Health vulnerability ocurred due to atmospheric emissions: A case study in Santa Catarina State, Brazil

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1. Introduction
2. Main goal
3. Methodology
4. Results and Discussion
5. Conclusion

1. INTRODUCTION

The greatest environmental risk to human health

UNEA, 2017

90% of the population lives in areas that exceed the patterns established by WHO

WHO, 2016

- **Increase of deaths and hospitalizations**
- **Respiratory diseases**

COHEN et al., 2017; HEI, IHME, 2019

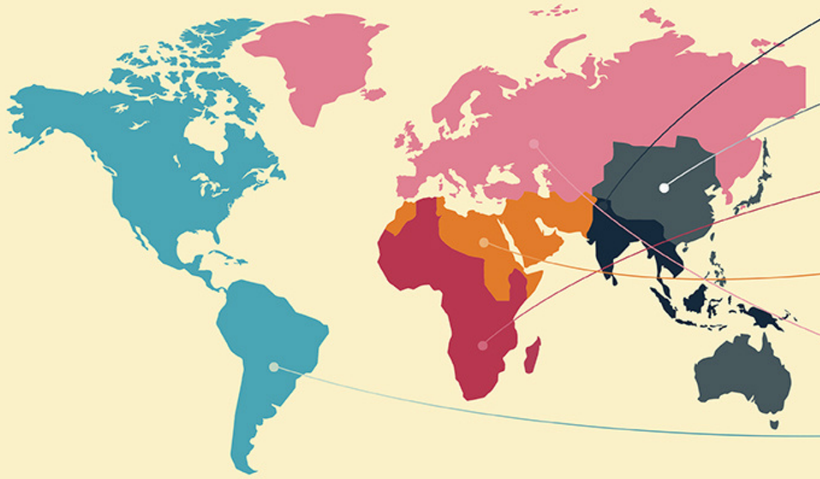
AIR POLLUTION – THE SILENT KILLER

Every year, around **7 MILLION DEATHS** are due to exposure from both outdoor and household air pollution.

Air pollution is a major environmental risk to health. By reducing air pollution levels, countries can reduce:

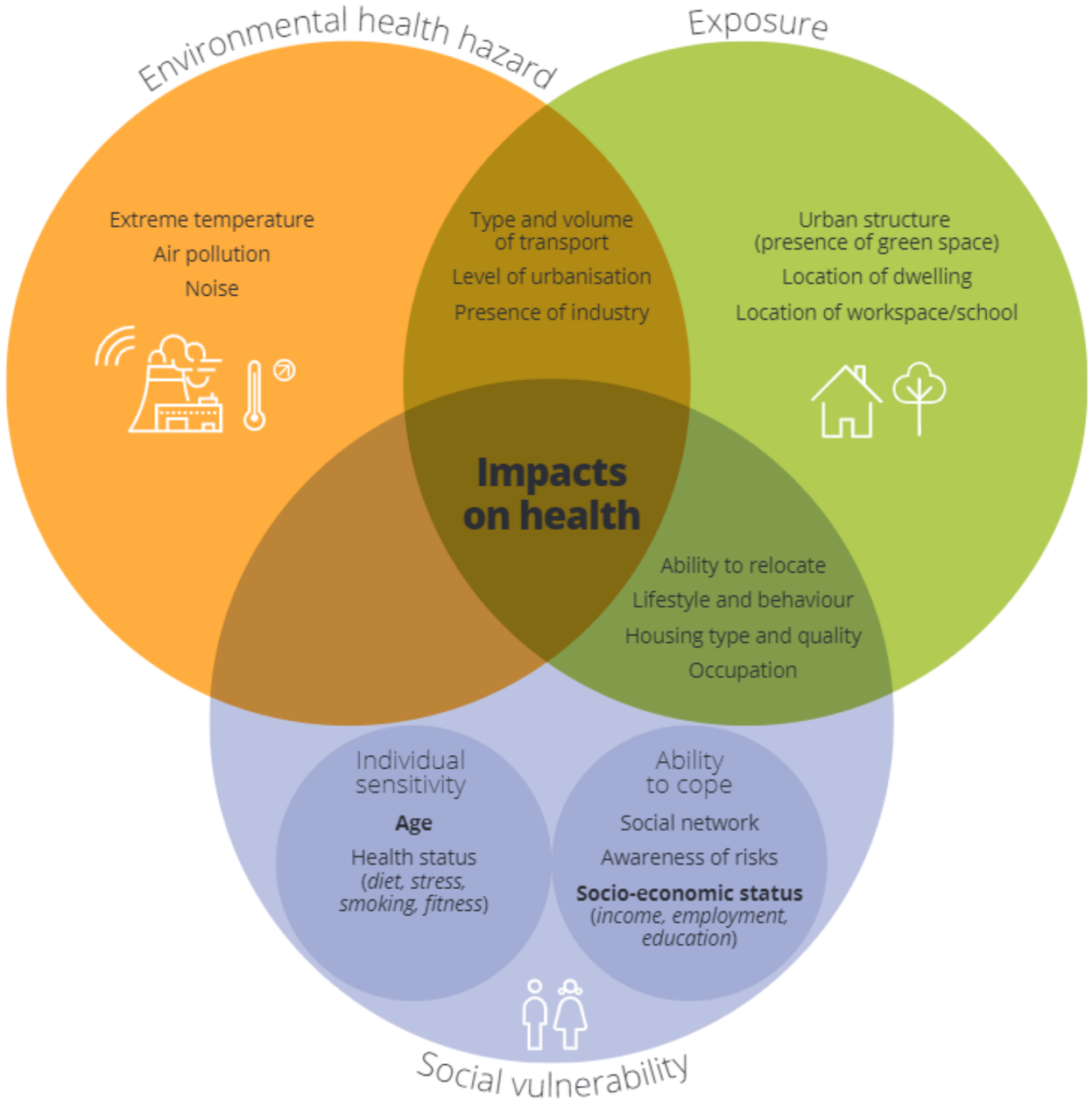
- **Stroke**
- **Heart disease**
- **Lung cancer, and both chronic and acute respiratory diseases, including asthma**

REGIONAL ESTIMATES ACCORDING TO WHO REGIONAL GROUPINGS:



- **Over 2 million** in South-East Asia Region
- **Over 2 million** in Western Pacific Region
- **Nearly 1 million** in Africa Region
- **About 500 000** deaths in Eastern Mediterranean Region
- **About 500 000** deaths in European Region
- **More than 300 000** in the Region of the Americas

CLEAN AIR FOR HEALTH #AirPollution World Health Organization



FONTE: EEA, 2018

THE STATE OF SANTA CATARINA

- Most number of vehicles per inhabitants in 2017.
- The 4th state with the most number of industries in 2018.
- Considerables emissions by wildfires when compared to previous years.
- There are few studies in the state.

Source: LCQAr file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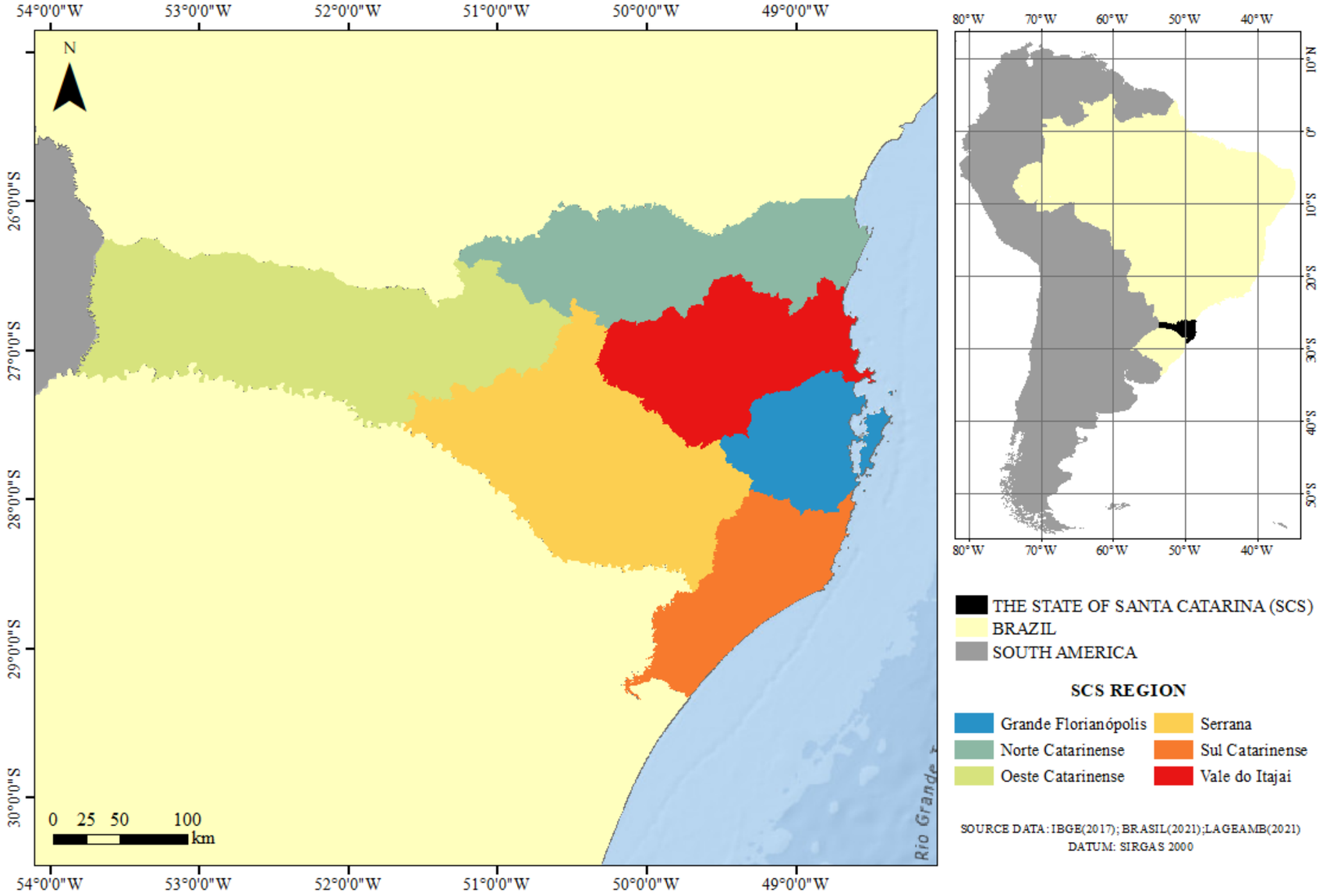
Source: LCQAr file

Source: (CNI,2020;CNT,2020,TEIXEIRA,2020)

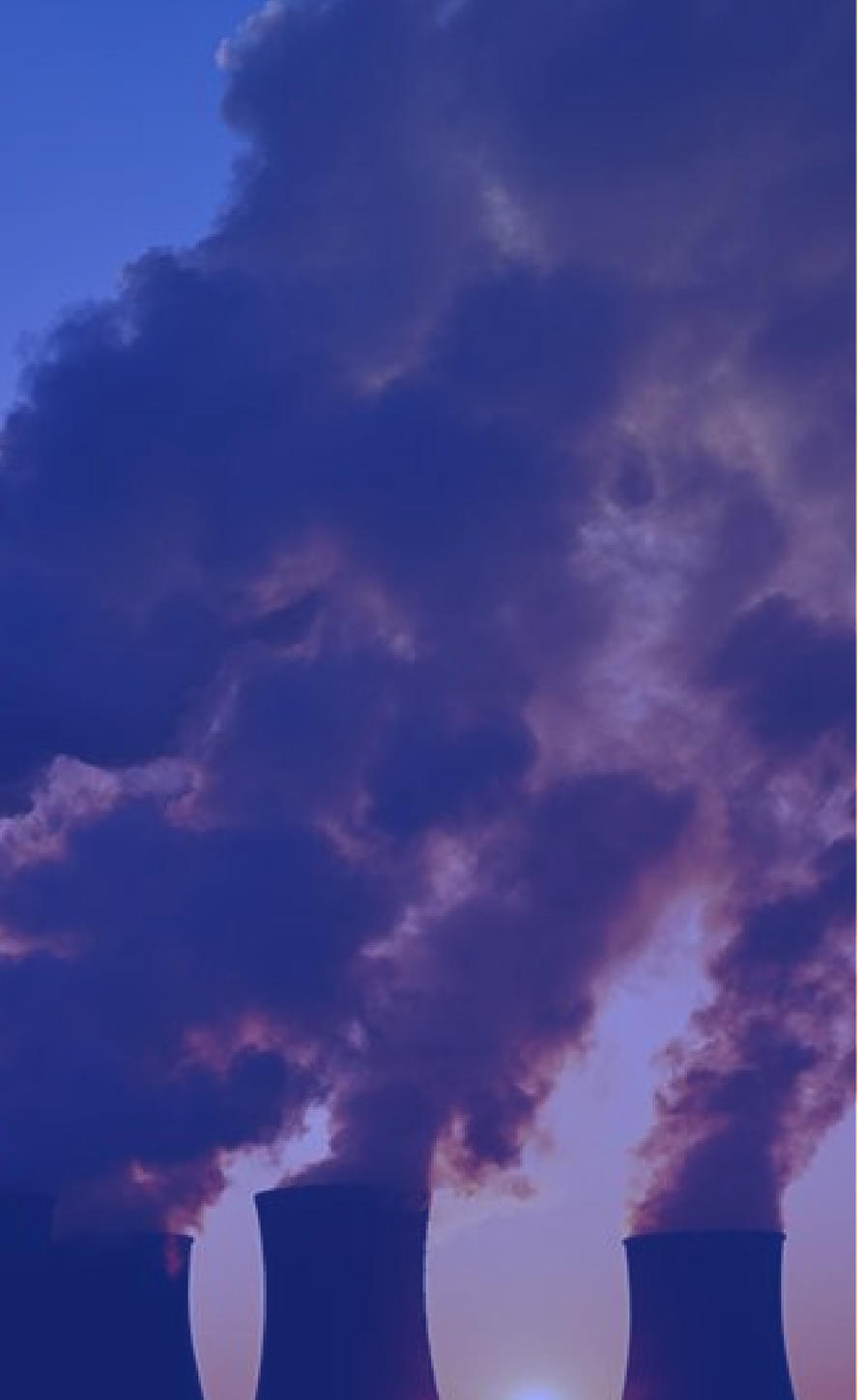
This study aimed in assessing the association between atmospheric emissions, hospitalizations by respiratory diseases and the role of socioeconomic status in the State of Santa Catarina.

2. METHODOLOGY

Study Area

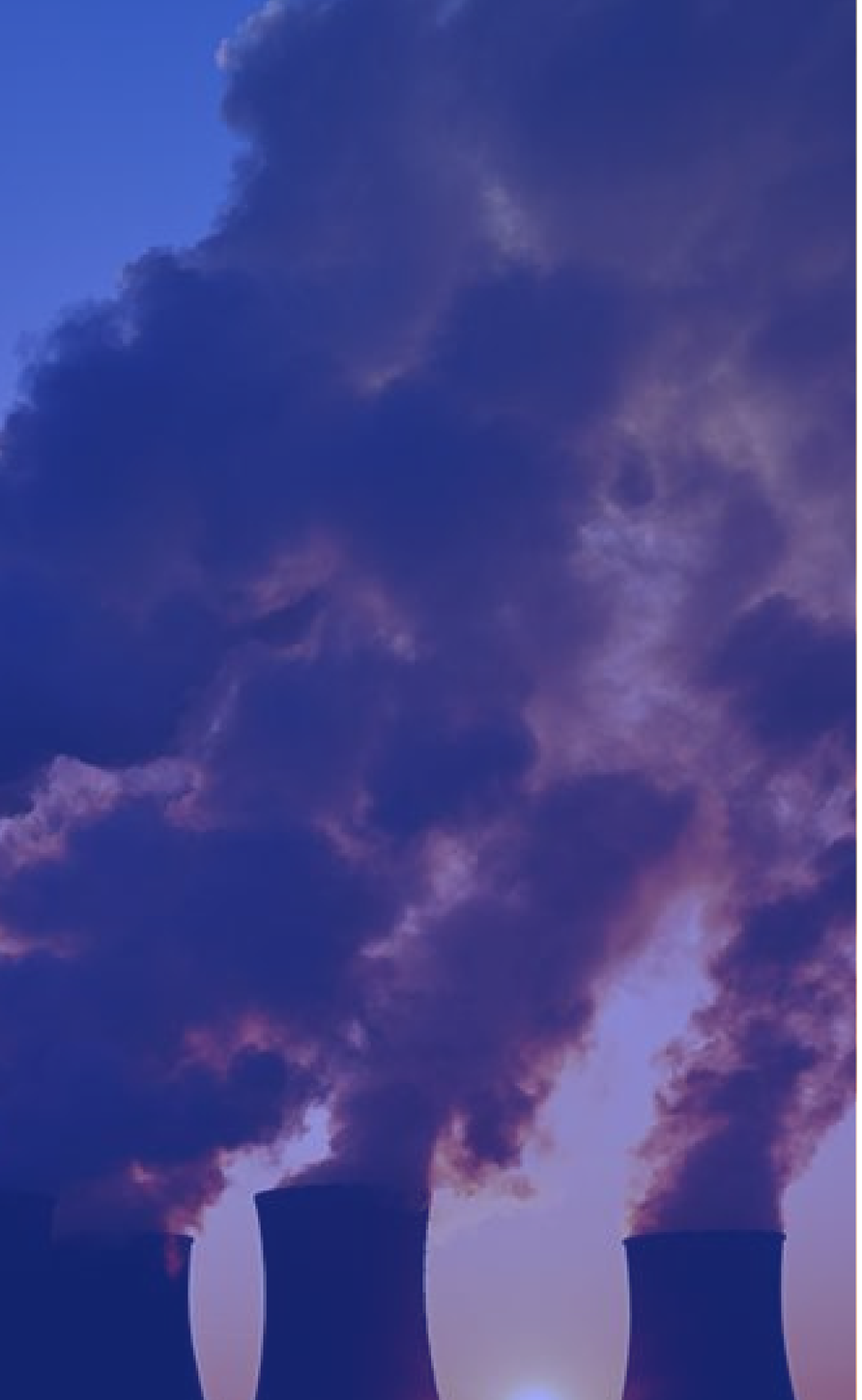


Elaborated by authors



Data

	Source	Pollutants	Year	Data Source
Air Pollution	Vehicular Emission	CO, NOx e MP	2017	LCQAr, 2020
	Wildfires Emissions	CO, NOx e MP2.5	2017	LCQAr, 2021
	Number of industries	Industrial Segments	2017	IBGE, 2020
Socioeconomic Index	Gross Domestic Product (GDP) per capita		2017	IBGE, 2017
	Municipal Human Development Index (M - HDI)		2010	PNUD;IPEA; FJP, 2013
	Gini Coefficient		2010	PNUD;IPEA; FJP, 2013
Health	ICD - Chapter X	**Age**		
		14 ≥years (children);	2017	DATASUS, 2017
		15≤years≤59 (adults);	2017	DATASUS, 2017
		60≤years (elderly).	2017	DATASUS, 2017



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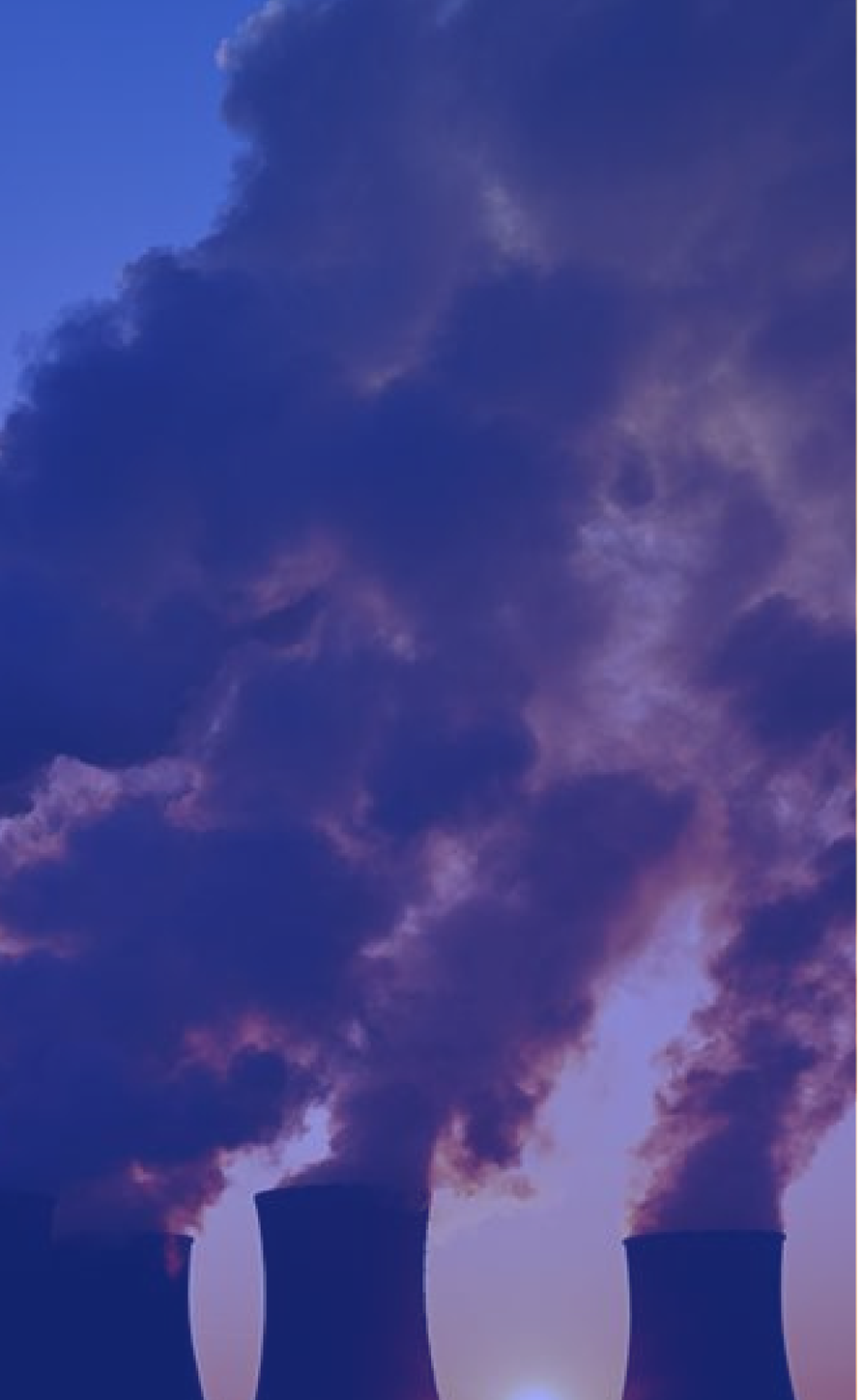
M - HDI	Levels
Very low	0 - 0.499
Low	0.500 - 0.599
Medium	0.600 - 0.699
High	0.700 - 0.799
Very High	0.800 - 1.000



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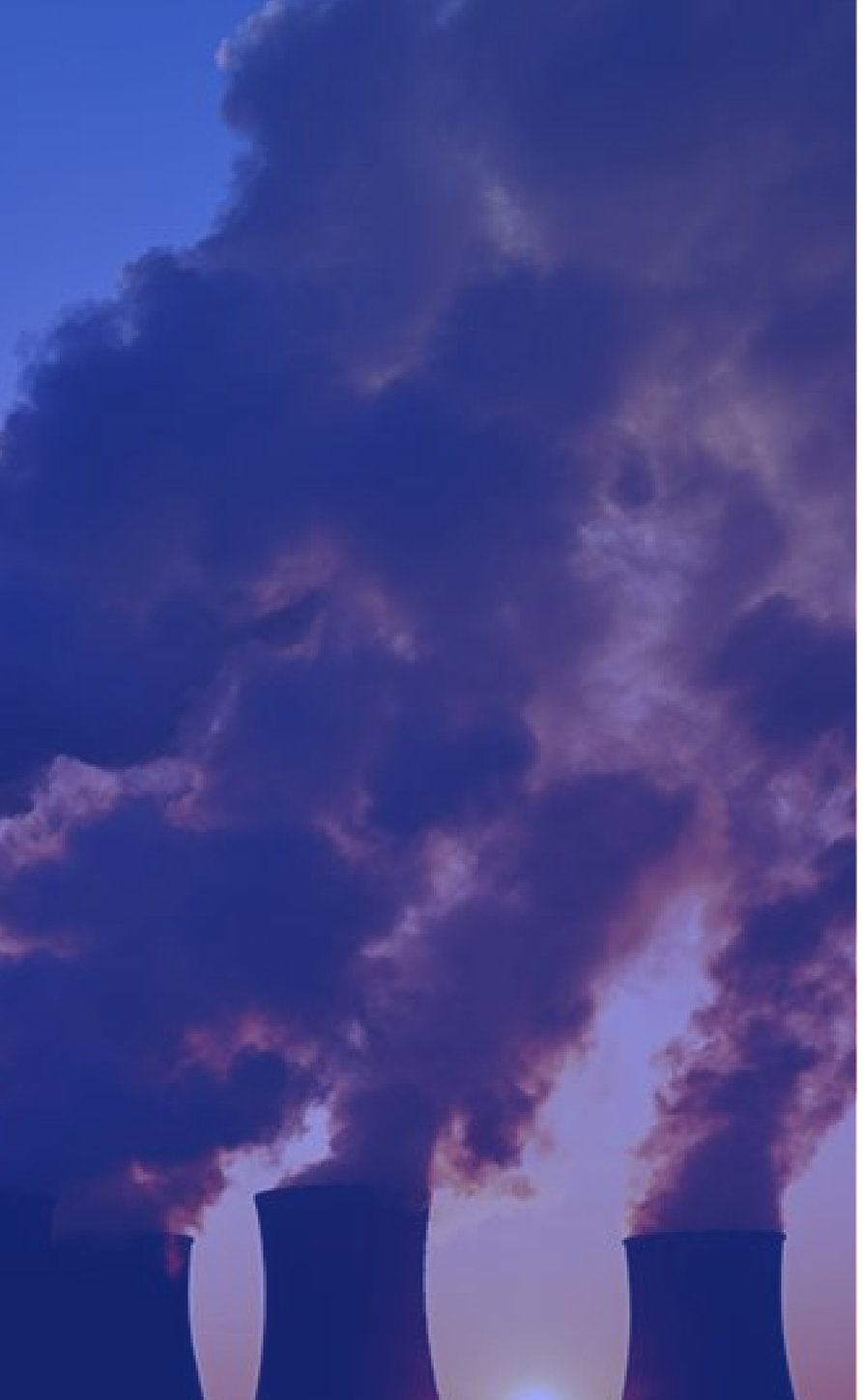


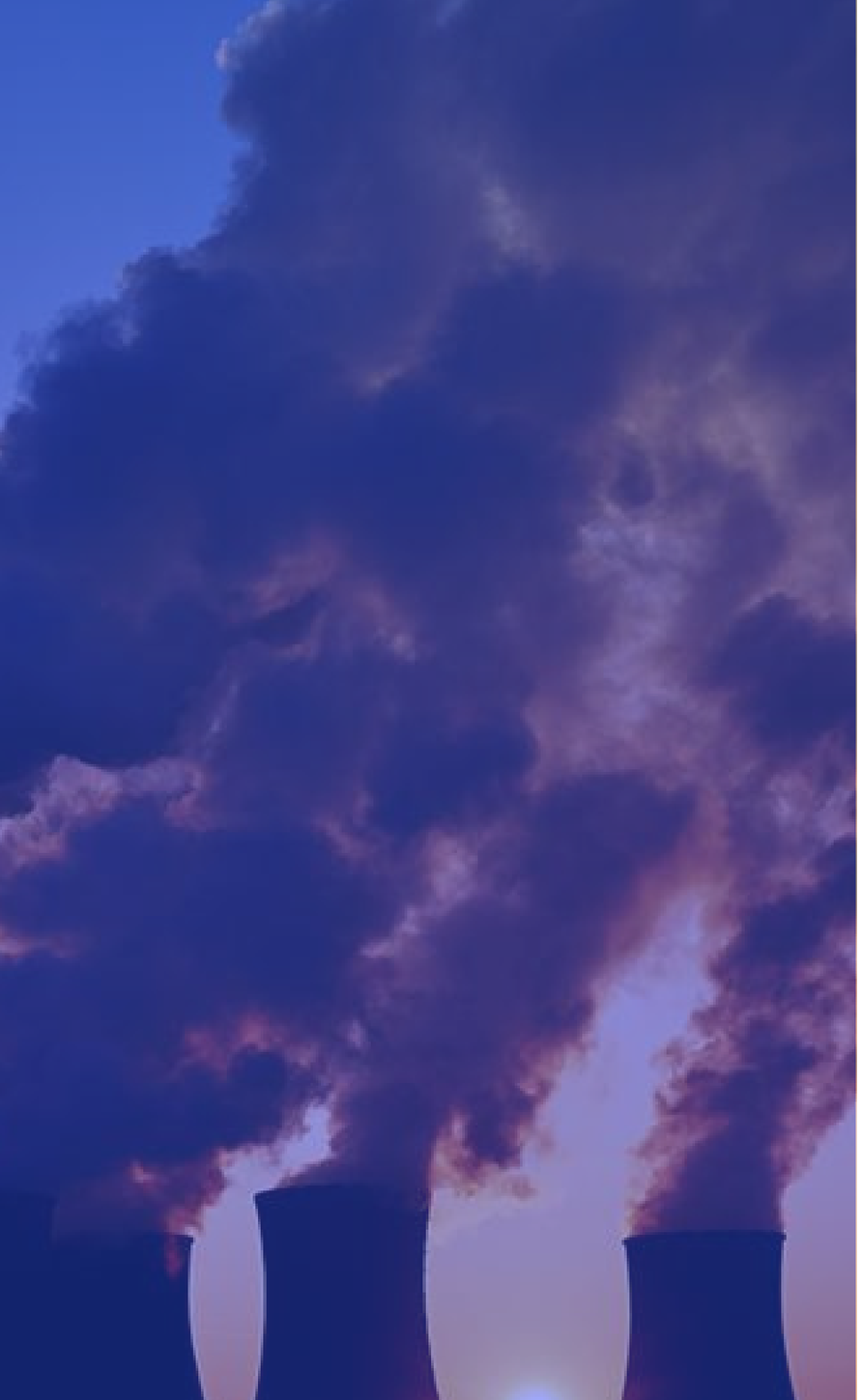
Statistical Analysis

- **Bivariate Analysis**

Vehicular Emissions
Wildfires Emissions
Number of industries
GDP per capita
M-HDI
Gini coefficient

- Hospitalization by Respiratory Disease
- 14 ⩾years (children);
- 15⩽years⩽59 (adults);
- 60⩽years (elderly).

- Analysis using aggregated data in Santa Catarina
- Analysis by M-HDI groups



Statistical Analysis

- **Bivariate Analysis - Correlations**

Parametric Method - Pearson

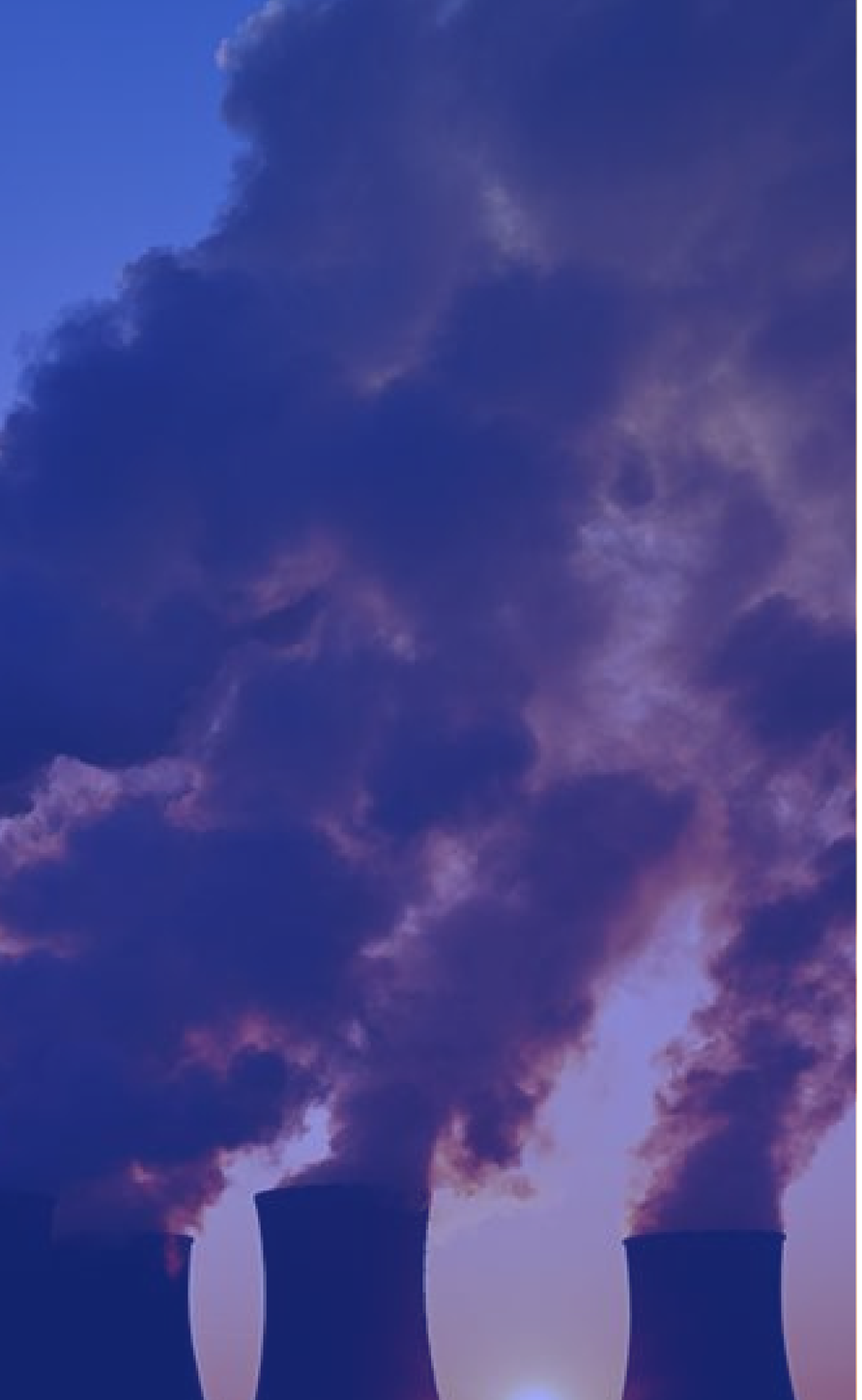
$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{(n-1)s_x s_y}$$

n is the number of pairs xy,
xi and yi are the data values for each position,
$\bar{x}$ *and* $\bar{y}$ are the media of each sample, and
s_x *and* s_y are the univariate standard deviations.

Non Parametric Method - Spearman

$$r_{xy} = 1 - \frac{6\ \sum_{i=1}^{n} d_i^2}{n(n^2-1)}$$

d_i is the rank difference between two variables, and
n is the sample size



Statistical Analysis

- Hypothesis Test

Mann - Whitney

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1$$

$$U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2$$

n_1 and n_2 are the samples 1 and 2 sizes, and

R_1 and R_2 are the sums of the ranks of samples 1 and 2.

$$\hat{z} = \frac{\left|U - \frac{n_1 n_2}{2}\right|}{\sqrt{\left(\frac{n_1 n_2}{S(S-1)}\right) \cdot \left(\frac{S^3 - S}{12} - \sum_{i=1}^{i=r} \frac{t_i^3 - t_i}{12}\right)}}$$

S=$n1$+$n2$

R is the number of tied values, and

t_i is the number of occurrences of the i-th tied value

3. RESULTS AND DISCUSSION

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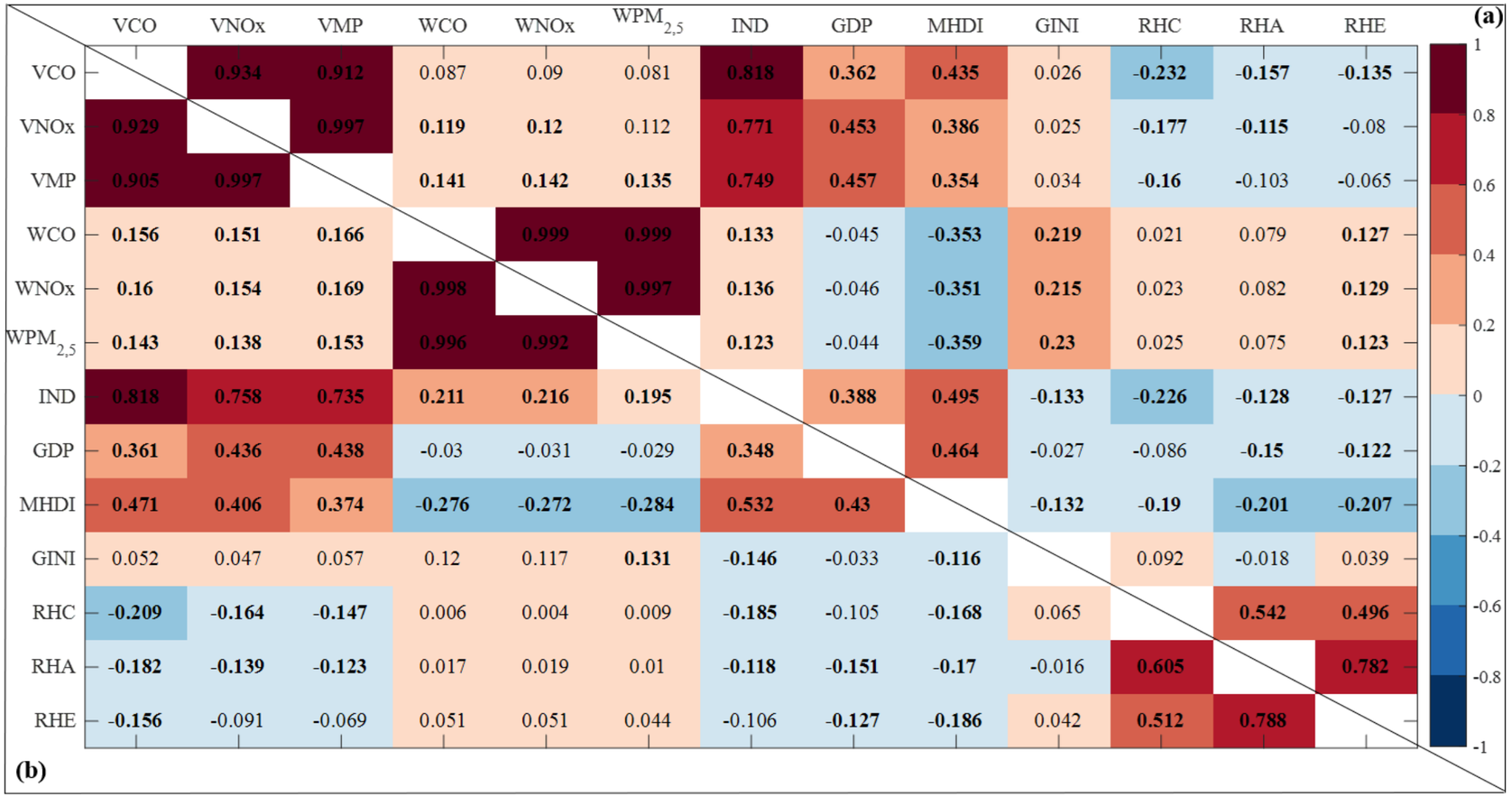
(a) Spearman method; (b) Pearson method



	VCO	VNOx	VMP	WCO	WNOx	$WPM_{2,5}$	IND	GDP	MHDI	GINI	RHC	RHA	RHE
VCO		**0.934**	**0.912**	0.087	0.09	0.081	**0.818**	**0.362**	**0.435**	0.026	**-0.232**	**-0.157**	**-0.135**
VNOx	**0.929**		**0.997**	**0.119**	**0.12**	0.112	**0.771**	**0.453**	**0.386**	0.025	**-0.177**	**-0.115**	-0.08
VMP	**0.905**	**0.997**		**0.141**	**0.142**	**0.135**	**0.749**	**0.457**	**0.354**	0.034	**-0.16**	-0.103	-0.065
WCO	**0.156**	**0.151**	**0.166**		**0.999**	**0.999**	**0.133**	-0.045	**-0.353**	**0.219**	0.021	0.079	**0.127**
WNOx	**0.16**	**0.154**	**0.169**	**0.998**		**0.997**	**0.136**	-0.046	**-0.351**	**0.215**	0.023	0.082	**0.129**
$WPM_{2,5}$	**0.143**	**0.138**	**0.153**	**0.996**	**0.992**		**0.123**	-0.044	**-0.359**	**0.23**	0.025	0.075	**0.123**
IND	**0.818**	**0.758**	**0.735**	**0.211**	**0.216**	**0.195**		**0.388**	**0.495**	**-0.133**	**-0.226**	**-0.128**	**-0.127**
GDP	**0.361**	**0.436**	**0.438**	-0.03	-0.031	-0.029	**0.348**		**0.464**	-0.027	-0.086	**-0.15**	**-0.122**
MHDI	**0.471**	**0.406**	**0.374**	**-0.276**	**-0.272**	**-0.284**	**0.532**	**0.43**		**-0.132**	**-0.19**	**-0.201**	**-0.207**
GINI	0.052	0.047	0.057	0.12	0.117	**0.131**	**-0.146**	-0.033	**-0.116**		0.092	-0.018	0.039
RHC	**-0.209**	**-0.164**	**-0.147**	0.006	0.004	0.009	**-0.185**	-0.105	**-0.168**	0.065		**0.542**	**0.496**
RHA	**-0.182**	**-0.139**	**-0.123**	0.017	0.019	0.01	**-0.118**	**-0.151**	**-0.17**	-0.016	**0.605**		**0.782**
RHE	**-0.156**	-0.091	-0.069	0.051	0.051	0.044	-0.106	**-0.127**	**-0.186**	0.042	**0.512**	**0.788**	

Bold values represent statistical significance at the $p<0.05$ level

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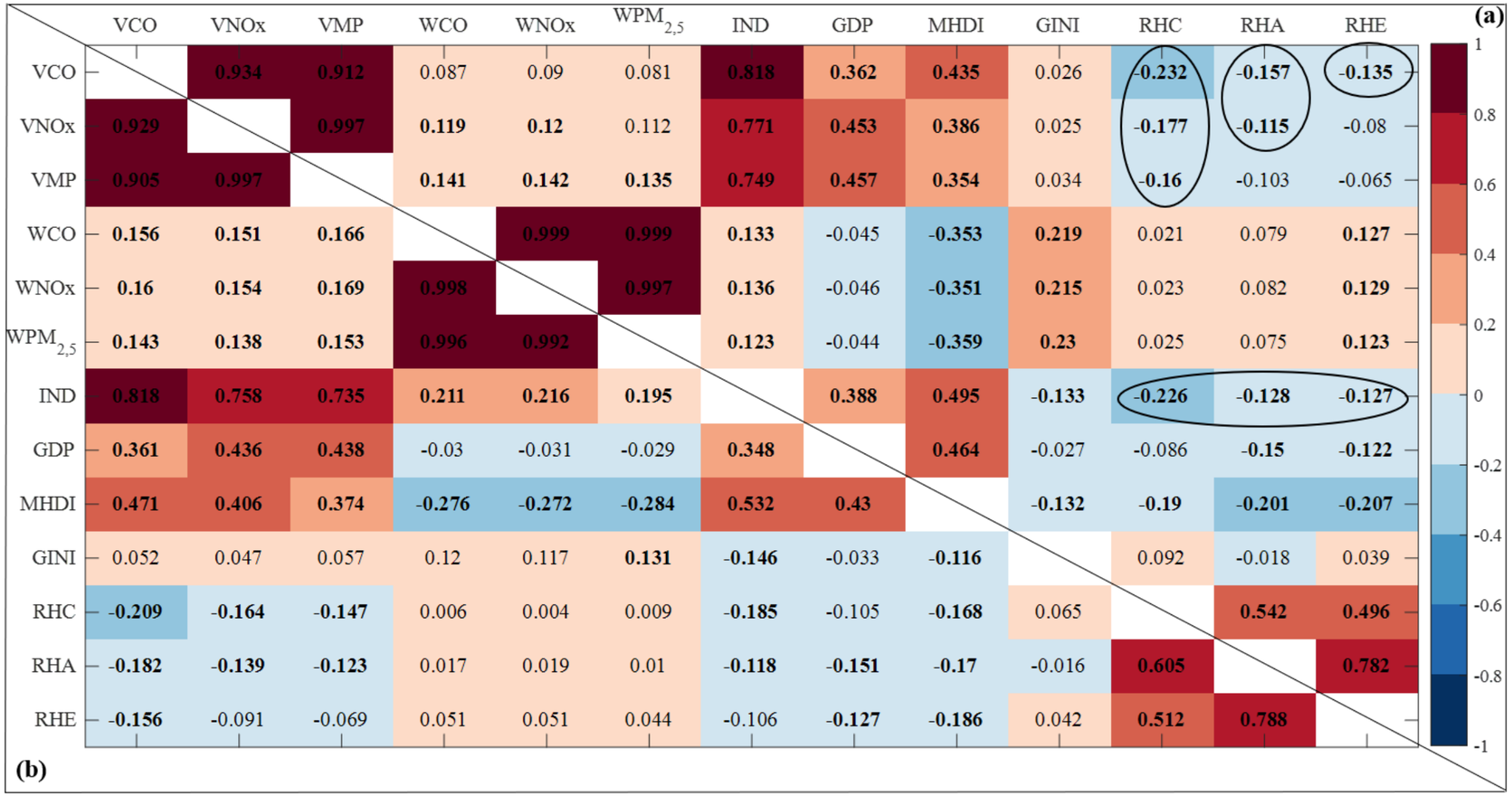

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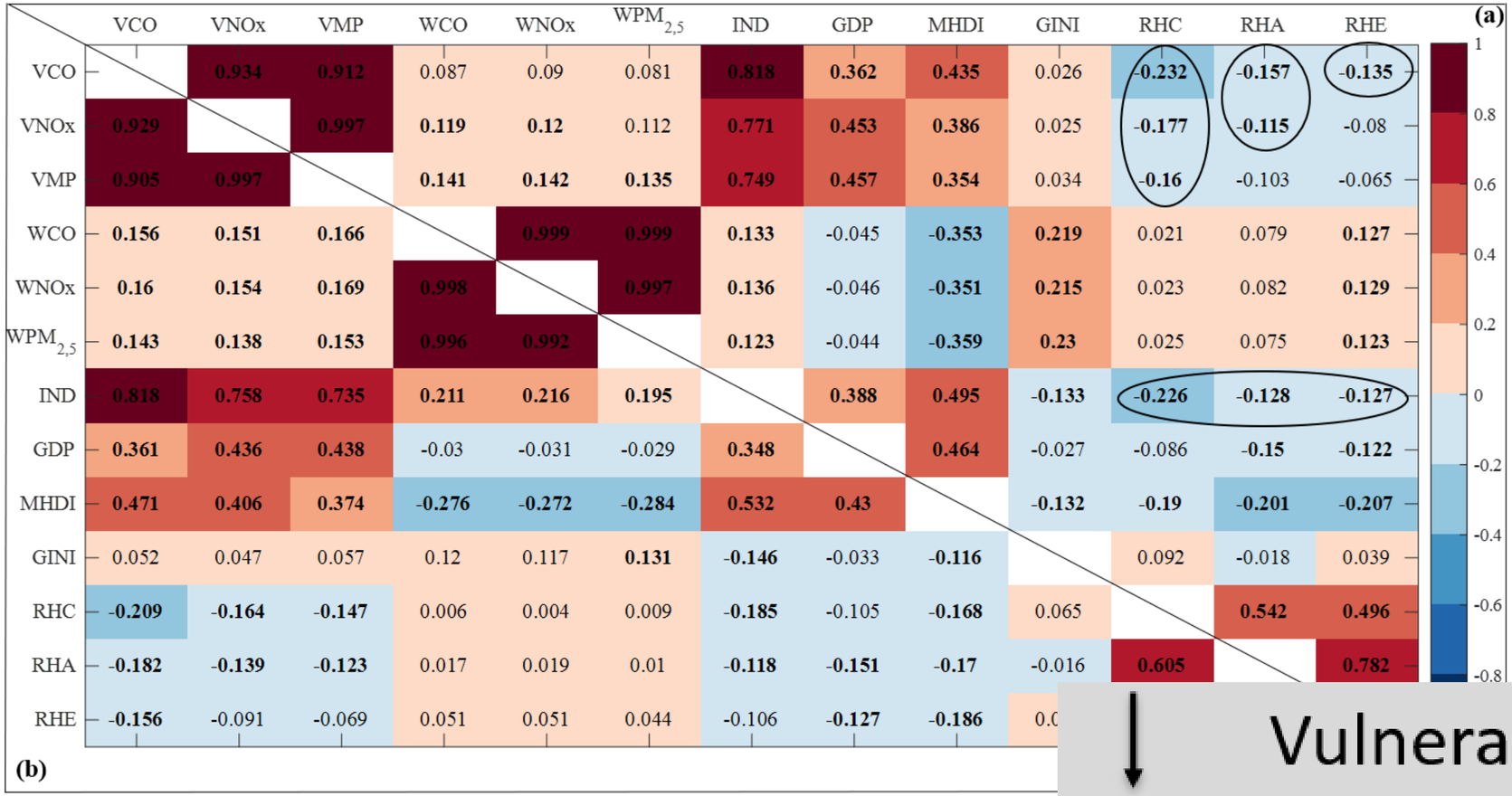

Vulnerability

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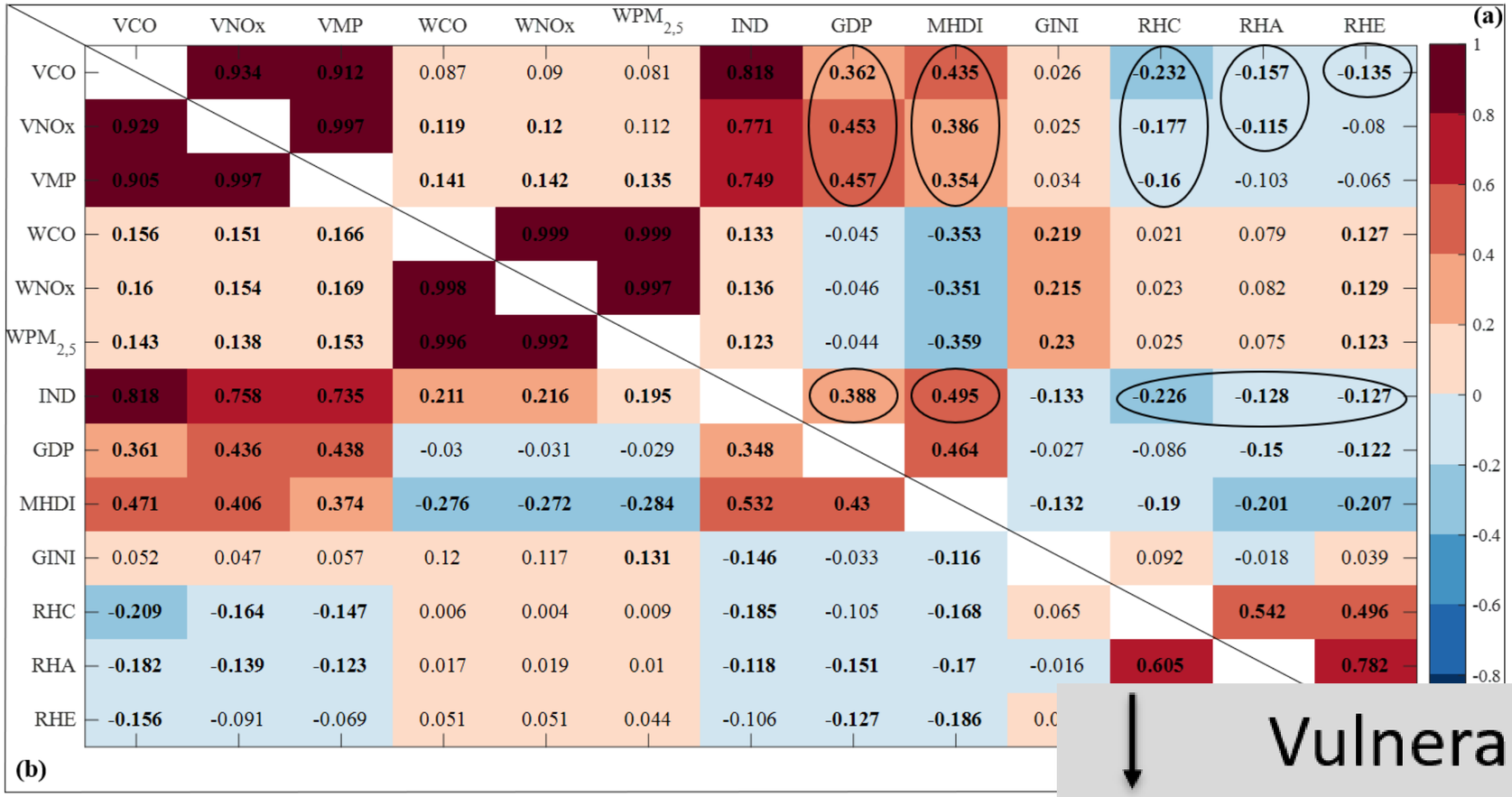

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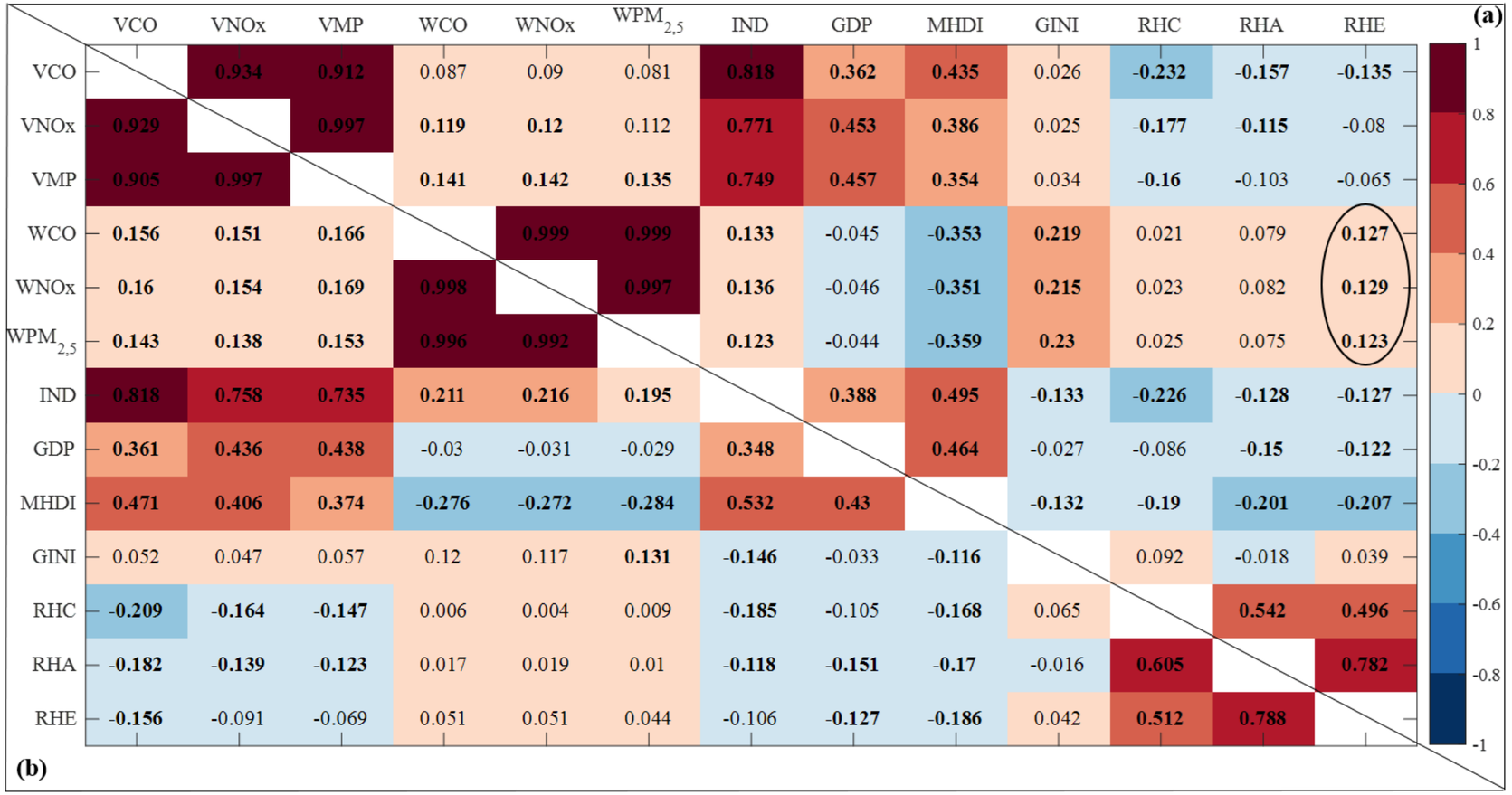

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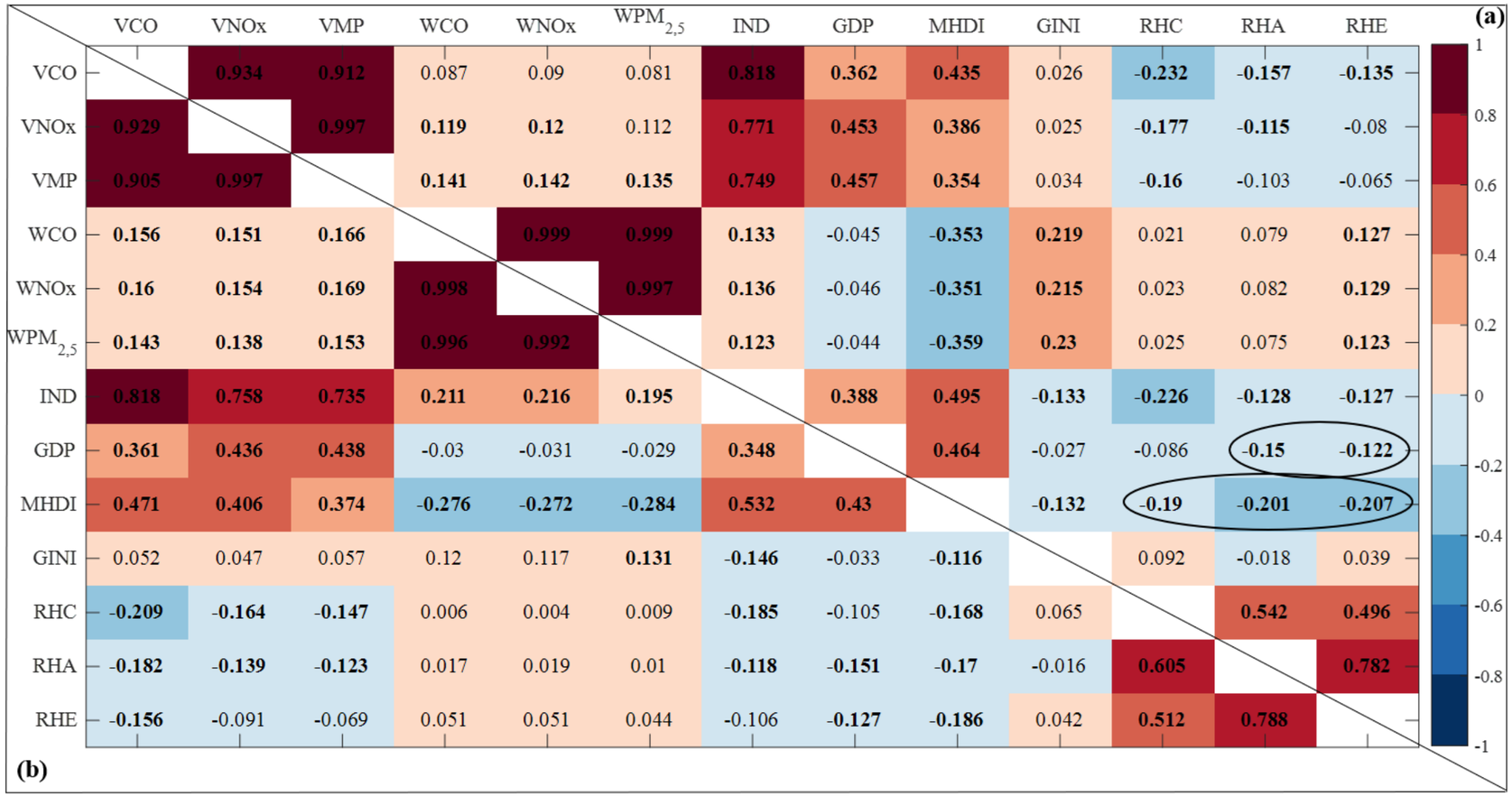

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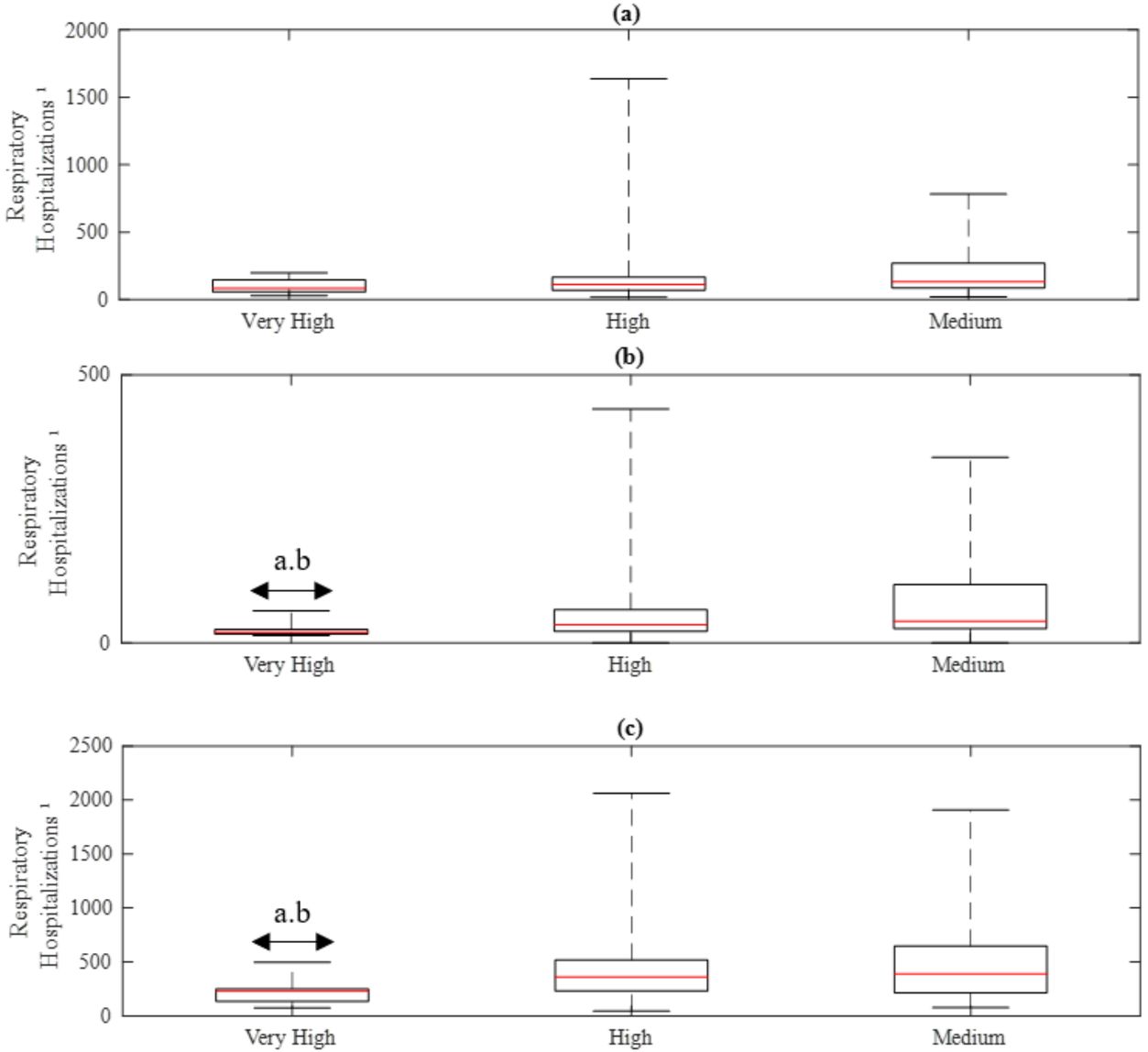
WNOx	**0.16**	**0.154**	**0.169**	**0.998**		**0.997**	**0.136**	-0.046	**-0.351**	**0.215**	0.023	0.082	**0.129**
$WPM_{2,5}$	**0.143**	**0.138**	**0.153**	**0.996**	**0.992**		**0.123**	-0.044	**-0.359**	**0.23**	0.025	0.075	**0.123**
IND	**0.818**	**0.758**	**0.735**	**0.211**	**0.216**	**0.195**		**0.388**	**0.495**	**-0.133**	**-0.226**	**-0.128**	**-0.127**
GDP	**0.361**	**0.436**	**0.438**	-0.03	-0.031	-0.029	**0.348**		**0.464**	-0.027	-0.086	**-0.15**	**-0.122**
MHDI	**0.471**	**0.406**	**0.374**	**-0.276**	**-0.272**	**-0.284**	**0.532**	**0.43**		**-0.132**	**-0.19**	**-0.201**	**-0.207**
GINI	0.052	0.047	0.057	0.12	0.117	**0.131**	**-0.146**	-0.033	**-0.116**		0.092	-0.018	0.039
RHC	**-0.209**	**-0.164**	**-0.147**	0.006	0.004	0.009	**-0.185**	-0.105	**-0.168**	0.065		**0.542**	**0.496**
RHA	**-0.182**	**-0.139**	**-0.123**	0.017	0.019	0.01	**-0.118**	**-0.151**	**-0.17**	-0.016	**0.605**		**0.782**
RHE	**-0.156**	-0.091	-0.069	0.051	0.051	0.044	-0.106	**-0.127**	**-0.186**	0.042	**0.512**	**0.788**	

Bold values represent statistical significance at the p<0.05 level

VCO - CO by vehicular emission; VNOx - NOx by vehicular emissions; VPM – PM by vehicular emissions; WCO - CO by wildfire emissions; WNOx – NOx by wildfire emissions; WPM2.5 – PM2.5 by wildfire emissions; IND – number of industries; GDP – Gross Domestic Product per capita; MHDI – Municipal Human Development Index; GINI – Gini Coefficient; RHC – Respiratory hospitalizations in children; RHA – Respiratory hospitalization in adults; RHE – Respiratory hospitalization in elderly

Hypothesis Test

(a) 14 ≥years (children); (b) 15≤years≤59 (adults); (c) 60≤years (elderly).



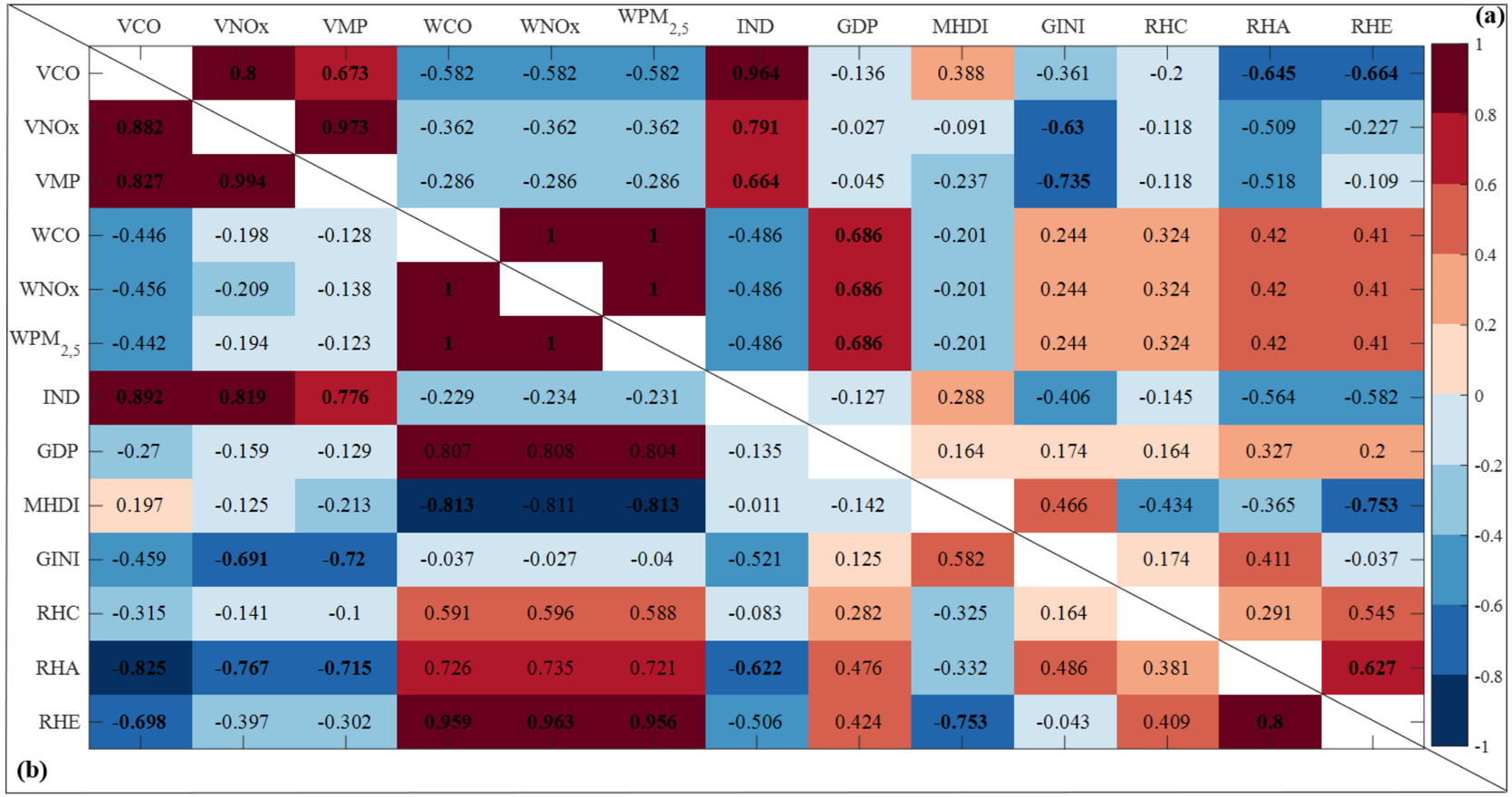
¹ Hospitalizations in each 10000 inhabitants

a = median difference of High M-HDI

b = median difference of Medium M-HDI

M-HDI VERY HIGH

(a) Spearman method; (b) Pearson method

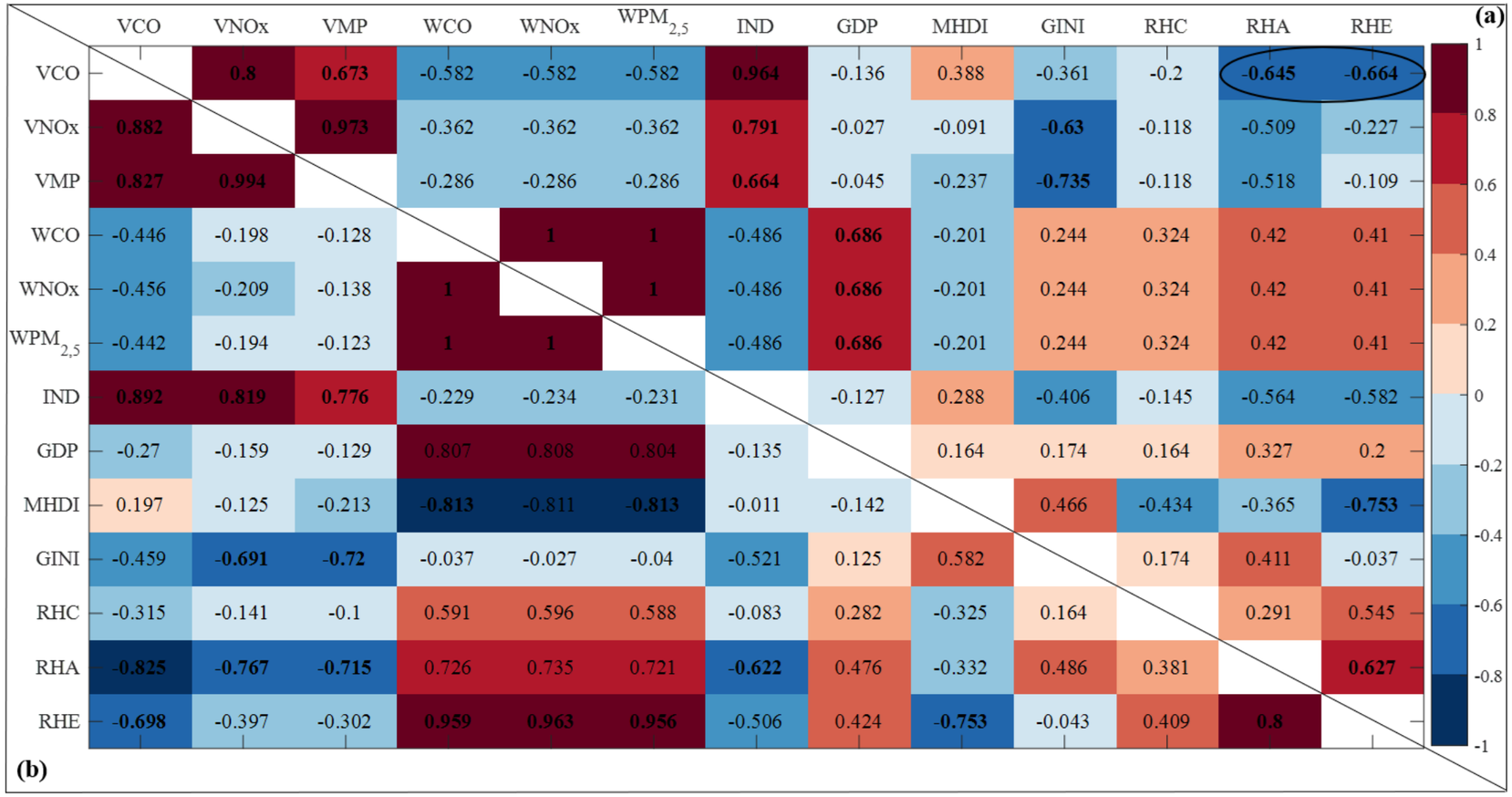


Bold values represent statistical significance at the p<0.05 level

VCO - CO by vehicular emission; VNOx - NOx by vehicular emissions; VPM – PM by vehicular emissions; WCO - CO by wildfire emissions; WNOx – NOx by wildfire emissions; WPM2.5 – PM2.5 by wildfire emissions; IND – number of industries; GDP – Gross Domestic Product per capita; MHDI – Municipal Human Development Index; GINI – Gini Coefficient; RHC – Respiratory hospitalizations in children; RHA – Respiratory hospitalization in adults; RHE – Respiratory hospitalization in elderly

M-HDI VERY HIGH

(a) Spearman method; (b) Pearson method

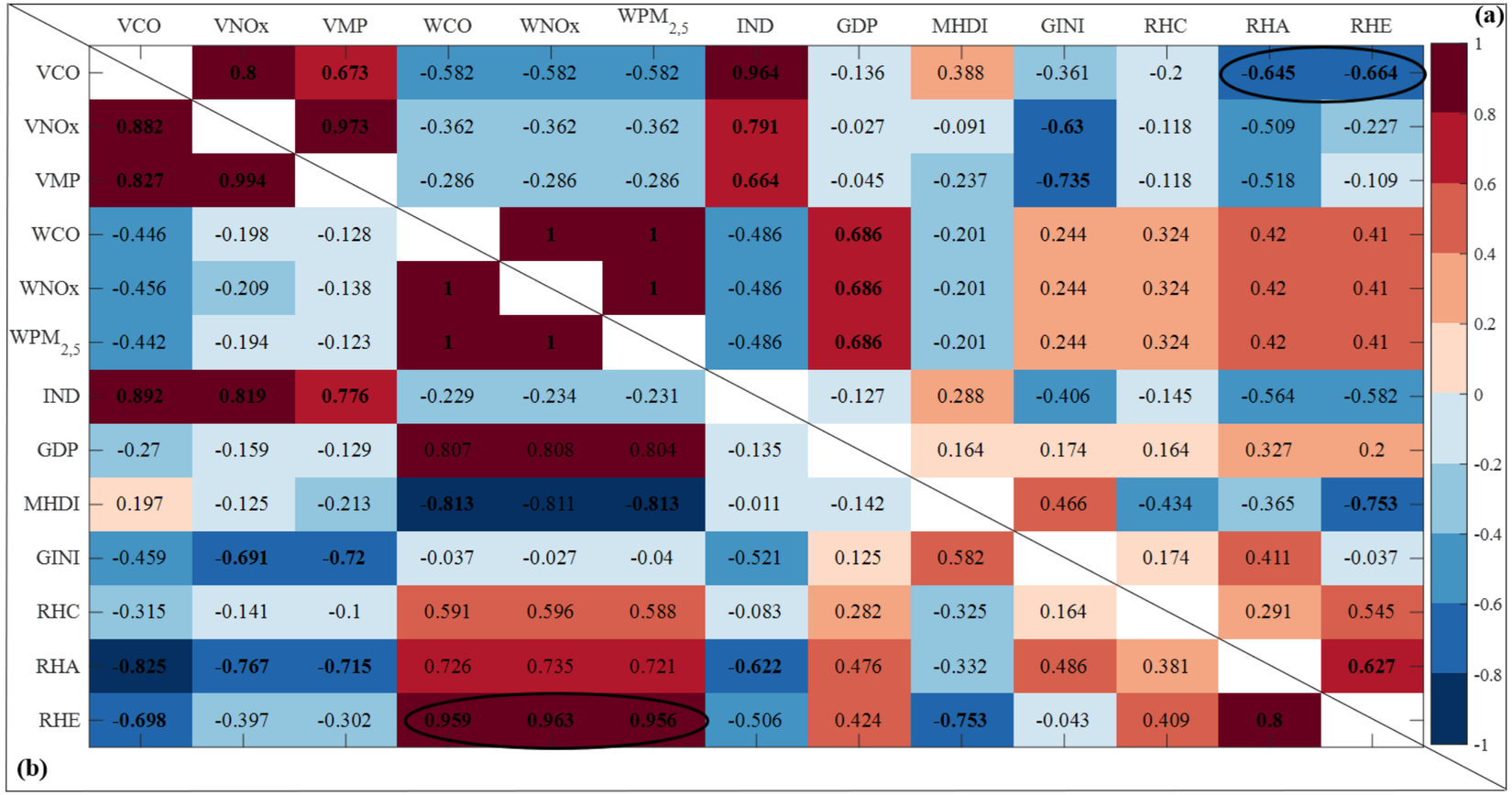


Bold values represent statistical significance at the p<0.05 level

VCO - CO by vehicular emission; VNOx - NOx by vehicular emissions; VPM – PM by vehicular emissions; WCO - CO by wildfire emissions; WNOx – NOx by wildfire emissions; WPM2.5 – PM2.5 by wildfire emissions; IND – number of industries; GDP – Gross Domestic Product per capita; MHDI – Municipal Human Development Index; GINI – Gini Coefficient; RHC – Respiratory hospitalizations in children; RHA – Respiratory hospitalization in adults; RHE – Respiratory hospitalization in elderly

M-HDI VERY HIGH

(a) Spearman method; (b) Pearson method

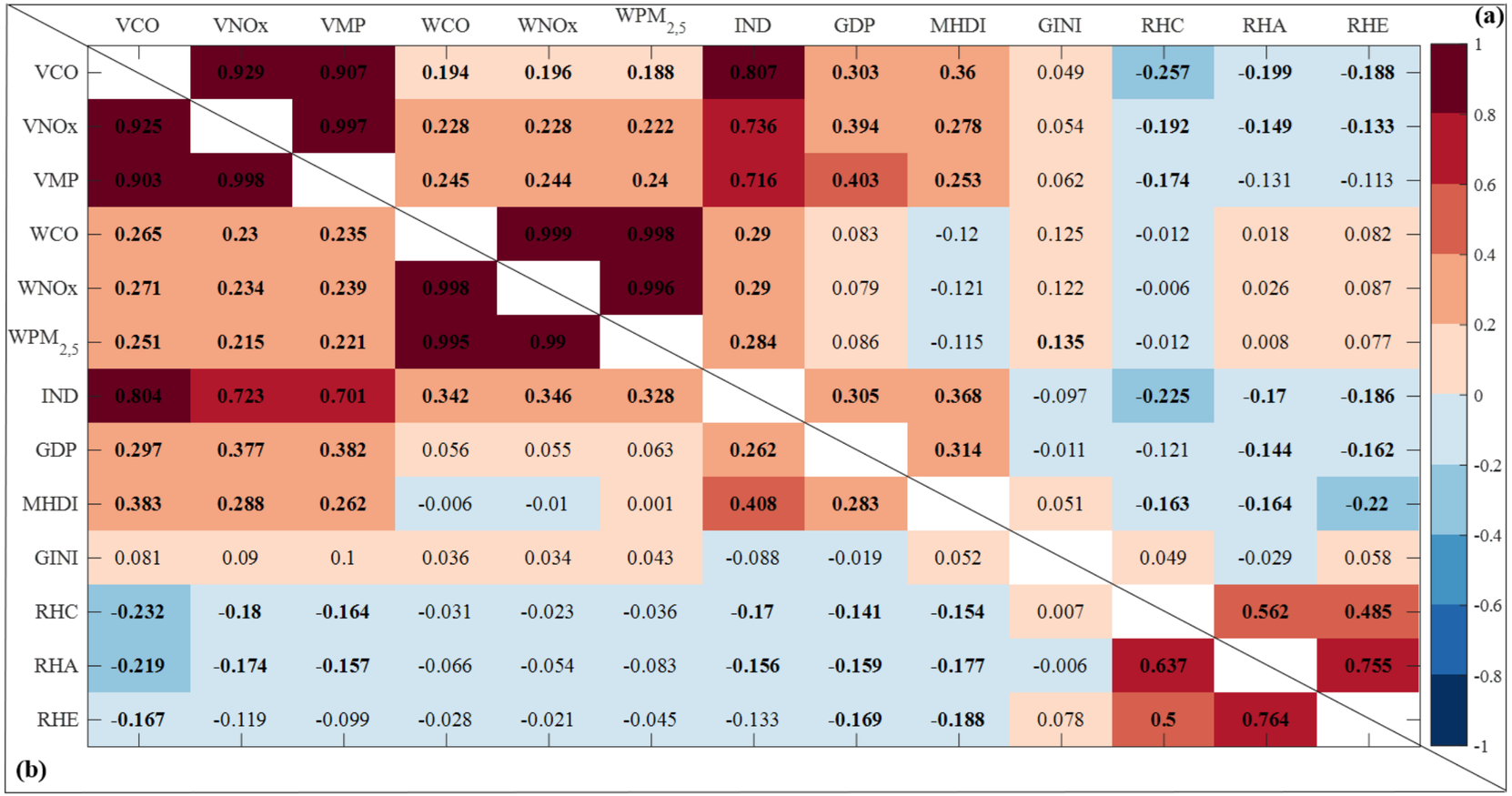


Bold values represent statistical significance at the $p<0.05$ level

VCO - CO by vehicular emission; VNOx - NOx by vehicular emissions; VPM – PM by vehicular emissions; WCO - CO by wildfire emissions; WNOx – NOx by wildfire emissions; WPM2.5 – PM2.5 by wildfire emissions; IND – number of industries; GDP – Gross Domestic Product per capita; MHDI – Municipal Human Development Index; GINI – Gini Coefficient; RHC – Respiratory hospitalizations in children; RHA – Respiratory hospitalization in adults; RHE – Respiratory hospitalization in elderly

M-HDI HIGH

(a) Spearman method; (b) Pearson method



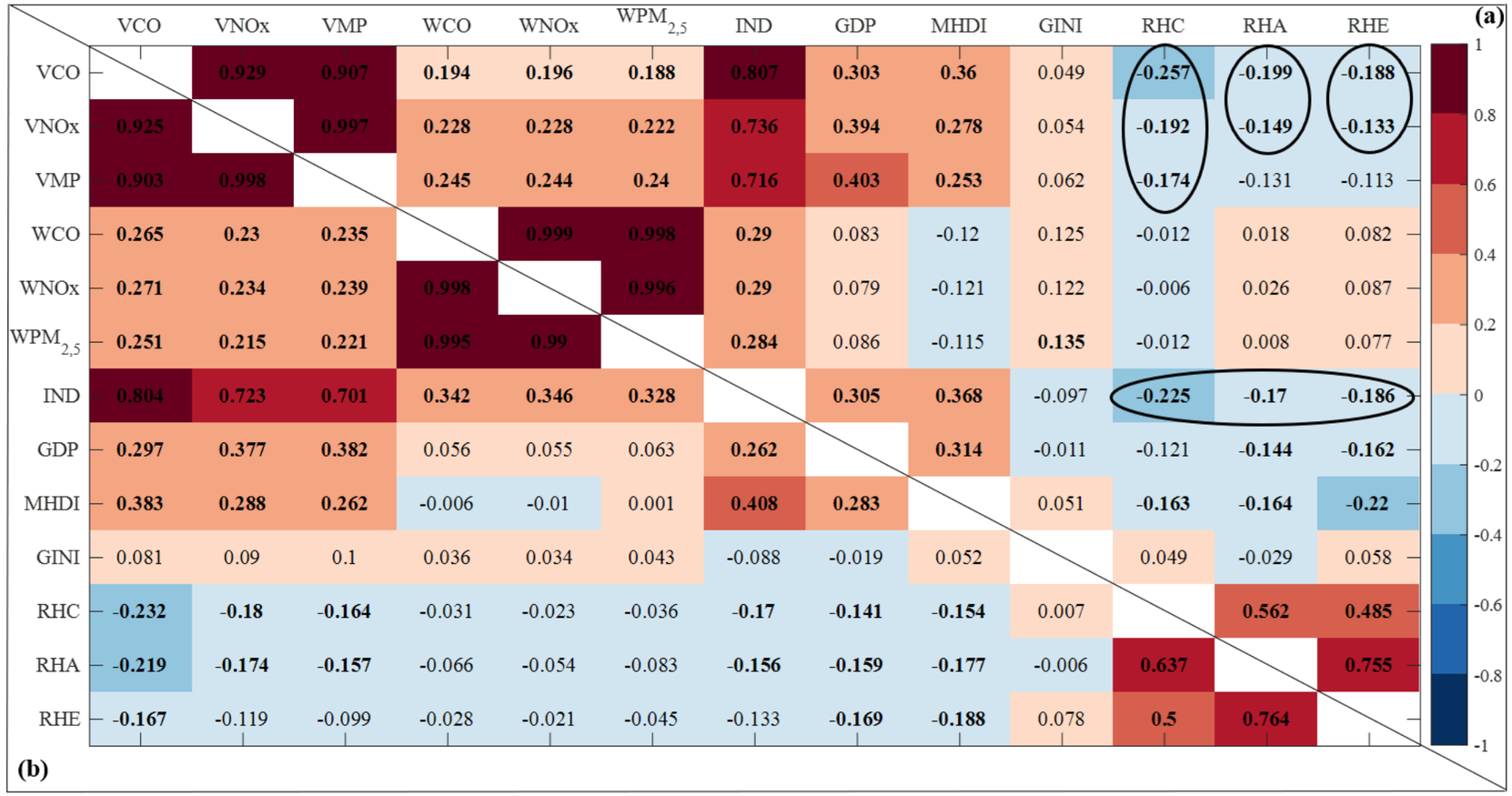
	VCO	VNOx	VMP	WCO	WNOx	$WPM_{2,5}$	IND	GDP	MHDI	GINI	RHC	RHA	RHE
VCO		**0.929**	**0.907**	**0.194**	**0.196**	**0.188**	**0.807**	**0.303**	**0.36**	0.049	**-0.257**	**-0.199**	**-0.188**
VNOx	**0.925**		**0.997**	**0.228**	**0.228**	**0.222**	**0.736**	**0.394**	**0.278**	0.054	**-0.192**	**-0.149**	**-0.133**
VMP	**0.903**	**0.998**		**0.245**	**0.244**	**0.24**	**0.716**	**0.403**	**0.253**	0.062	**-0.174**	-0.131	-0.113
WCO	**0.265**	**0.23**	**0.235**		**0.999**	**0.998**	**0.29**	0.083	-0.12	0.125	-0.012	0.018	0.082
WNOx	**0.271**	**0.234**	**0.239**	**0.998**		**0.996**	**0.29**	0.079	-0.121	0.122	-0.006	0.026	0.087
$WPM_{2,5}$	**0.251**	**0.215**	**0.221**	**0.995**	**0.99**		**0.284**	0.086	-0.115	**0.135**	-0.012	0.008	0.077
IND	**0.804**	**0.723**	**0.701**	**0.342**	**0.346**	**0.328**		**0.305**	**0.368**	-0.097	**-0.225**	**-0.17**	**-0.186**
GDP	**0.297**	**0.377**	**0.382**	0.056	0.055	0.063	**0.262**		**0.314**	-0.011	-0.121	**-0.144**	**-0.162**
MHDI	**0.383**	**0.288**	**0.262**	-0.006	-0.01	0.001	**0.408**	**0.283**		0.051	**-0.163**	**-0.164**	**-0.22**
GINI	0.081	0.09	0.1	0.036	0.034	0.043	-0.088	-0.019	0.052		0.049	-0.029	0.058
RHC	**-0.232**	**-0.18**	**-0.164**	-0.031	-0.023	-0.036	**-0.17**	**-0.141**	**-0.154**	0.007		**0.562**	**0.485**
RHA	**-0.219**	**-0.174**	**-0.157**	-0.066	-0.054	-0.083	**-0.156**	**-0.159**	**-0.177**	-0.006	**0.637**		**0.755**
RHE	**-0.167**	-0.119	-0.099	-0.028	-0.021	-0.045	-0.133	**-0.169**	**-0.188**	0.078	**0.5**	**0.764**	

Bold values represent statistical significance at the p<0.05 level

VCO - CO by vehicular emission; VNOx - NOx by vehicular emissions; VPM – PM by vehicular emissions; WCO - CO by wildfire emissions; WNOx – NOx by wildfire emissions; WPM2.5 – PM2.5 by wildfire emissions; IND – number of industries; GDP – Gross Domestic Product per capita; MHDI – Municipal Human Development Index; GINI – Gini Coefficient; RHC – Respiratory hospitalizations in children; RHA – Respiratory hospitalization in adults; RHE – Respiratory hospitalization in elderly

M-HDI HIGH

(a) Spearman method; (b) Pearson method

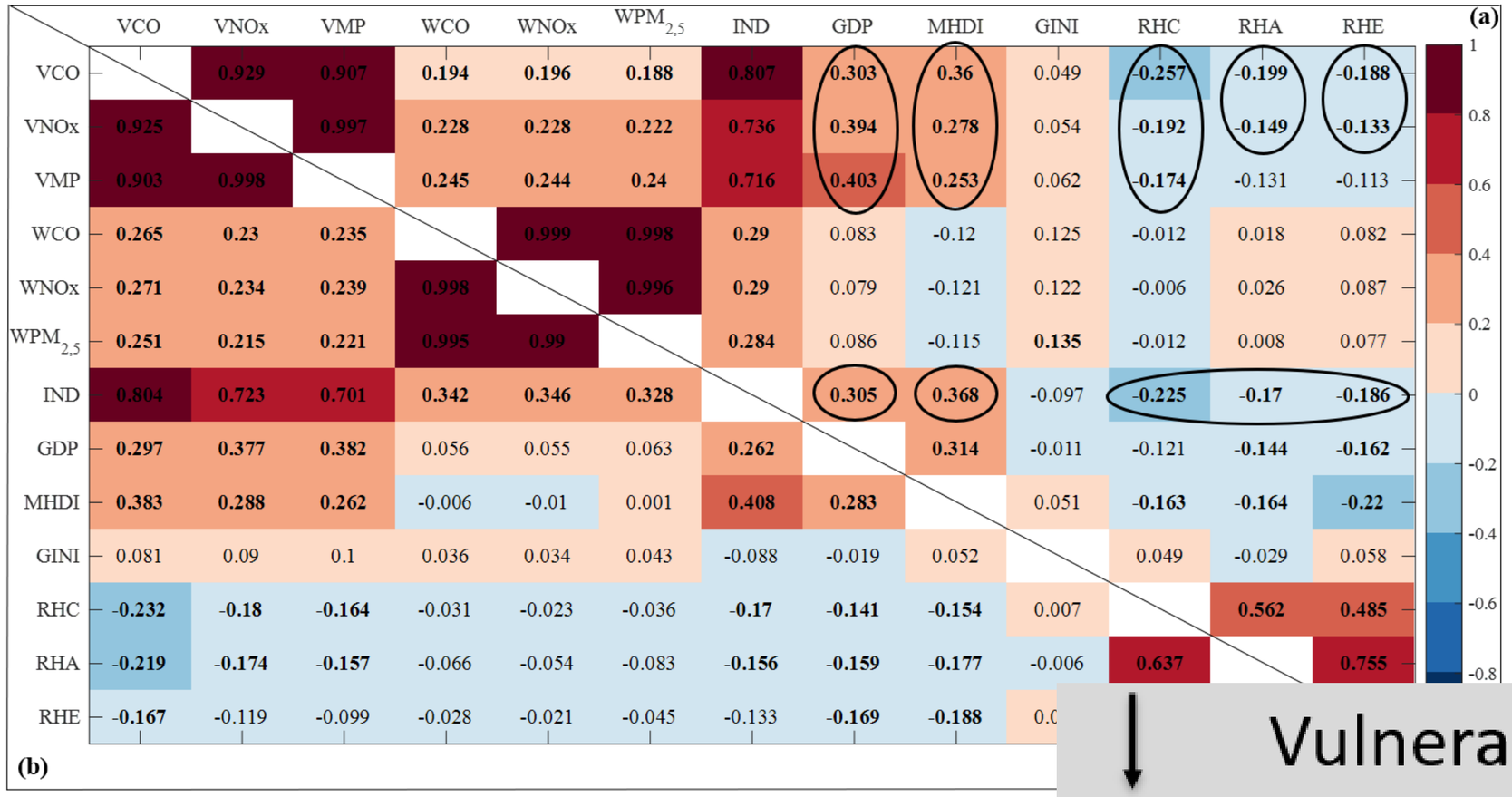


Bold values represent statistical significance at the $p<0.05$ level

VCO - CO by vehicular emission; VNOx - NOx by vehicular emissions; VPM – PM by vehicular emissions; WCO - CO by wildfire emissions; WNOx – NOx by wildfire emissions; WPM2.5 – PM2.5 by wildfire emissions; IND – number of industries; GDP – Gross Domestic Product per capita; MHDI – Municipal Human Development Index; GINI – Gini Coefficient; RHC – Respiratory hospitalizations in children; RHA – Respiratory hospitalization in adults; RHE – Respiratory hospitalization in elderly

M-HDI HIGH

(a) Spearman method; (b) Pearson method



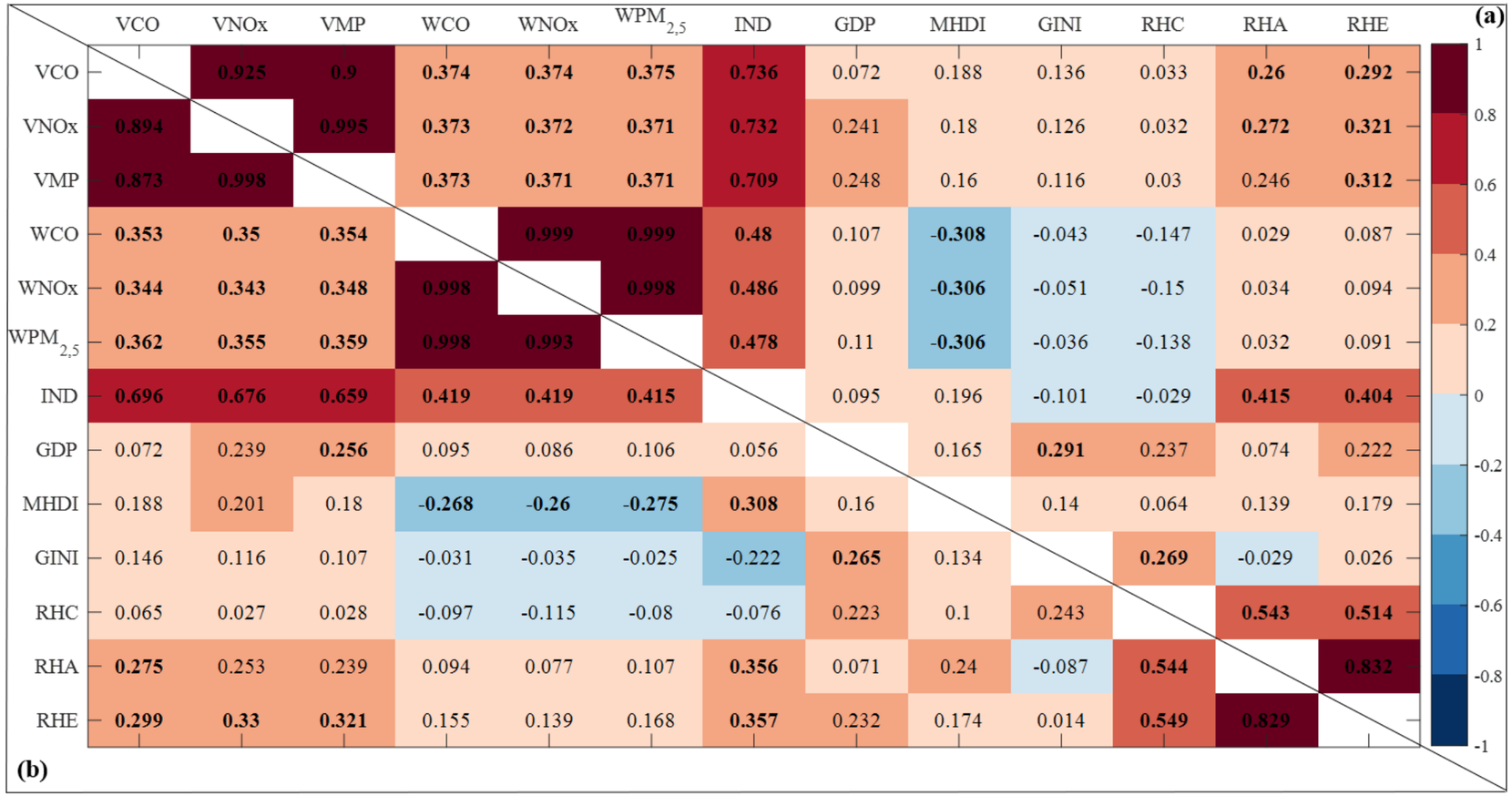
Vulnerability

Bold values represent statistical significance at the p<0.05 level

VCO - CO by vehicular emission; VNOx - NOx by vehicular emissions; VPM – PM by vehicular emissions; WCO - CO by wildfire emissions; WNOx – NOx by wildfire emissions; WPM2.5 – PM2.5 by wildfire emissions; IND – number of industries; GDP – Gross Domestic Product per capita; MHDI – Municipal Human Development Index; GINI – Gini Coefficient; RHC – Respiratory hospitalizations in children; RHA – Respiratory hospitalization in adults; RHE – Respiratory hospitalization in elderly

M-HDI MEDIUM

(a) Spearman method; (b) Pearson method



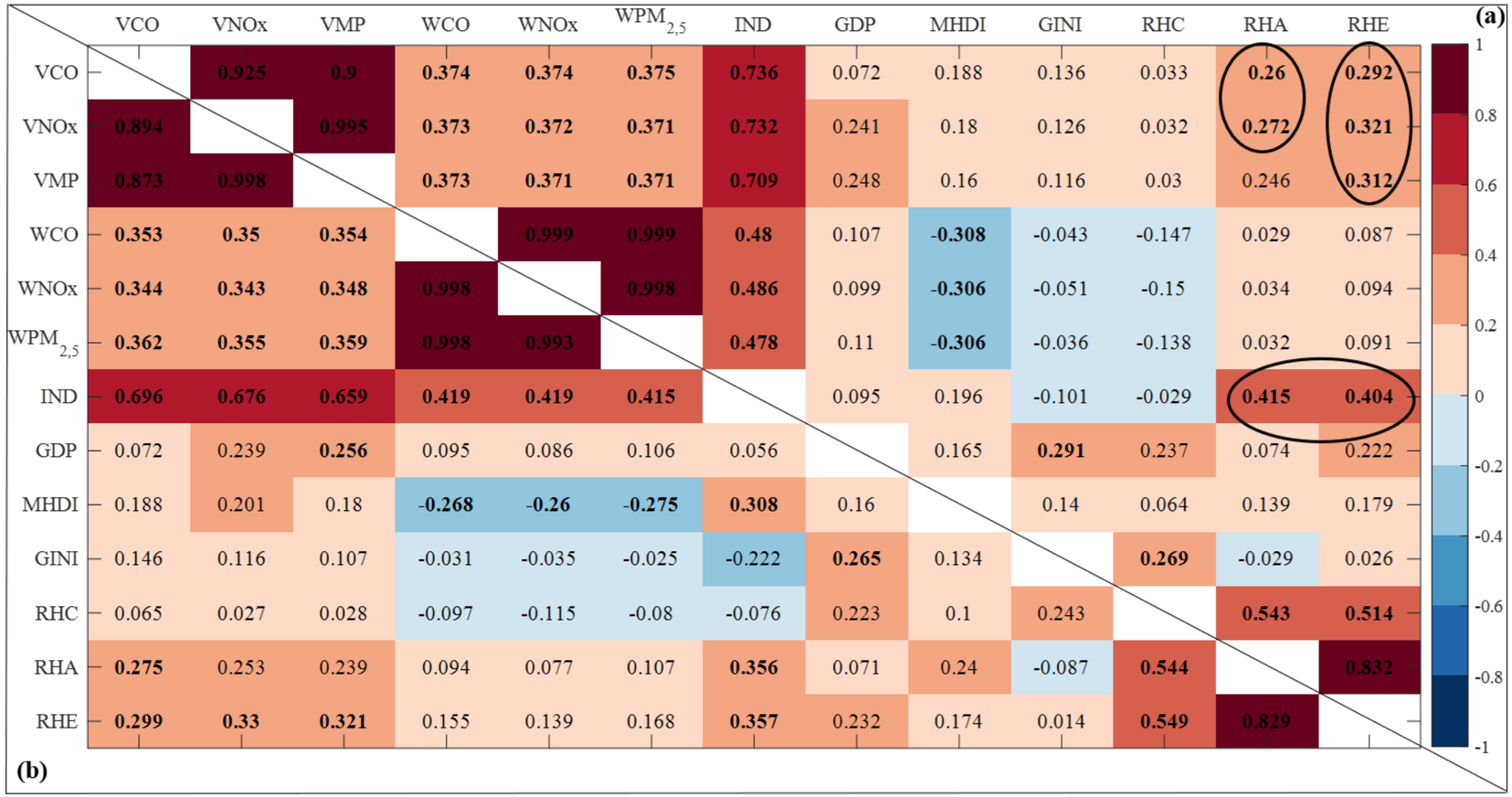
	VCO	VNOx	VMP	WCO	WNOx	$WPM_{2,5}$	IND	GDP	MHDI	GINI	RHC	RHA	RHE
VCO		**0.925**	**0.9**	**0.374**	**0.374**	**0.375**	**0.736**	0.072	0.188	0.136	0.033	**0.26**	**0.292**
VNOx	**0.894**		**0.995**	**0.373**	**0.372**	**0.371**	**0.732**	0.241	0.18	0.126	0.032	**0.272**	**0.321**
VMP	**0.873**	**0.998**		**0.373**	**0.371**	**0.371**	**0.709**	0.248	0.16	0.116	0.03	0.246	**0.312**
WCO	**0.353**	**0.35**	**0.354**		**0.999**	**0.999**	**0.48**	0.107	**-0.308**	-0.043	-0.147	0.029	0.087
WNOx	**0.344**	**0.343**	**0.348**	**0.998**		**0.998**	**0.486**	0.099	**-0.306**	-0.051	-0.15	0.034	0.094
$WPM_{2,5}$	**0.362**	**0.355**	**0.359**	**0.998**	**0.993**		**0.478**	0.11	**-0.306**	-0.036	-0.138	0.032	0.091
IND	**0.696**	**0.676**	**0.659**	**0.419**	**0.419**	**0.415**		0.095	0.196	-0.101	-0.029	**0.415**	**0.404**
GDP	0.072	0.239	**0.256**	0.095	0.086	0.106	0.056		0.165	**0.291**	0.237	0.074	0.222
MHDI	0.188	0.201	0.18	**-0.268**	**-0.26**	**-0.275**	**0.308**	0.16		0.14	0.064	0.139	0.179
GINI	0.146	0.116	0.107	-0.031	-0.035	-0.025	-0.222	**0.265**	0.134		**0.269**	-0.029	0.026
RHC	0.065	0.027	0.028	-0.097	-0.115	-0.08	-0.076	0.223	0.1	0.243		**0.543**	**0.514**
RHA	**0.275**	0.253	0.239	0.094	0.077	0.107	**0.356**	0.071	0.24	-0.087	**0.544**		**0.832**
RHE	**0.299**	**0.33**	**0.321**	0.155	0.139	0.168	**0.357**	0.232	0.174	0.014	**0.549**	**0.829**	

Bold values represent statistical significance at the p<0.05 level

VCO - CO by vehicular emission; VNOx - NOx by vehicular emissions; VPM – PM by vehicular emissions; WCO - CO by wildfire emissions; WNOx – NOx by wildfire emissions; WPM2.5 – PM2.5 by wildfire emissions; IND – number of industries; GDP – Gross Domestic Product per capita; MHDI – Municipal Human Development Index; GINI – Gini Coefficient; RHC – Respiratory hospitalizations in children; RHA – Respiratory hospitalization in adults; RHE – Respiratory hospitalization in elderly

M-HDI MEDIUM

(a) Spearman method; (b) Pearson method

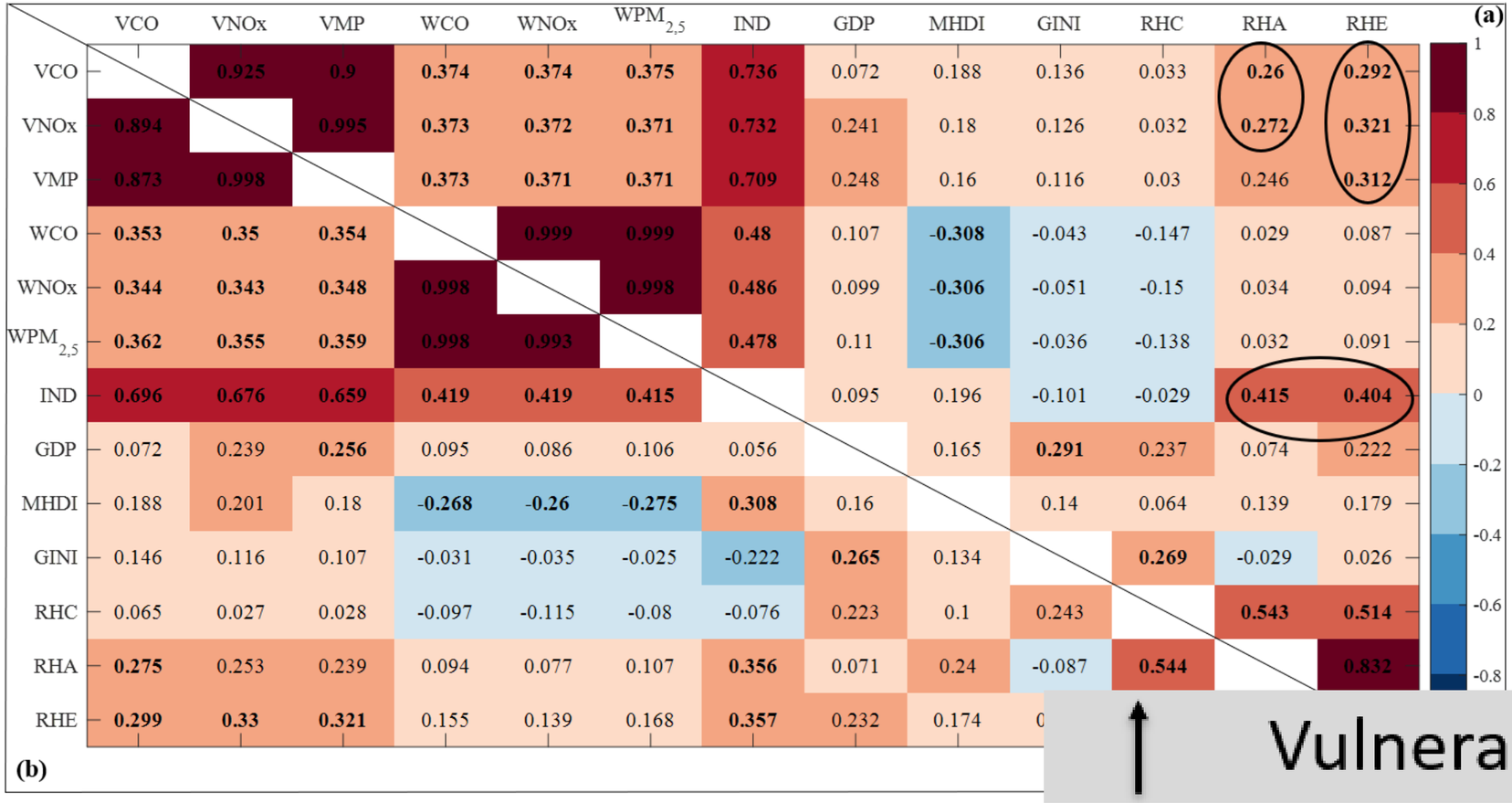


Bold values represent statistical significance at the p<0.05 level

VCO - CO by vehicular emission; VNOx - NOx by vehicular emissions; VPM – PM by vehicular emissions; WCO - CO by wildfire emissions; WNOx – NOx by wildfire emissions; WPM2.5 – PM2.5 by wildfire emissions; IND – number of industries; GDP – Gross Domestic Product per capita; MHDI – Municipal Human Development Index; GINI – Gini Coefficient; RHC – Respiratory hospitalizations in children; RHA – Respiratory hospitalization in adults; RHE – Respiratory hospitalization in elderly

M-HDI MEDIUM

(a) Spearman method; (b) Pearson method



Bold values represent statistical significance at the p<0.05 level

VCO - CO by vehicular emission; VNOx - NOx by vehicular emissions; VPM – PM by vehicular emissions; WCO - CO by wildfire emissions; WNOx – NOx by wildfire emissions; WPM2.5 – PM2.5 by wildfire emissions; IND – number of industries; GDP – Gross Domestic Product per capita; MHDI – Municipal Human Development Index; GINI – Gini Coefficient; RHC – Respiratory hospitalizations in children; RHA – Respiratory hospitalization in adults; RHE – Respiratory hospitalization in elderly

4. Conclusions and Recomendations

- When fully evaluated, vehicle emissions and number of industries did not show that they could affect hospitalizations. Only emissions from fires possibly impacted the elderly age group.

- The results also indicate that municipalities with lower GDP per capita and M-HDI may have the highest number of admissions for respiratory diseases.

- The air pollution, caused by vehicular emissions and the number of industries, may have affected those municipalities that have the lowest M-HDI index for the year 2017.

- The population of municipalities with the Very High M-HDI may have presented a limit in relation to their adaptive capacity.

- Greater attention from decision makers is recommended, especially for municipalities that have a Medium M-HDI.
- More studies are needed to clearly understand the limitations of Santa Catarina's municipalities in adapting to air pollution.
- Finally, the importance of understanding the totalized effect of pollution is mentioned, as well as more robusted methods that should be performed in future research.

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Thank you for your attention!

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