Barcelona
Supercomputing
Center
Centro Nacional de Supercomputación

EXCELENCIA
SEVERO
OCHOA

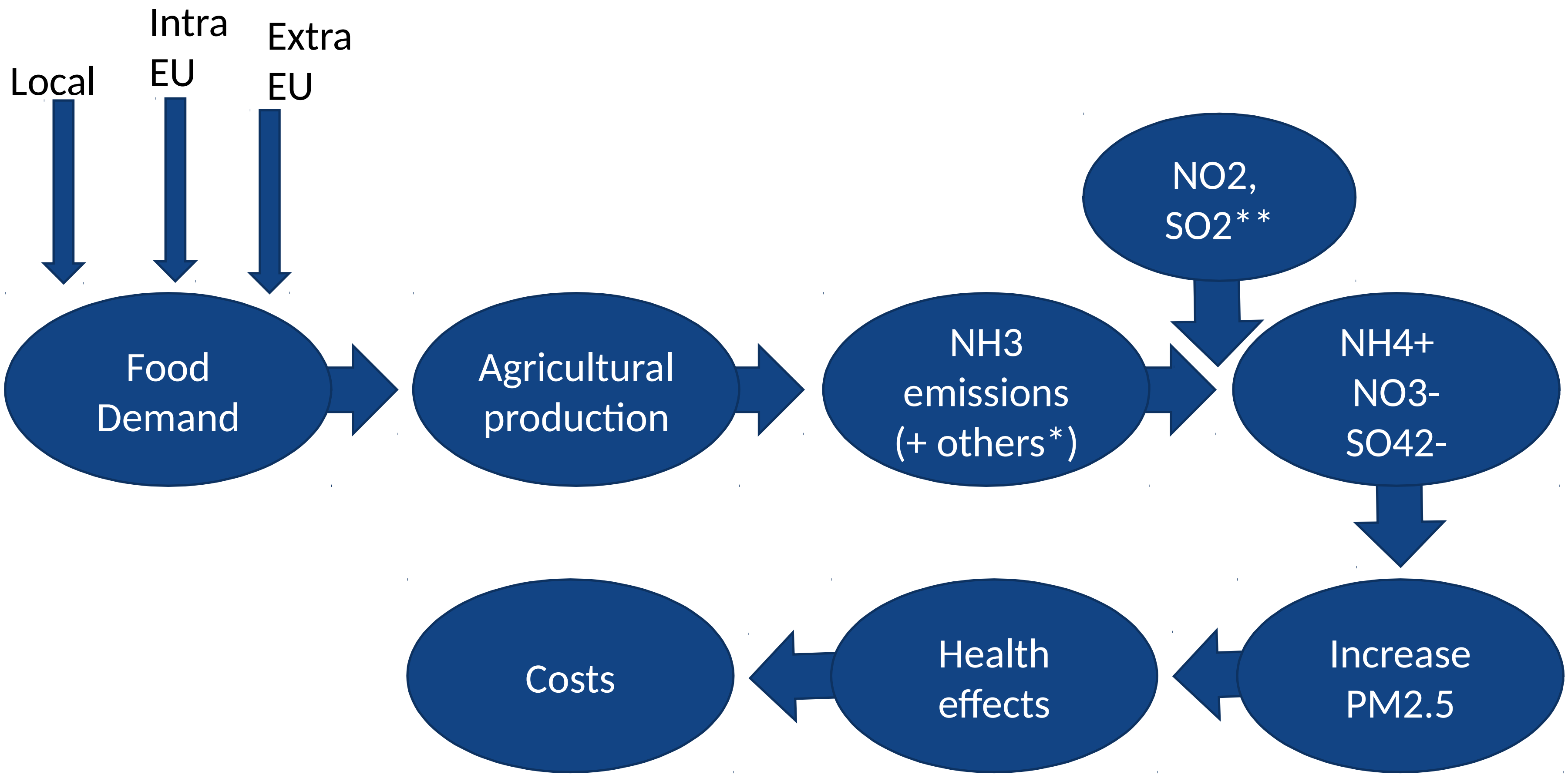
PM source apportionment: the agricultural sector

Vanessa N. dos Santos
María Teresa Pay

14/03/2019

Barcelona

Agricultural emissions and air quality



Local

Intra EU

Extra EU

Food Demand

Agricultural production

NH3 emissions (+ others*)

NO2, SO2**

NH4+ NO3- SO42-

Increase PM2.5

Health effects

Costs

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

* CO, NMVOC, PM2.5, PM10, SOx, NOx

** Mainly NO2 and SO2 from combustion

Agriculture facts

- Global NH3 emissions increased over 50% in the last 70 years.
- **Agriculture** is identified as the main source of NH3 (livestock 66%; 33% N-fertilizer).
- **Agriculture** contribution to PM2.5:
  - > 20% of annual PM2.5 in 99 out of 150 EU cities (Thunis et al. 2018)
  - up to 14% and 16% in summer and winter, respectively, to monthly PM2.5 (16 EU cities). Highest in Central and Eastern EU (Karamchandani et al. 2017)
- **Agriculture** is responsible for the largest impact on mortality linked to air pollution in 2010 (Lelieveld et al, 2015; Bauer et al. 2016)
- Secondary inorganic aerosols (i.e.: NH4+,NO3-, SO42-) accounted for ~ 50% of PM2.5 mass in EU.
- PM2.5 is sensitive to a decrease in NH3, SOx and NOx emissions (Bauer et al. 2016).
  - Decreasing NOx was found to mitigate PM2.5 in EU.
  - Decreasing NH3 is effective for PM2.5 mitigation in winter.
  - Decreasing SO2 is more effective for PM2.5 mitigation in summer.

EU directive 2016/2284/EU: EU countries committed to decrease NH3 emissions by 2020 – 2029 (relative to 2005 values). A **mean decrease of 6%** is expected for EU. Spain: **NH3/PM2.5-> 3/15 %**; Denmark: **NH3/PM2.5-> 24/33 %** by 2029).

Global mortality associated with agricultural emissions in 2010

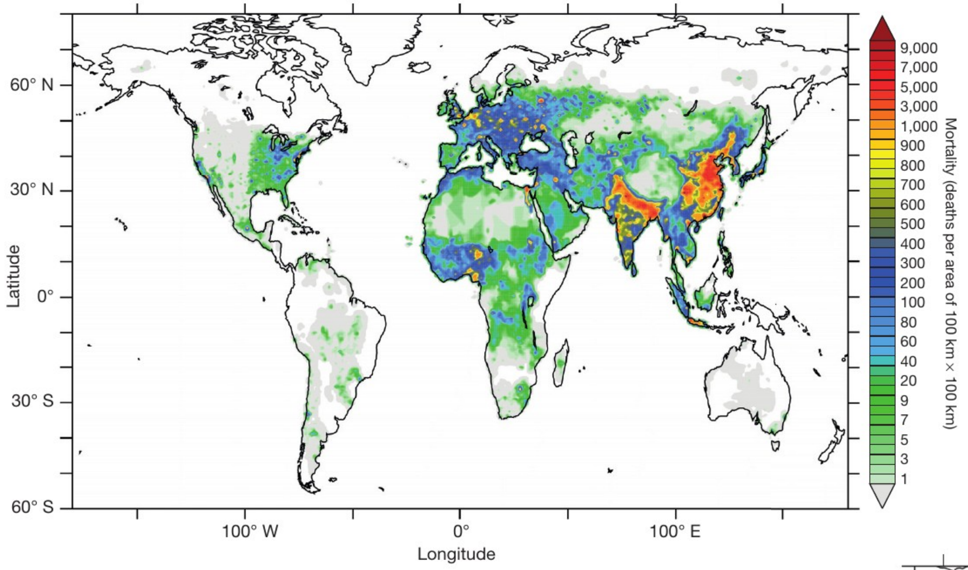
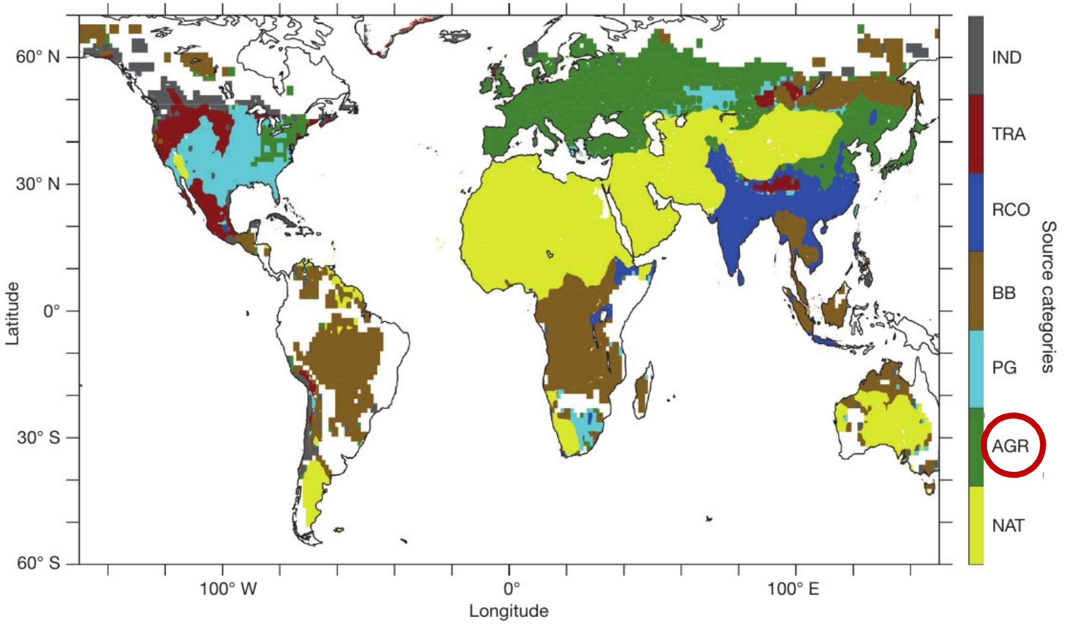


Figure 1 | Mortality linked to outdoor air pollution in 2010. In the white areas, annual mean PM2.5 and O3 are below the concentration–response thresholds where no excess mortality is expected.

Agriculture is the sector that most impact air pollution related mortality in EU

Figure 2 | Source categories responsible for the largest impact on mortality linked to outdoor air pollution in 2010. IND, industry; TRA, land traffic; RCO, residential and commercial energy use(e.g:, heating, cooking); BB, biomass burning; PG, power generation; **AGR, agriculture**; and NAT, natural. In the white areas, annual mean PM2.5 is below the concentration–response threshold".



Source: Lelieveld et al., 2015 (Nature)

Impacts of agriculture on PM2.5 - current and future

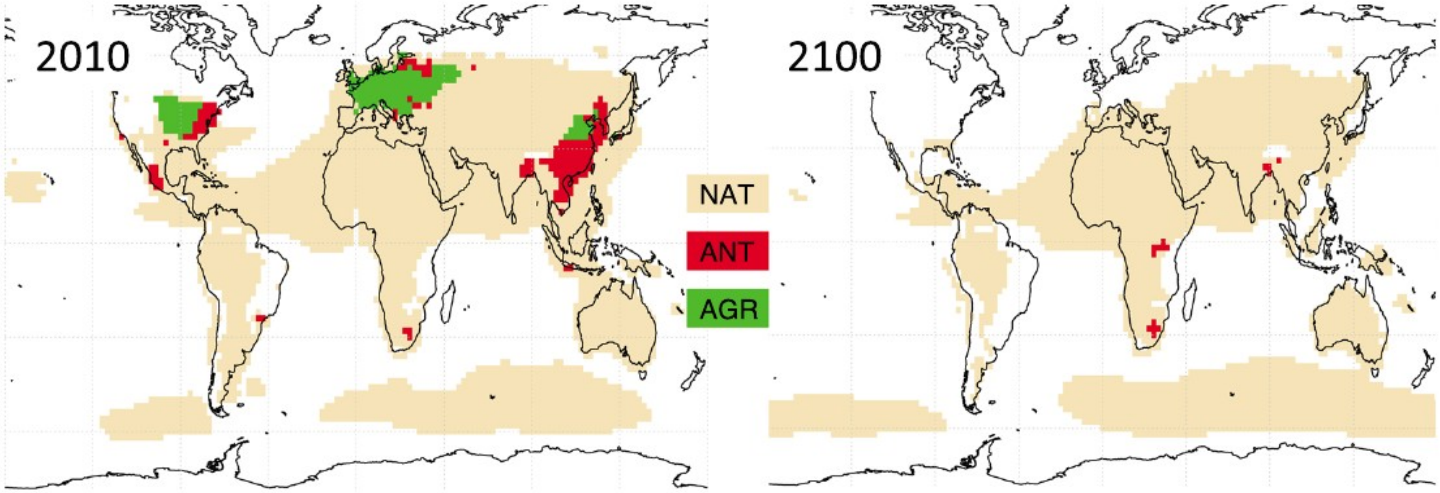
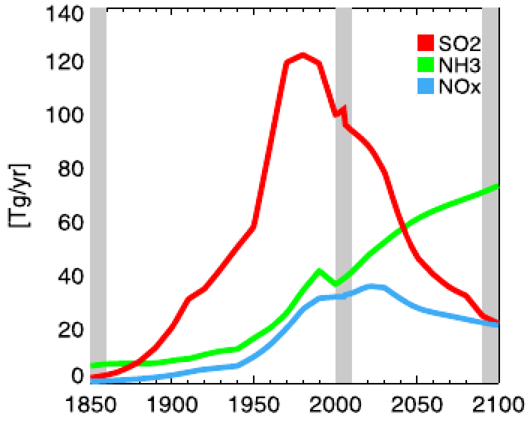


Figure 2. Dominant contributor to $PM_{2.5}$ concentrations with respect to natural, anthropogenic (without agriculture), and agricultural sources. (left) Present-day conditions and (right) 2100 conditions for the RCP8.5 scenario. Areas with $PM_{2.5}$ concentrations below 3 $\mu g/m^3$ are white.

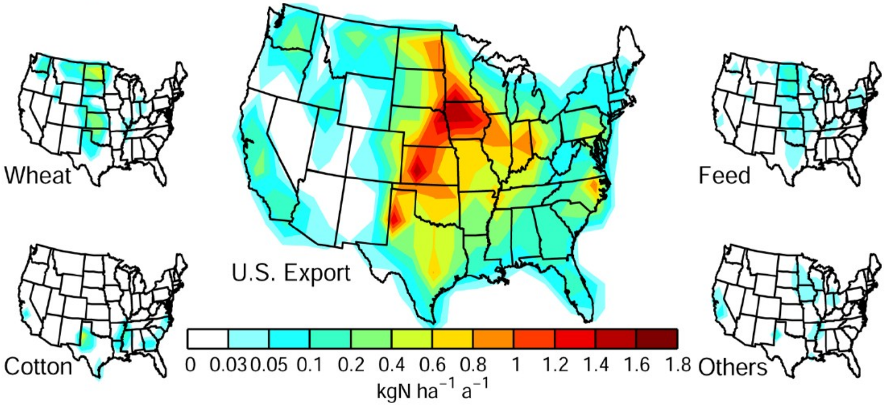


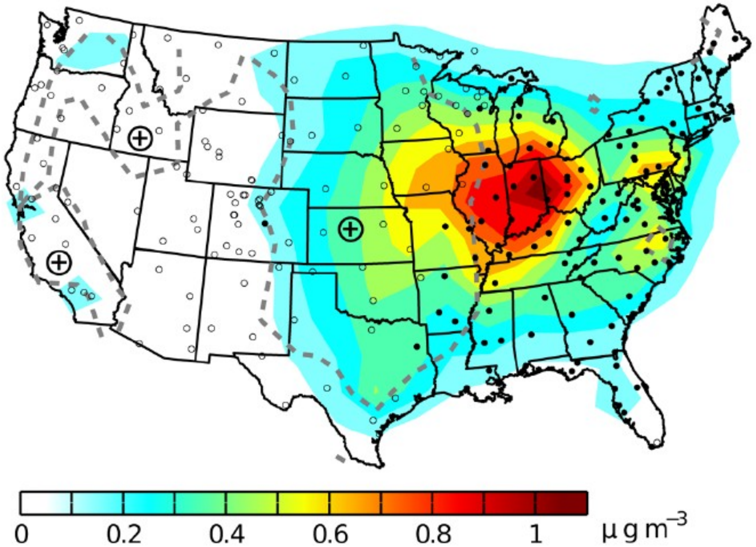
Source: Bauer et al., 2016

Figure 3. (left) Time evolution of historical and future global mean SO_2, NO_x, and NH_3 emissions according to the RCP8.5 scenario (Tg/yr).

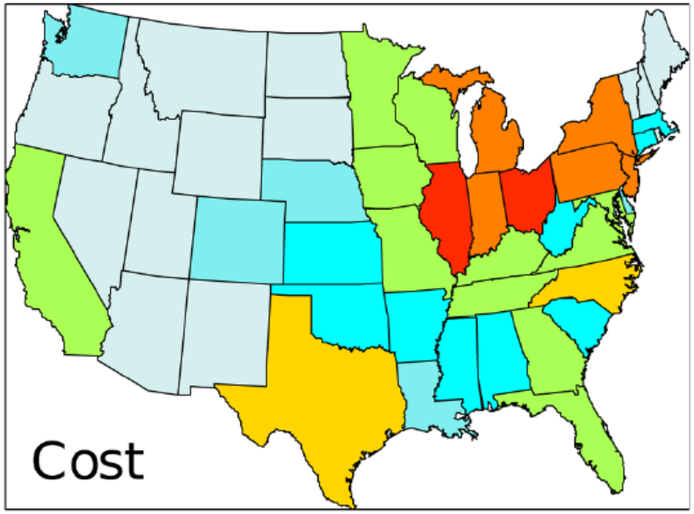
Non-linearities in agricultural emissions, PM2.5 and health effects: the export case study

NH3 **emissions** associated with food exports in US.





Impacts of NH3 emissions from food exports on annual **mean PM2.5.**



Health costs due to increased exposure to PM2.5 caused by NH3 emissions from food exports.

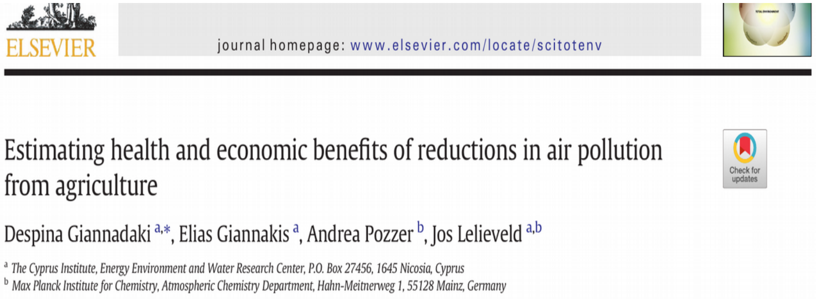
Eliminating food export-NH3 emissions would have greater health benefits than reduction of NAAQS for PM2.5 from 15 to 12 µg/m3 (Paulot et al., 2016).

Sources: Paulot et al 2016; Ginnakis et al. 2019

Agricultural emissions: increasing concern on the impacts on air quality, health and costs

Ginnadaki et al. 2018:
- A **50% reduction** of global annual agriculture emissions = decrease in 200 thousand PM2.5 related mortality worldwide = economy of billions of dollars.
- EU -> 18% decrease in mortality = economy of 89 billion dóllars.

Giannakis et al. 2019:
- A **20% increase** in agriculture output demand (eg.: increase in population) increases PM2.5 mortality in EU by 24%.
- Most affected countries: Cyprus (49.5%), Spain (50.3%), Greece (56.5%), Malta (89.1%).



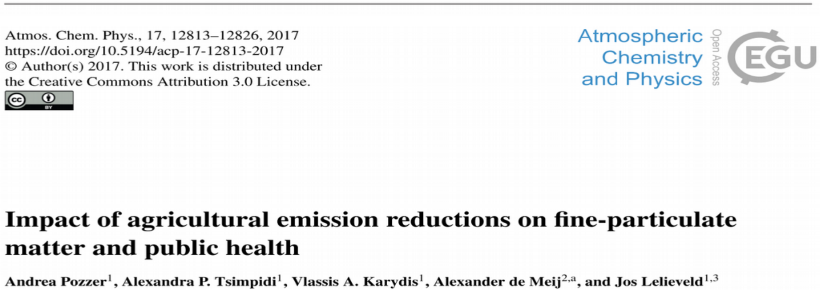
ELSEVIER

journal homepage: www.elsevier.com/locate/scitotenv

Estimating health and economic benefits of reductions in air pollution from agriculture

Despina Giannadaki [a,*], Elias Giannakis [a], Andrea Pozzer [b], Jos Lelieveld [a,b]

[a] The Cyprus Institute, Energy Environment and Water Research Center, P.O. Box 27456, 1645 Nicosia, Cyprus
[b] Max Planck Institute for Chemistry, Atmospheric Chemistry Department, Hahn-Meitnerweg 1, 55128 Mainz, Germany

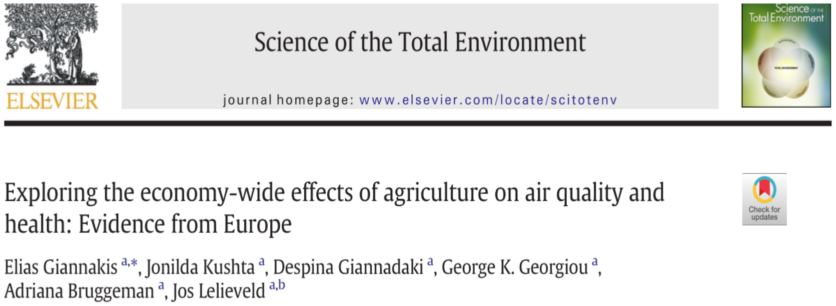


Atmos. Chem. Phys., 17, 12813–12826, 2017
https://doi.org/10.5194/acp-17-12813-2017
© Author(s) 2017. This work is distributed under the Creative Commons Attribution 3.0 License.

Atmospheric Chemistry and Physics
Open Access
EGU

Impact of agricultural emission reductions on fine-particulate matter and public health

Andrea Pozzer[1], Alexandra P. Tsimpidi[1], Vlassis A. Karydis[1], Alexander de Meij[2,a], and Jos Lelieveld[1,3]



ELSEVIER

Science of the Total Environment

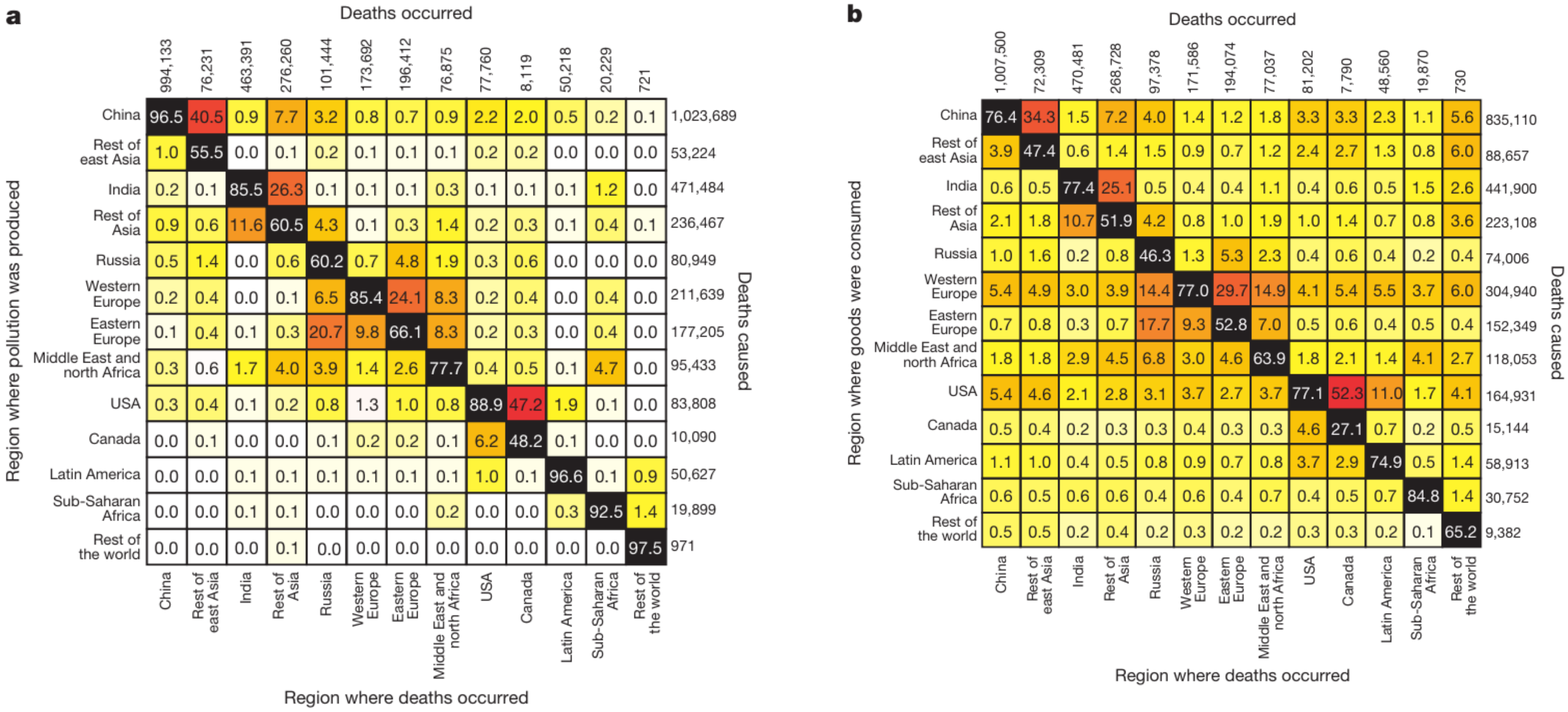
journal homepage: www.elsevier.com/locate/scitotenv

Exploring the economy-wide effects of agriculture on air quality and health: Evidence from Europe

Elias Giannakis [a,*], Jonilda Kushta [a], Despina Giannadaki [a], George K. Georgiou [a], Adriana Bruggeman [a], Jos Lelieveld [a,b]

Barcelona
Supercomputing
Center
Centro Nacional de Supercomputación

Production and Consumption Matrices of mortality



Production

	China	Rest of east Asia	India	Rest of Asia	Russia	Western Europe	Eastern Europe	Middle East and north Africa	USA	Canada	Latin America	Sub-Saharan Africa	Rest of the world	
	994,133	76,231	463,391	276,260	101,444	173,692	196,412	76,875	77,760	8,119	50,218	20,229	721	
China	96.5	40.5	0.9	7.7	3.2	0.8	0.7	0.9	2.2	2.0	0.5	0.2	0.1	1,023,689
Rest of east Asia	1.0	55.5	0.0	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.0	0.0	0.0	53,224
India	0.2	0.1	85.5	26.3	0.1	0.1	0.1	0.3	0.1	0.1	0.1	1.2	0.0	471,484
Rest of Asia	0.9	0.6	11.6	60.5	4.3	0.1	0.3	1.4	0.2	0.3	0.1	0.4	0.1	236,467
Russia	0.5	1.4	0.0	0.6	60.2	0.7	4.8	1.9	0.3	0.6	0.0	0.0	0.0	80,949
Western Europe	0.2	0.4	0.0	0.1	6.5	85.4	24.1	8.3	0.2	0.4	0.0	0.4	0.0	211,639
Eastern Europe	0.1	0.4	0.1	0.3	20.7	9.8	66.1	8.3	0.2	0.3	0.0	0.4	0.0	177,205
Middle East and north Africa	0.3	0.6	1.7	4.0	3.9	1.4	2.6	77.7	0.4	0.5	0.1	4.7	0.0	95,433
USA	0.3	0.4	0.1	0.2	0.8	1.3	1.0	0.8	88.9	47.2	1.9	0.1	0.0	83,808
Canada	0.0	0.1	0.0	0.0	0.1	0.2	0.2	0.1	6.2	48.2	0.1	0.0	0.0	10,090
Latin America	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	1.0	0.1	96.6	0.1	0.9	50,627
Sub-Saharan Africa	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.3	92.5	1.4	19,899
Rest of the world	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.5	971

Consumption

	China	Rest of east Asia	India	Rest of Asia	Russia	Western Europe	Eastern Europe	Middle East and north Africa	USA	Canada	Latin America	Sub-Saharan Africa	Rest of the world	
	1,007,500	72,309	470,481	268,728	97,378	171,586	194,074	77,037	81,202	7,790	48,560	19,870	730	
China	76.4	34.3	1.5	7.2	4.0	1.4	1.2	1.8	3.3	3.3	2.3	1.1	5.6	835,110
Rest of east Asia	3.9	47.4	0.6	1.4	1.5	0.9	0.7	1.2	2.4	2.7	1.3	0.8	6.0	88,657
India	0.6	0.5	77.4	25.1	0.5	0.4	0.4	1.1	0.4	0.6	0.5	1.5	2.6	441,900
Rest of Asia	2.1	1.8	10.7	51.9	4.2	0.8	1.0	1.9	1.0	1.4	0.7	0.8	3.6	223,108
Russia	1.0	1.6	0.2	0.8	46.3	1.3	5.3	2.3	0.4	0.6	0.4	0.2	0.4	74,006
Western Europe	5.4	4.9	3.0	3.9	14.4	77.0	29.7	14.9	4.1	5.4	5.5	3.7	6.0	304,940
Eastern Europe	0.7	0.8	0.3	0.7	17.7	9.3	52.8	7.0	0.5	0.6	0.4	0.5	0.4	152,349
Middle East and north Africa	1.8	1.8	2.9	4.5	6.8	3.0	4.6	63.9	1.8	2.1	1.4	4.1	2.7	118,053
USA	5.4	4.6	2.1	2.8	3.1	3.7	2.7	3.7	77.1	52.3	11.0	1.7	4.1	164,931
Canada	0.5	0.4	0.2	0.3	0.3	0.4	0.3	0.3	4.6	27.1	0.7	0.2	0.5	15,144
Latin America	1.1	1.0	0.4	0.5	0.8	0.9	0.7	0.8	3.7	2.9	74.9	0.5	1.4	58,913
Sub-Saharan Africa	0.6	0.5	0.6	0.6	0.4	0.6	0.4	0.7	0.4	0.5	0.7	84.8	1.4	30,752
Rest of the world	0.5	0.5	0.2	0.4	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.1	65.2	9,382

Figure 2 | Proportion of $PM_{2.5}$-related deaths in a given region that are linked to emissions produced or goods and services consumed in that and other regions. a, b, Each cell in the grid shows the fraction of deaths (%) that occurred in the region indicated by the column due to pollution produced (**a**) or due to goods and services consumed (**b**) in the region indicated by the row. The diagonal thus reflects deaths in a region due to pollution produced (**a**) or goods and services consumed (**b**) in that same region.

Source: Zhang et al. 2017

Barcelona
Supercomputing
Center
Centro Nacional de Supercomputación

Production and Consumption Matrices of mortality in Eu countries caused by agricultural consumption intra-EU

How will our study differ from Zhang et al. 2017?

Parameter	Zhang et al. 2017	Our study
SA method	Brute force	Tagging
Scale	Global	Regional (EU)
Source sector	All	Agriculture
Emission resolution	Coarse (global)	Fine (regional)
Costs	Not estimated	Estimated (?)

Design of the SA study

Barcelona
Supercomputing
Center
Centro Nacional de Supercomputación

Study: Agriculture Consumption/Production in EU

Gap of knowledge:

1. Health impacts of transboundary pollution from agricultural production (**Production matrix**).

2. Health impacts of agricultural production related to consumption (**Consumption matrix**)
    - How is agricultural consumption in EU countries affecting PM2.5 related premature mortality in neighbor EU countries?
    - How much of the hypothetical 50.3% increase in mortality in Spain would have been caused by Spanish food exports?

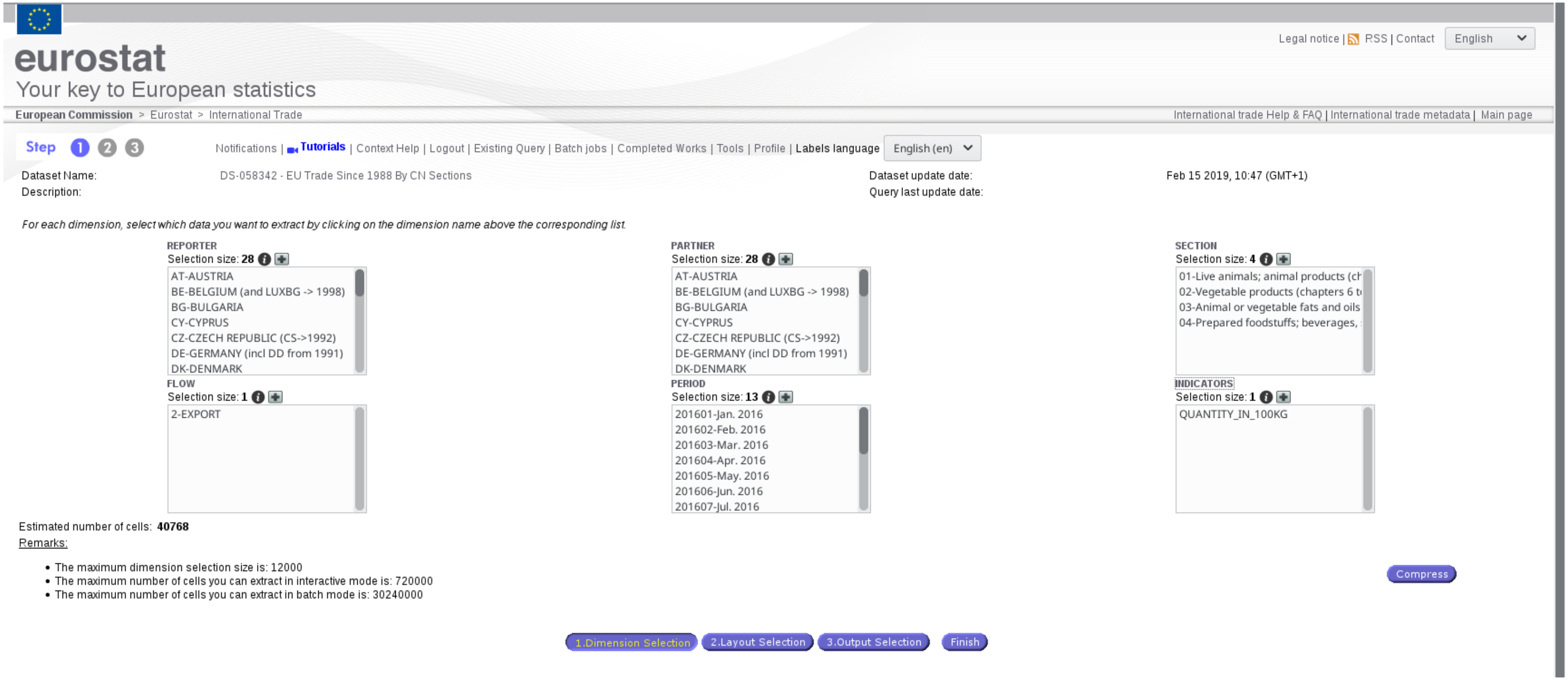
Giannakis et al. 2019:
- A 20% increase in agriculture output demand increases by 24% PM2.5 mortality in EU.
- Most affected countries: Cyprus (49.5%), **Spain (50.3%)**, Greece (56.5%), Malta (89.1%).

What information do we need for each EU country?

- Total production of an agricultural sector (pigmeat, cereal, bovinemeat (?)…)
- Total exports (Intra EU + Extra EU)
- Quantity exported from one country to each EU country (Intra EU exports)
- Emissions generated by the chosen agriculture sector

Data collection: EUROSTAT Database

- Several agricultural sectors available (Comext);
- Import/export data for both intra and extra EU;
- Available for all EU countries;
- Resolution: monthly (1999 – 2018)



Dataset Name: DS-058342 - EU Trade Since 1988 By CN Sections

Description:

Dataset update date: Feb 15 2019, 10:47 (GMT+1)

Query last update date:

For each dimension, select which data you want to extract by clicking on the dimension name above the corresponding list.

REPORTER
Selection size: **28**
AT-AUSTRIA
BE-BELGIUM (and LUXBG -> 1998)
BG-BULGARIA
CY-CYPRUS
CZ-CZECH REPUBLIC (CS->1992)
DE-GERMANY (incl DD from 1991)
DK-DENMARK

PARTNER
Selection size: **28**
AT-AUSTRIA
BE-BELGIUM (and LUXBG -> 1998)
BG-BULGARIA
CY-CYPRUS
CZ-CZECH REPUBLIC (CS->1992)
DE-GERMANY (incl DD from 1991)
DK-DENMARK

SECTION
Selection size: **4**
01-Live animals; animal products (ch
02-Vegetable products (chapters 6 t
03-Animal or vegetable fats and oils
04-Prepared foodstuffs; beverages,

FLOW
Selection size: **1**
2-EXPORT

PERIOD
Selection size: **13**
201601-Jan. 2016
201602-Feb. 2016
201603-Mar. 2016
201604-Apr. 2016
201605-May. 2016
201606-Jun. 2016
201607-Jul. 2016

INDICATORS
Selection size: **1**
QUANTITY_IN_100KG

Estimated number of cells: **40768**

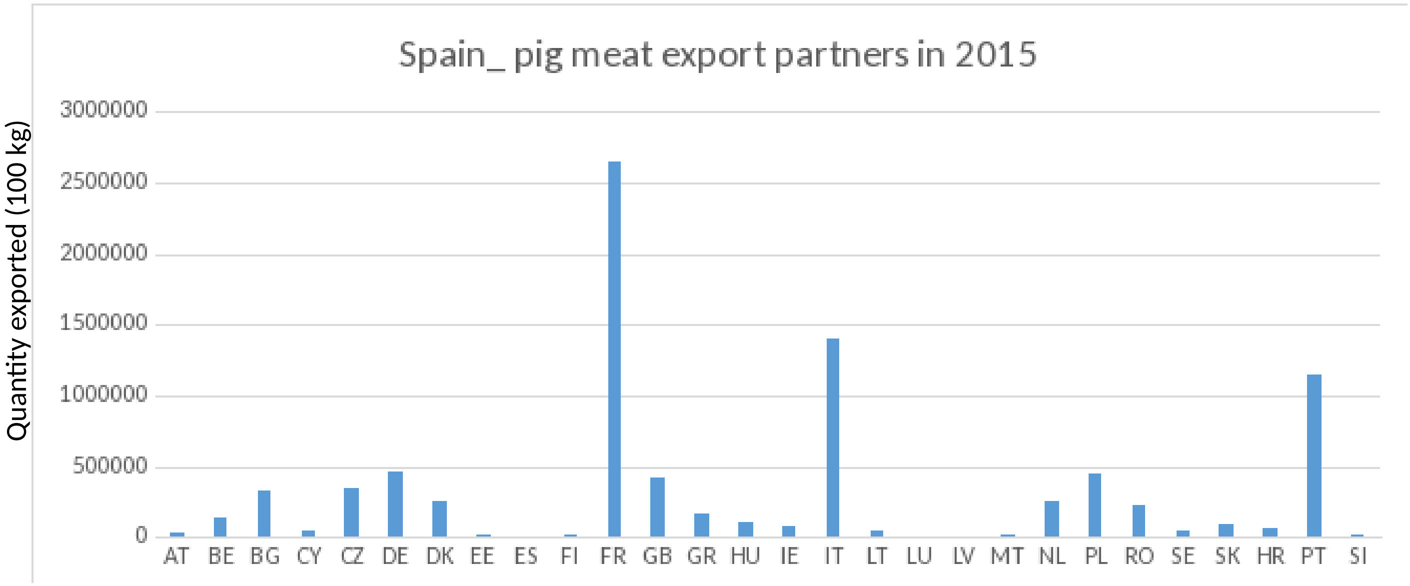
Remarks:

- The maximum dimension selection size is: 12000
- The maximum number of cells you can extract in interactive mode is: 720000
- The maximum number of cells you can extract in batch mode is: 30240000

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

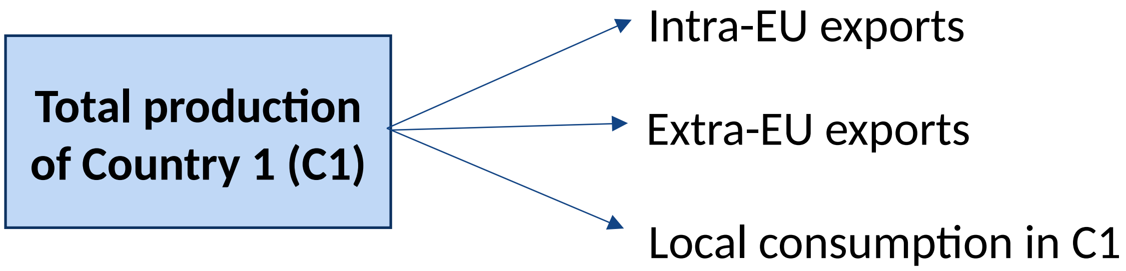
Intra EU exports of Spanish pig's meat

Main intra EU consumers of Spanish pig's meat in 2015 were France, Italy and Portugal.



What fraction of PM2.5 emissions in Spain can be attributed to the consumption of these countries 3 countries?

Calculations



Total production of Country 1 (C1)

Intra-EU exports

Extra-EU exports

Local consumption in C1

Total exports = Intra-EU exports + Extra-EU exports

Local consumption C1= Total production – total exports

SR export factor of C1 = exported quantity by EU country / total production

Emissions attributed to consumption of partner country = Total agriculture emission of sector x SR export factor

Calculation of health impacts and costs

Final output: SR matrix on impacts of agriculture exports on premature mortality

a) Transboundary b) Consumption

BSC
Barcelona
Supercomputing
Center
Centro Nacional de Supercomputación

EXCELENCIA
SEVERO
OCHOA

THANK YOU!

www.bsc.es