THE ECONOMIC BURDEN OF PREMATURE MORTALITY RELATED TO $PM_{2.5}$ AND O_3 EXPOSURE IN GREECE: BEYOND THE STATE-OF-THE-ART

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INTRODUCTION: Fast facts (1)

Almost 90% of the global population lives in regions with poor air quality.

Estimations on the annual number of deaths attributed to ambient air pollution range between 3 and 8.8 million globally, with low- and middle-income countries being more afflicted.

Short/long-term exposure is linked with adverse health outcomes and mortality related to impaired function of the cardiovascular, respiratory and nervous system.

The adverse impact is more profound for the elderly and people with already compromised health which comprise the most susceptible groups of population.

The adverse health effects can occur even when exposed to concentrations below the recommended levels, indicating that the existing air quality standards might be inadequate.

INTRODUCTION: The Mediterranean region

- Complex topography and climate favourable to air pollution
- Transport of pollution from the industrialized north/west
- Dust storms originating from Africa and the Middle East
- In coastal regions, sea-salt aerosols constitute a considerable portion of the PM load
- Climate change hot spot

INTRODUCTION: Recent evidence from Greece and Cyprus (1/4)

Both cities feature Mediterranean climate with hot and dry summers and mild winters

Thessaloniki, in **Northern Greece** (1,030,338 residents)

Limassol, in **Cyprus** (239,842 residents)

In Cyprus dust storms are more frequent compared to Greece

INTRODUCTION: Recent evidence from Greece and Cyprus (2/4)

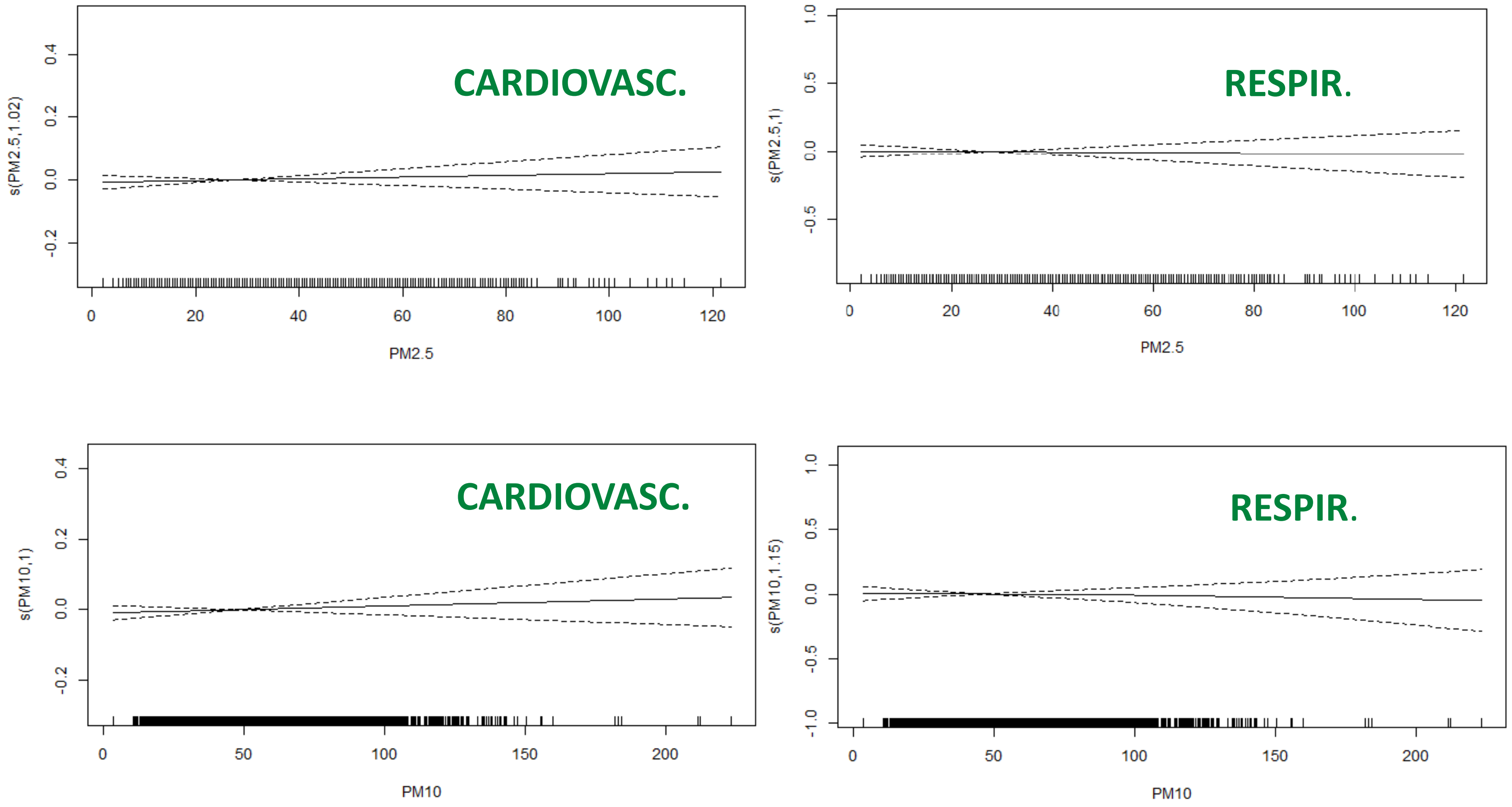


Fig. 1 Penalized spline terms for the PM effect for Thessaloniki. The dfs were chosen using the Generalized Cross Validation criterion of the GAM model.

INTRODUCTION: Recent evidence from Greece and Cyprus (3/4)

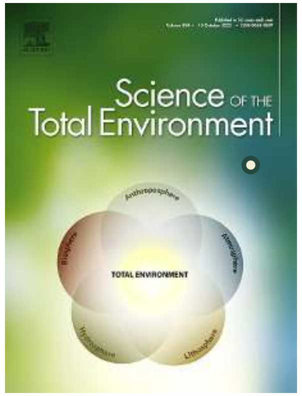
TABLE 1. Percent change in daily mortality (95% CI) associated with a 10 μg/m^3 increase in PM concentrations at lag 0

Thessaloniki	**$PM_{2.5}$**	**PM_{10}**
Cardiovascular	**1.10 (-0.13, 2.34)***	0.40 (-0.26,1.05)
Respiratory	0.16 (-2.45, 2.84)	0.94 (-0.56,2.46)
Limassol	**$PM_{2.5}$**	**PM_{10}**
All-cause	**3.07 (-0.90, 7.20)**	0.30 (-1.19, 1.81)
Cardiovascular	0.64 (-5.61, 7.29)	1.12 (-1.22,3.51)

**statistically significant at 0.10 level*

The association became significant after adjusting for O_3 and NO

- Adjusting for co-pollutants **did not significantly change the results**.



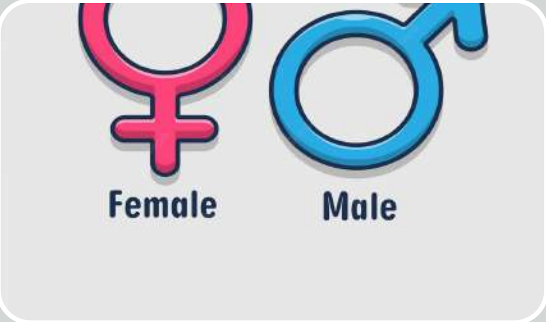
MORE IN: Psistaki K., Achilleos S., Middleton N., Paschalidou A.K (2022) Exploring the impact of Particulate Matter on mortality in coastal Mediterranean environments. ***Science of the Total Environment, 865, 161147.***

INTRODUCTION: Recent evidence from Greece and Cyprus (4/4)

DUST EVENTS
- Thessaloniki: "protective effect"
- The association between PM and mortality didn't change

DUST STORMS

Thessaloniki: a decrease in change in daily PM-related mortality



GENDER

Statistically significant associations (positive) were estimated only for males

GENDER ANALYSIS
- Thessaloniki: between PM_{10} and respiratory mortality
- Limassol: between $PM_{2.5}$ and all-cause mortality

INTRODUCTION: Fast facts (2)

4-9 million deaths annually are attributed to $PM_{2.5}$ and O_3 exposure

Major economic losses resulting from lower labor productivity, hospitalization, mortality and loss of welfare

In 2019, the economic loss associated with exposure to fine PM ranged between 1.7% of North America's GDP and 10.3% of South Asia's GDP, causing a total economic damage of $ 8.1 trillion globally

OBJECTIVE

To quantify the economic burden of premature mortality related to long-term exposure to $PM_{2.5}$ and ground-level O_3 in Greece, examining both the country as a whole and its various sub-regions separately from 2004 to 2019

DATA SOURCES

Time-period: 2004-2019

Copernicus Atmosphere Monitoring Service (CAMS) global reanalysis (EAC4)	Hellenic Statistical Authority	Demographic censuses of 2011 and 2021
Pollutant data 3-h surface $PM_{2.5}$ and O_3 concentrations ($\mu g/m^3$), with a 0.75° × 0.75° spatial resolution for the 16-year time period (2004–2019)	**Mortality data** Daily all-cause casualties per region **Economic data** GDP per capita for each region and Consumer Price Index (CPI)	**Demographical data** Region-level and age-specific population data

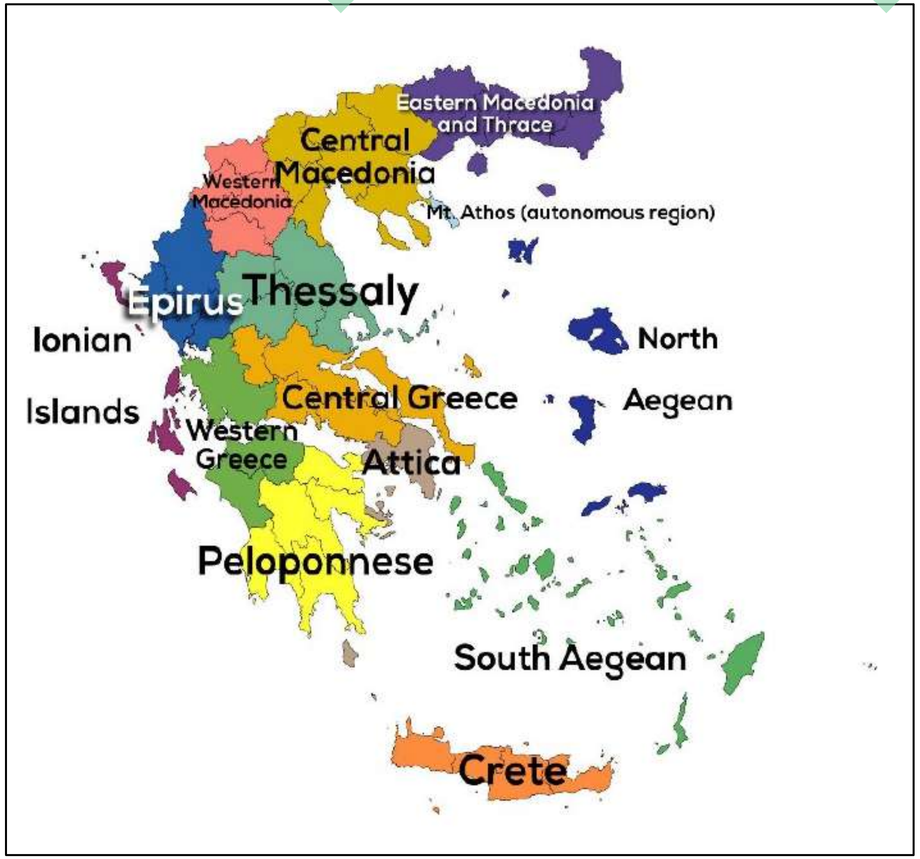
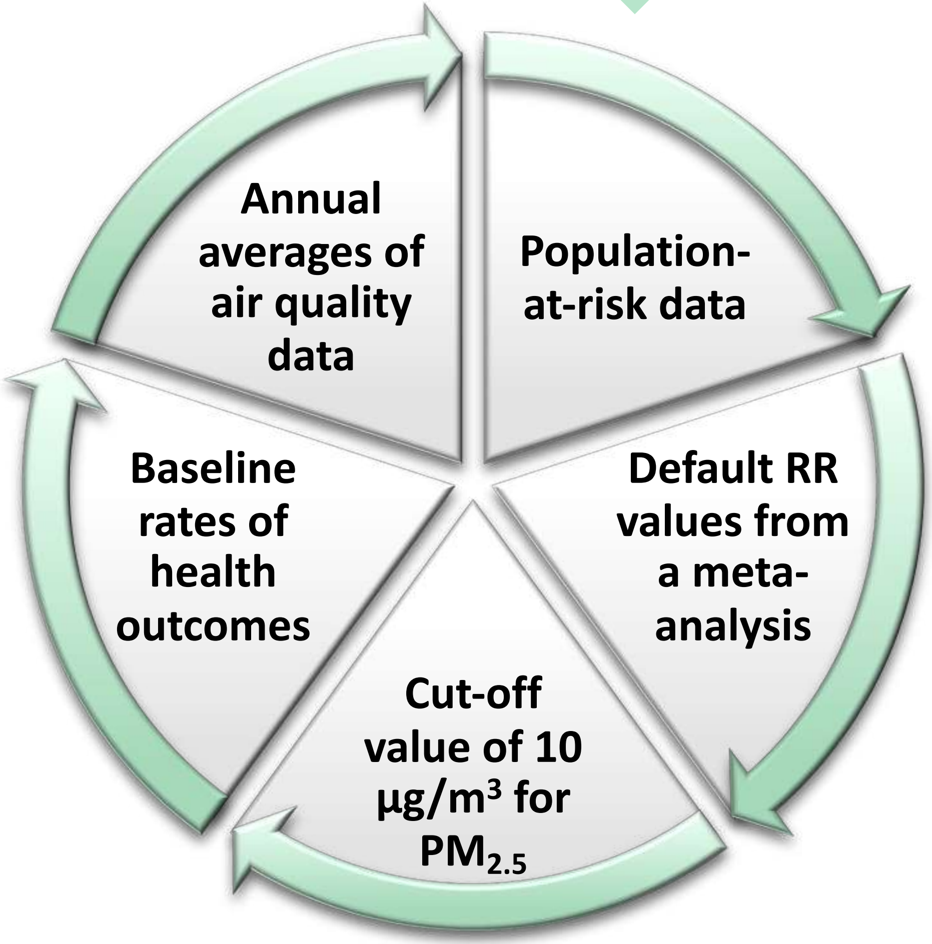


Fig. 2 The 13 regions studied

METHODS: Estimation of premature mortality

- In order to estimate the health burden resulting from $PM_{2.5}$ and O_3 exposure, the AirQ+ software was used
- AirQ+ is a tool developed by the WHO Regional Office for Europe for quantifying the health impacts of air pollution
- All calculations performed with AirQ+ are based on methodologies and concentration–response functions established by previous epidemiological studies



METHODS: Estimation of the economic burden

VSL represents the willingness of people to sacrifice wealth (willingness to pay—WTP)

VSL is the local tradeoff rate between fatality risk and money

Value of a statistical life (VSL)

Options for adopting different scenarios - Flexibility

Widely applied in many sectors in order to develop relevant policies (environment, transportation, medicine etc.)

METHODS: Scenario development

Constant scenario

- The income elasticity is constant and equal across all regions of Greece
- The VSL is constant, with 2005 being the standardized year for all regions and for the whole time period (2004-2019)
- 2005 was selected as the reference year
- $\boldsymbol{VSL_{constant} = VSL_{2005} * \left(\frac{Y_c}{Y_{2005}}\right)^{\beta}}$
- $\boldsymbol{VSL_{2005}}$ is the base value for the OECD countries. $\boldsymbol{Y_{2005}}$ is the GDP per capita in Greece for 2005 and $\boldsymbol{Y_c}$ is the GDP per capita in each region for 2005. **β** denotes the income elasticity of the VSL (0.8)

Changing scenario

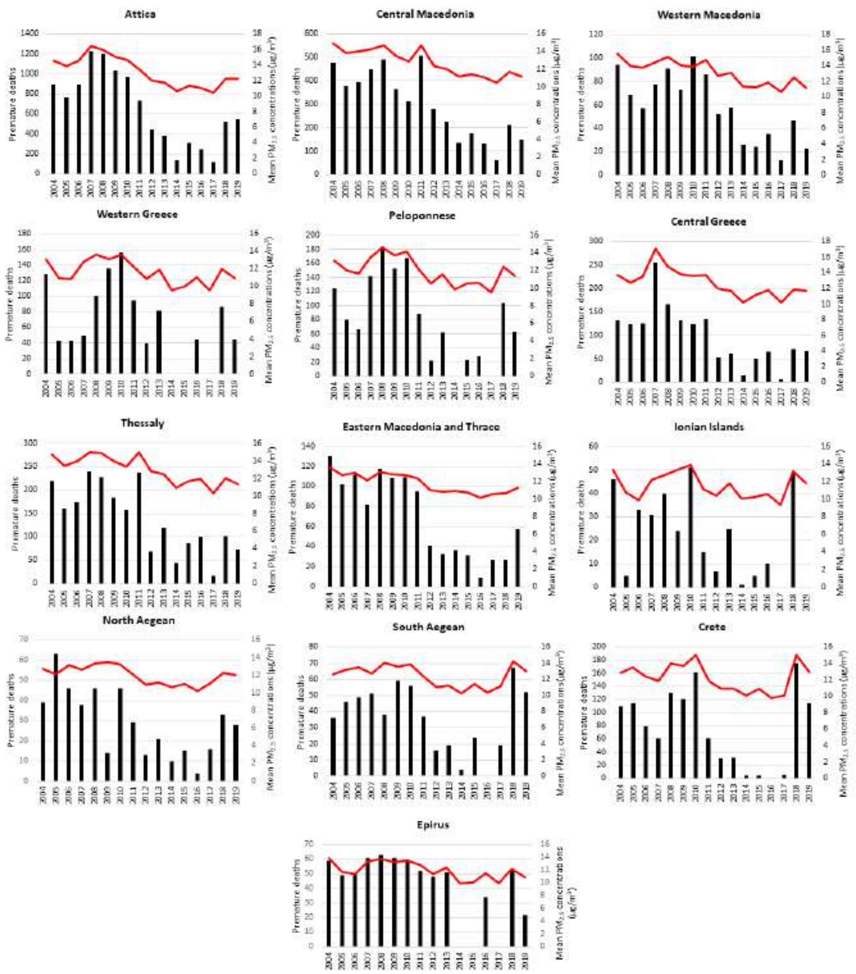
- VSL following the annual change in GDP and CPI per region
- Population, mortality rate and air pollutants' concentrations constitute driving forces for the changes in economic loss
- The changes in GDP and CPI are important
- $\boldsymbol{VSL_{changing} = VSL_{2005} * \left(\frac{Y_c}{Y_{2005}}\right)^{\beta} * (1 + \%_{\Delta}P + \%_{\Delta}Y)^{\beta}}$
- $\boldsymbol{\%_{\Delta}P}$ and $\boldsymbol{\%_{\Delta}Y}$ are the percentage changes in CPI and GDP per capital growth, in each region from 2004 to 2019

Economic burden (loss)

$$\boldsymbol{Economic\ Burden = VSL_{constant/changing} * M}$$

where *M* was calculated with the AirQ+ software

RESULTS: Pollutants and mortality trend analysis



- The annual concentration of $PM_{2.5}$ showed a statistically significant decline
- They remained stable until 2010, and followed a declining trend afterwards, reflecting the great financial crisis that started in late 2009
- No statistically significant trend was observed for O_3
- During the years that followed the fiscal recession, an increase in the annual mean O_3 concentrations was observed
- O_3 was found to have an almost negligible impact on death counts, while premature mortality was primarily driven by the levels of $PM_{2.5}$

Fig. 3 Annual values of $PM_{2.5}$ ($\mu g/m^3$) (line) and premature deaths attributed to long-term exposure to $PM_{2.5}$ per region (bars), for the period 2004–2019

RESULTS: Economic burden

Changing scenario

- The cost resulting from mortality due to exposure to $PM_{2.5}$ and O_3 ranged between EUR 45.6 billion in 2007 and EUR 1.3 billion in 2014
- A dramatic decline was observed after 2008
- Comparing the two pollutants, the contribution of $PM_{2.5}$ to the total economic loss ranged 98.7–99.8%

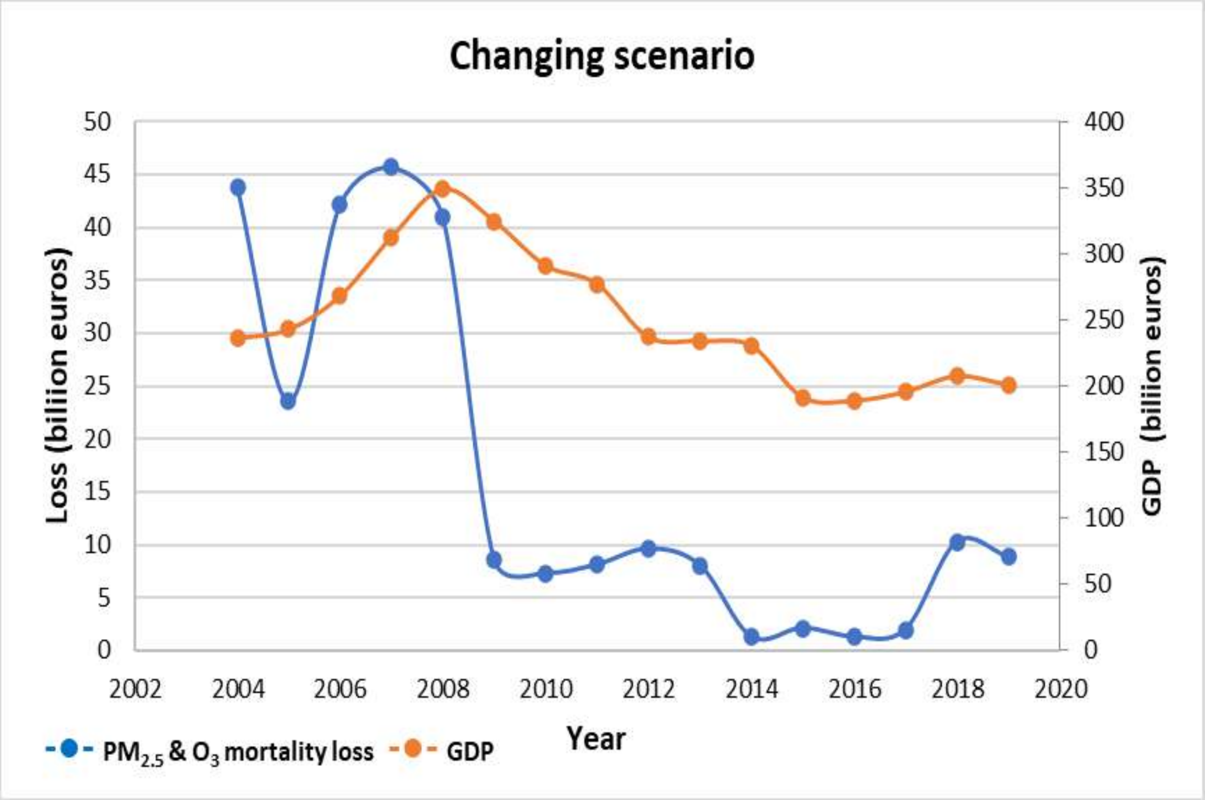


Fig. 4 Economic losses resulting from premature mortality due to $PM_{2.5}$ and O_3 exposure for the changing scenario

RESULTS: Spatial analysis

Spatial characteristics of the Economic Burden from Premature Mortality attributed to $PM_{2.5}$ and O_3 exposure

- The highest values of economic loss were observed in densely populated, urbanised regions with high $PM_{2.5}/O_3$ concentrations
- Increased economic damage was generally observed in regions with high GDP per capita, such as Attica
- Lower economic losses were found in regions with relatively low GDP per capita, such as Epirus and Eastern Macedonia and Thrace
- The Ionian and South Aegean Islands showed low losses despite their high GDP per capita

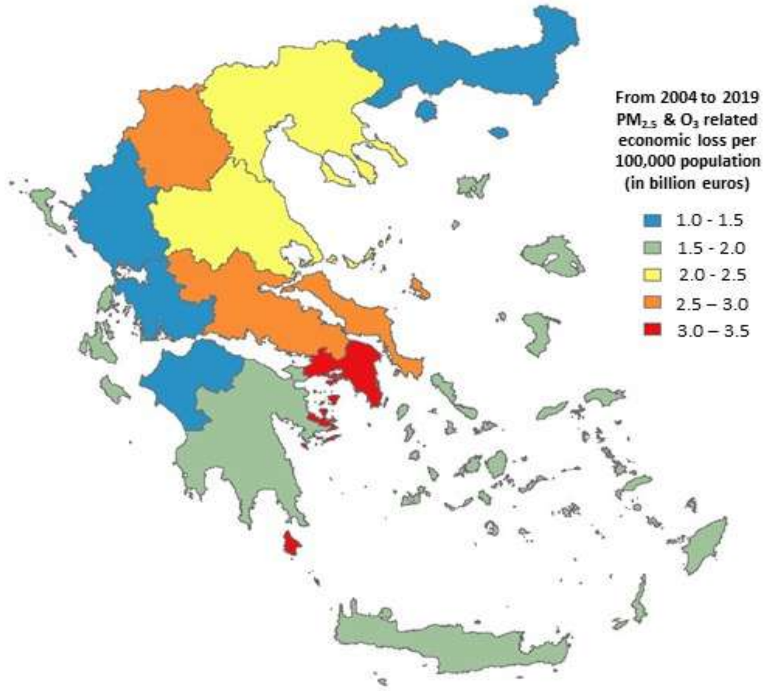
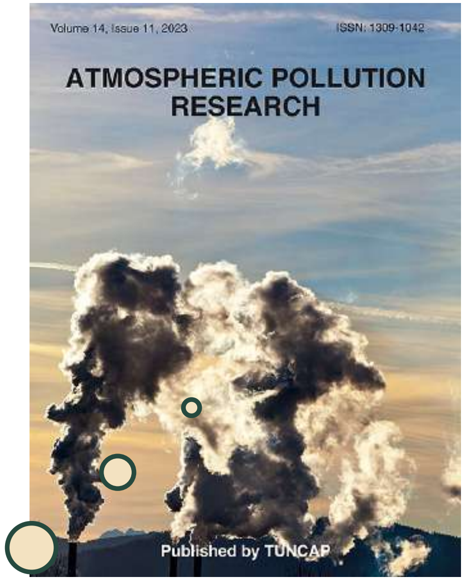


Fig. 5 Cumulative 2004-2019 economic burden (in € billion) resulting from premature mortality due to ambient $PM_{2.5}$ and O_3 exposure per 100,000 population, for the changing scenario

CONCLUSIONS

- O_3 had a rather negligible impact on mortality and economic burden compared to $PM_{2.5}$
- Annual changes in economic losses were mainly driven by the annual changes in $PM_{2.5}$ levels and the GDP per capita
- Reducing particulate air pollution could result not only in improvements in public health but also in significant economic benefits
- The regional GDP per capita did not necessarily coincide with the magnitude of the economic burden
- The willingness of people to pay in order to reduce air pollution mortality appears to have followed the evolution of GDP



MORE IN: Petrou I, Psistaki K., Kassomenos P. Dokas I., Paschalidou A.K. (2023) Studying the economic burden of premature mortality related to $PM_{2.5}$ and O_3 exposure in Greece between 2004 and 2019. ***Atmospheric Pollution Research (in press).***

Thank you!