comparability, between territories and even
705 sometimes within one same territory and their cross-discussion is limited given (i) the differences of
706 research question, and (ii) the wide variability of the methodological design.

707 This present work could be a first step towards a proposal of guidelines designed to provide a
708 consensual framework that could facilitate the exploitation of environmental health indices. We
709 recommended harmonizing practices in the selection and characterization of the dimensions and
710 sub-dimensions related to health, environment, social, economics, services and policy. The proposed
711 framework aimed to take up the challenge of constituting a relevant dataset for the development of
712 a composite index in environmental health. It could be used as a basis to guide authors in their
713 choice to include or exclude certain variables and thus make interterritorial comparisons more
714 robust.

715 The quality of the definition and measurement of the variables will influence the quality of the
716 composite index developed. The definition is all the more important as the evaluation of certain
717 phenomena involved in environmental health is inevitably subjective. The research for the most
718 holistic view is important, for example through the integration of data on soils, that is still anecdotal.
719 The will of transposability regularly mentioned in the conclusions of the studied articles is limited by
720 the contextualization of certain variables (*e.g.* related to the degree of technological development of
721 the studied geographical area). Spatial granularity can be the source of specific problems, either
722 when selecting variables (accessibility and/or availability of data on a fine scale), or when developing
723 the index and carrying out the subsequent analysis (developed index without discriminating power at
724 the chosen scale). When selecting variables, authors have to pay close attention to the accessibility
725 of data related to their problematic and at the spatial scale considered. This practice sometimes
726 encounters local obstacles, an improvement in the culture of information sharing would make it
727 possible to optimize the characterization of territories.

728 Control of uncertainties may be sufficient in some composite indices, but others may require
729 reworking in order to improve conclusions robustness. Only 5 studies mention the issue of missing
730 data. The explanation of their number and their mathematical treatment is however essential to
731 assess the reliability of the dataset. The weighting and aggregation steps, well known as crucial by
732 the authors and more broadly, are generally better explained. With the exception of Cutter et al.
733 (2010), none of them provided a sensitivity analysis, a step that can be used to assess the robustness
734 of composite indices. Presenting this step systematically would make it possible to remove certain
735 criticisms related to the unavoidable sources of uncertainties.

736 In view of these different aspects, it is therefore important that frameworks for variable integration
737 and index development methodology are clearly described in publications. This bid for transparency
738 could also increase the understanding and adoption of these tools by public authorities and general
739 public.

740

741 **Declarations of interest**

742 None

743

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747

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972 **Figure captions**

973 Figure 1: Results of the article search and outline of the entire article searching process for this
974 systematic review

975 Figure 2: Composite indices in environmental health, scientific vs institutional bodies, published
976 since 2001

977 Figure 3: Representativeness of the number of variables within dimensions

978 Figure 4: Good practice for developing composite indices (inspired by European Commission et al.
979 (2008))