LC-IMPACT

# Terrestrial acidification

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# Content

1. Introduction to acidification
2. Currently recommended method
3. Proposed method by LC-IMPACT
4. Main differences between currently and proposed methods
5. Conclusions of the lecture

# 1. Introduction to acidification

- Increase in acidity leading to decrease in plant performance and biodiversity losses. Chemical soil indicators for soil acidity: pH, base saturation, cation exchange capacity, or aluminium and manganese concentration

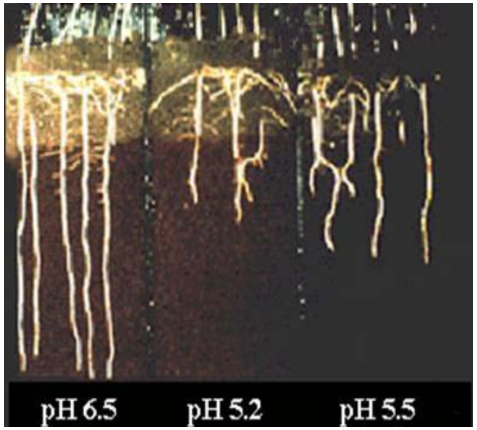
- The two most common nutrients driving acidification are nitrogen (N) and sulphur(S)

- In special cases, other nutrients may also trigger acidification, such as hydrogen chloride (HCl) and fluoride (HF). **Keep in mind** that increases in atmospheric carbon levels triggers acidification in marine systems!

# 1. Fate and effect of acidifying pollutants

Atmospheric fate

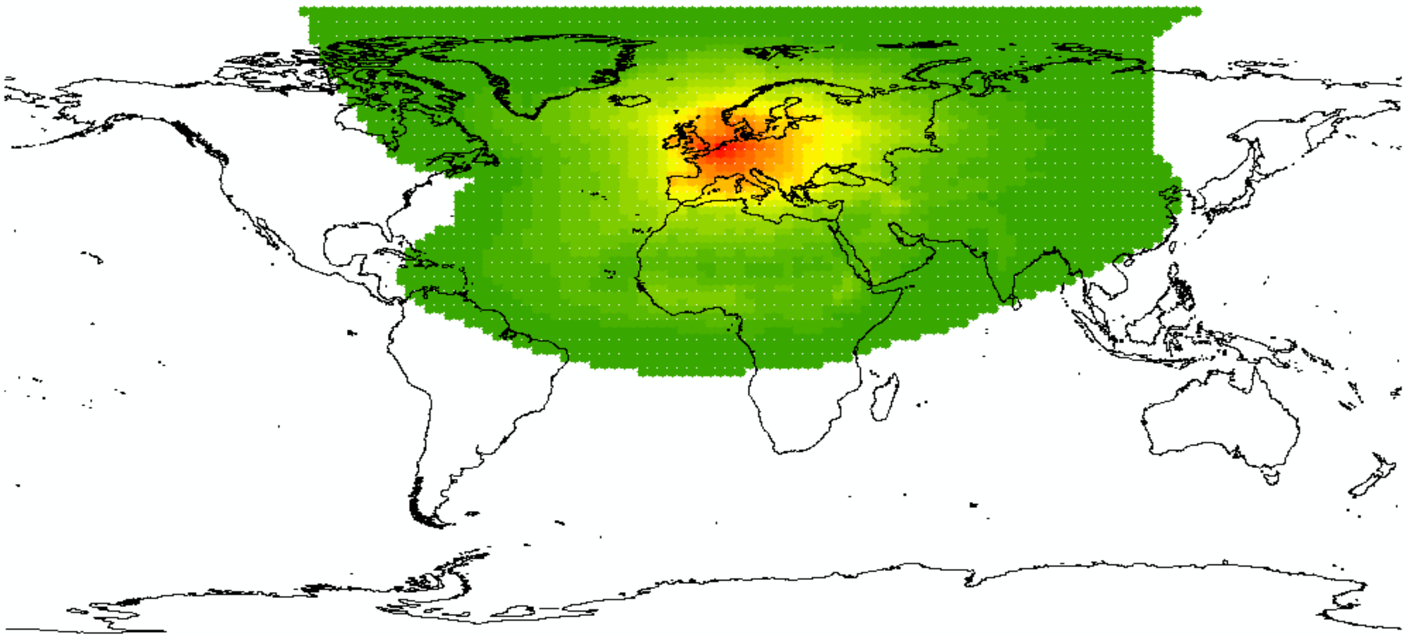
Soil fate




Effect

# 1. Atmospheric and soil fate of pollutants

## Particles of a specific emission (e.g. in Nijmegen, the Netherlands) affect many receiving soils



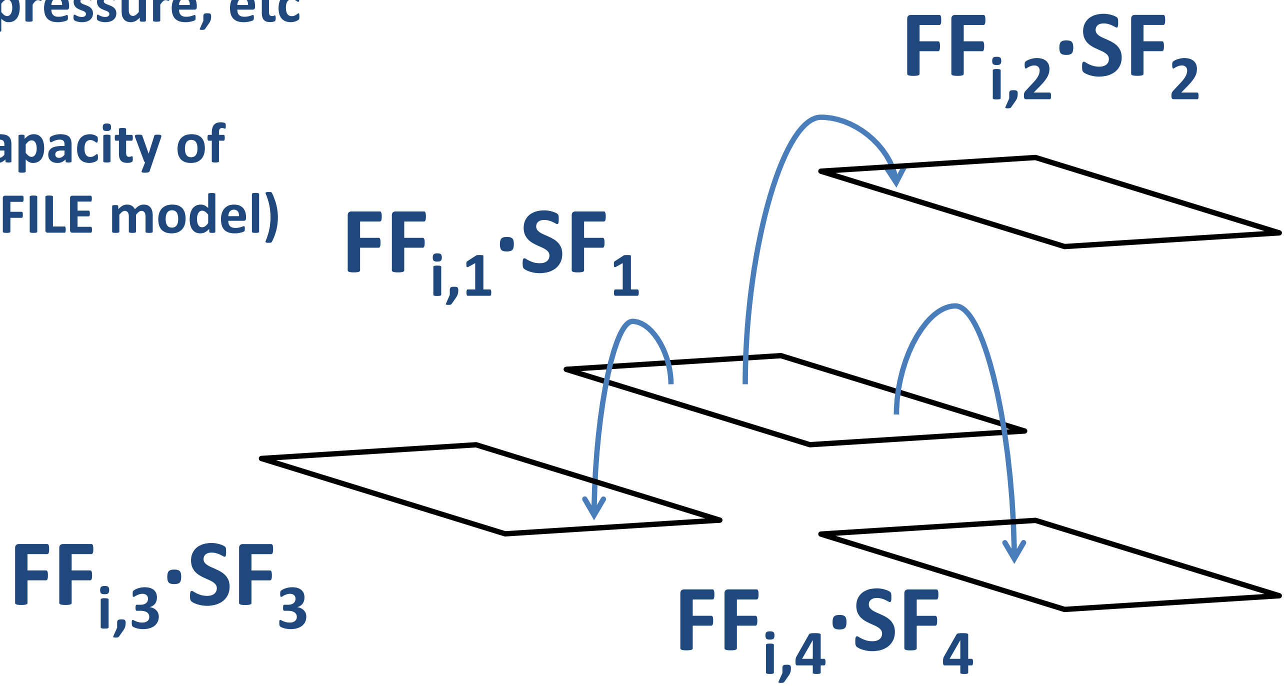
Picture provided by Pierre-Olivier Roy (2013)

# 1. The atmospheric fate (FF) and soil fate (SF) of an emitting grid to soils receiving N and S particles

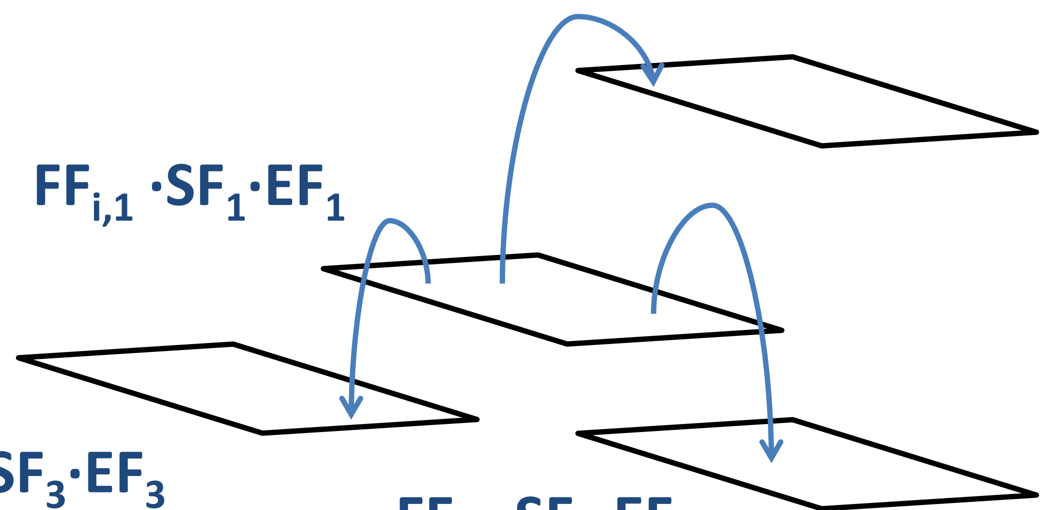
**Driving mechanisms:**

-Atmospheric processes, e.g. wind, atmospheric pressure, etc (GEOSChem model)

-Acid neutralizing capacity of receiving soils (PROFILE model)



# 1. Effect (EF) occurs in every soil grid receiving an emission from elsewhere




**Driving mechanisms:**
- Soil pH
- Location of effect, e.g. (sub)tropical forests, temperate coniferous forests

$$\boxed{CF_{i,p} = \sum_j \left( FF_{i \rightarrow j,p} \cdot SF_{j,p} \cdot EF_j \right)}$$

**In this example, j = 4 receiving grids (including the emitting grid itself) of pollutant p**

# 1. Currently (interim) method: OVERVIEW

- Coverage: Europe
- Resolution: 50km (approximately 0.45°)
- Fate model: based on EUTREND
- Effect model: based on stressor-response relationships

# 1. Currently (interim) method

## Recommended reading to understand the characterization model

*Environ. Sci. Technol.* **2007,** *41,* 922–927

### Time Horizon Dependent Characterization Factors for Acidification in Life-Cycle Assessment Based on Forest Plant Species Occurrence in Europe

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#### Introduction

Life-Cycle Assessment is a tool that deals with the environmental impacts associated with a product or service (*1*). It reviews the complete life cycle in different steps. An important part of this process is the life cycle impact assessment (LCIA), where inventory data are converted into impact indicators for various impact categories. Udo de Haes et al. (*2*) give an overview of impact categories, which comprises, among others, acidification. Atmospheric deposition of inorganic substances, such as sulfates and nitrates, cause a change in acidity in the soil. In the process from acid deposition on soil to ecosystem damage, two major sources of response delay are distinguished. Biogeochemical processes can delay chemical response to acid deposition in soil. Depending on the chemical status of a soil, atmospheric input of acidifying

## 3. Proposed method by LC-IMPACT

- Coverage: Global
- Resolution: 2.0° x 2.5 °
- Fate model: based on Roy et al., 2012 (Atmospheric Environment) and Roy et al., 2012 (ES&T)
- Effect model: based on stressor-response relationships (Azevedo et al., 2013 Environmental Pollution)

# 3. Description of characterization factor

$$CF_{i,p} = \sum_j FF_{i \to j,p} \cdot SF_{j,p} EF_j$$

**$CF_i$: Characterization factor in emitting grid i ($m^2 \cdot kg\ p^{-1} \cdot yr$)**
**$FF_{i \to j,p}$: Atmospheric fate factor of emitting grid i in grid j (keq $p \cdot m^{-2} \cdot yr^{-1} \cdot kg\ p^{-1} \cdot yr$)**
**$SF_{i,p}$: Soil fate factor in grid j ($ha \cdot keq\ p^{-1} \cdot m^2 \cdot yr$)**

**$EF_{i,j}$: Effect factor in grid j (dimensionless)**

# 3. Description of characterization factor

$$CF_{i,p} = \sum_j \frac{dDEP_{j,p}}{dEm_{i,p}} \cdot \frac{dpH_j}{dDep_{j,p}} \cdot \frac{dPNOF_j}{dpH_j}$$

**$dEm_{i,p}$ : marginal change in emissions of p from grid i**

**$dDEP_{j,p}$ : marginal change in deposition of p in grid j**

**$dpH_j$ : marginal change in soil pH in grid j**

**$dPNOF_j$ : marginal change in the potentially not occurring fraction (PNOF) of species grid j**

# 1. Atmospheric and soil fate of pollutants

# Recommended reading to understand the atmospheric and soil fate of acidifying pollutants

Atmospheric Environment 62 (2012) 74–81

Contents lists available at SciVerse ScienceDirect

Atmospheric Environment

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

Spatially-differentiated atmospheric source–receptor relationships for nitrogen oxides, sulfur oxides and ammonia emissions at the global scale for life cycle impact assessment

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Environmental Science & Technology

Article

pubs.acs.org/est

Life Cycle Impact Assessment of Terrestrial Acidification: Modeling Spatially Explicit Soil Sensitivity at the Global Scale

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# 1. Effect model

## Different vegetation types are affected differently by a decrease in soil pH

Environmental Pollution 174 (2013) 10–15

Contents lists available at SciVerse ScienceDirect

Environmental Pollution

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

ELSEVIER

Global assessment of the effects of terrestrial acidification on plant species richness

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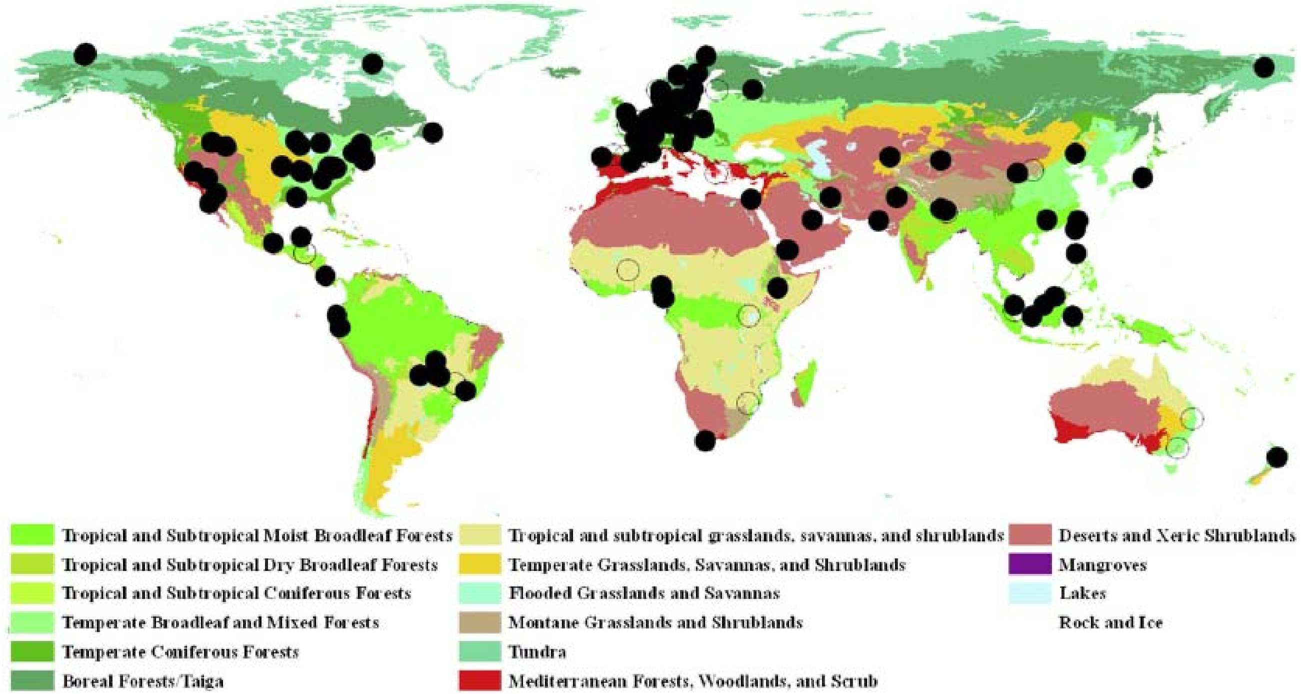
# 3. Description of EFFECT MODEL

**The stressor-response relationship representing the influence on pH on PNOF is described by Azevedo et al. (Environmental Pollution) for:**

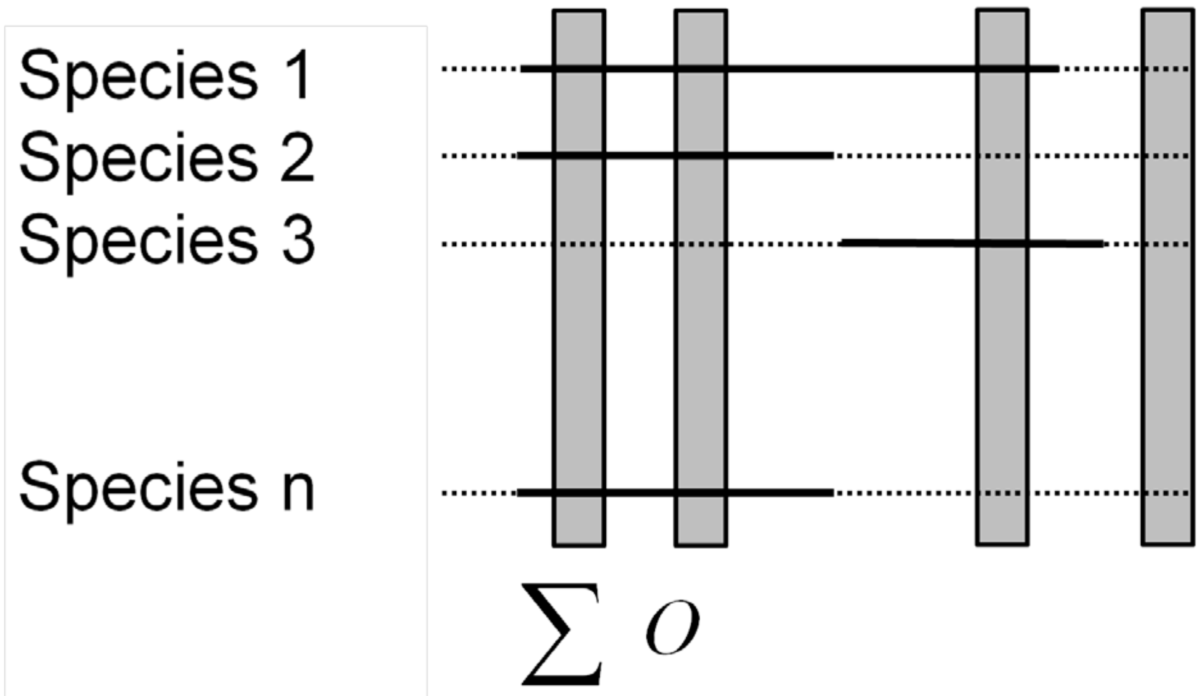
**- 13 world's biomes**

**- 1 species group (vascular plants)**



# 2. pH – PNOF relationships worldwide

## Step 1: Species occurrence ranges

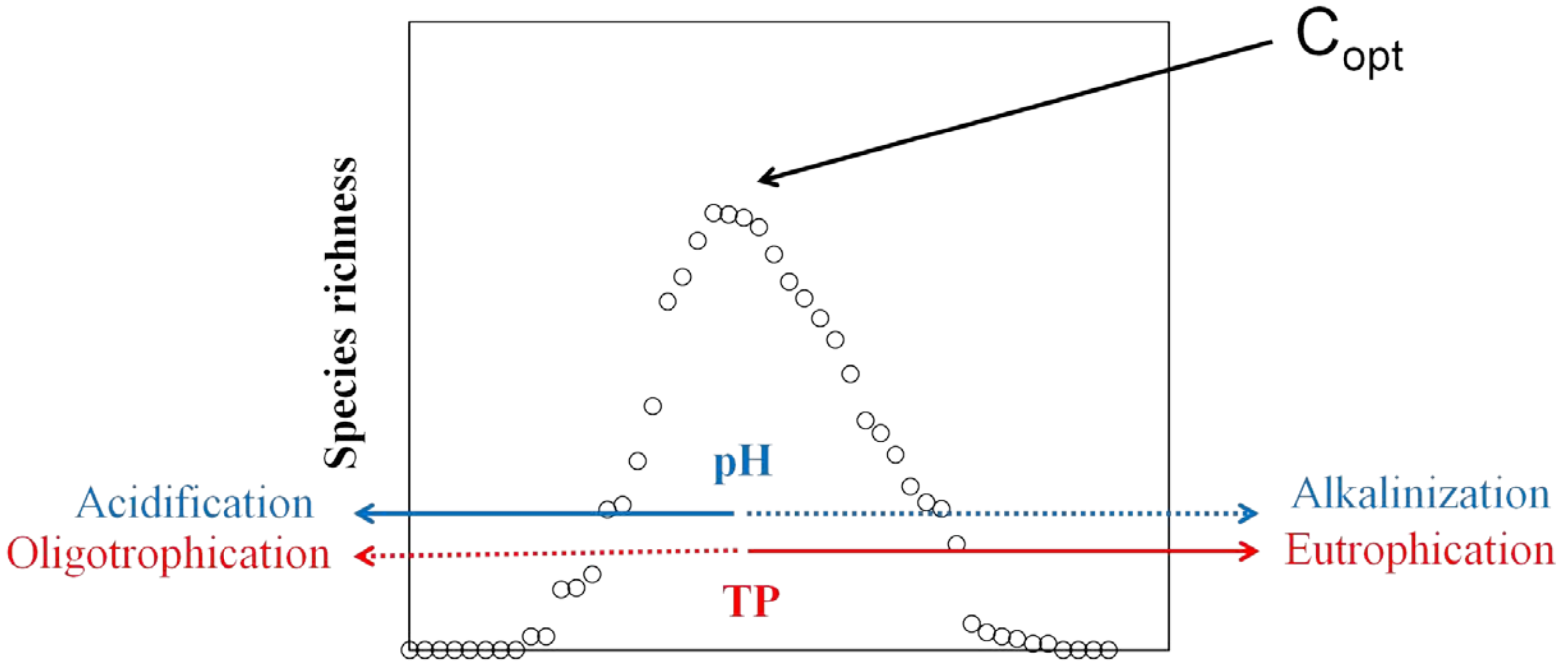



$$\sum_{n} O$$

*Based on Azevedo et al., 2013 (Environmental Pollution)*

# 3. pH – PNOF relationships worldwide

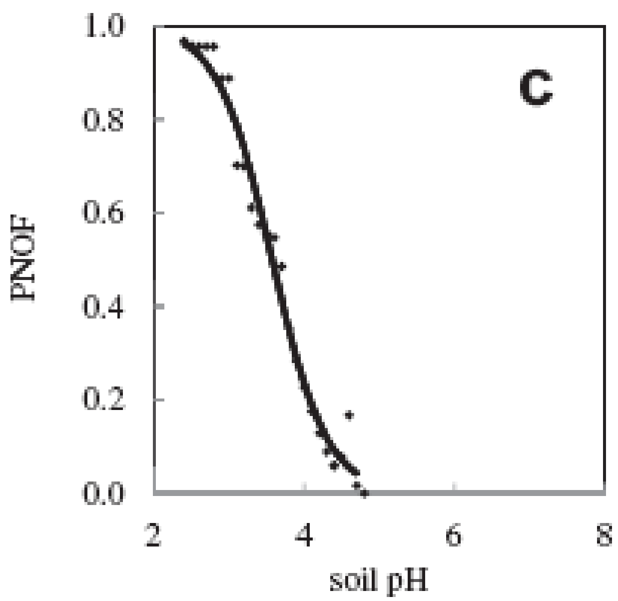
## Step 2: Defining the optimum




*Based on Azevedo et al., 2013 (Environmental Pollution)*

# 3. pH – PNOF relationships worldwide

## Step 3: Log-logistic regression




$$\mathrm{ePNOF}_{i,j} = 1 - \frac{S_{i,j}}{S_{\mathrm{opt},j}}$$

$$\mathrm{cPNOF}_{i,j} = \frac{1}{1 + e^{-\left(\frac{\alpha_j - \mathrm{pH}_{i,j}}{\beta_j}\right)}}, \quad \text{for } \mathrm{pH}_{i,j} \leq \mathrm{pH}_{\mathrm{opt},j}$$

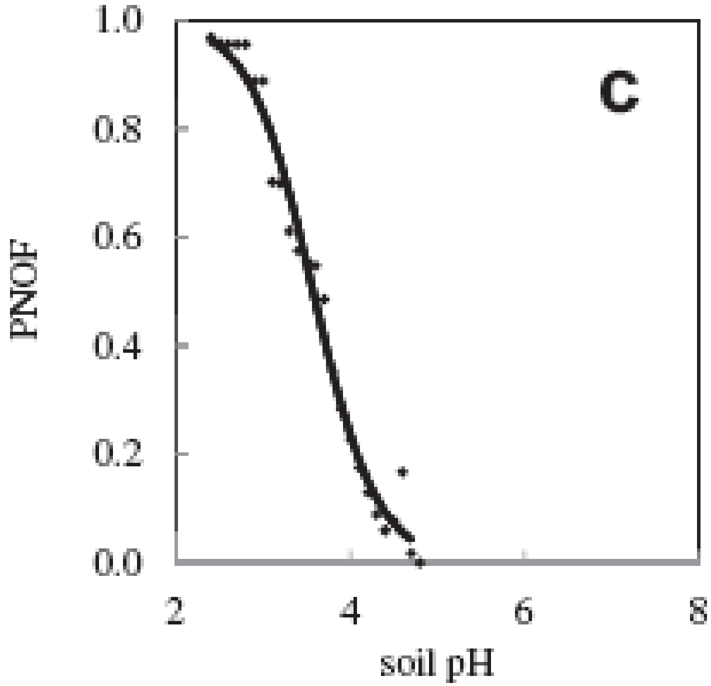
***Based on Azevedo et al., 2013 (Environmental Pollution)***

# 3. pH – PNOF relationships worldwide

**Example of PNOF – pH relationship**

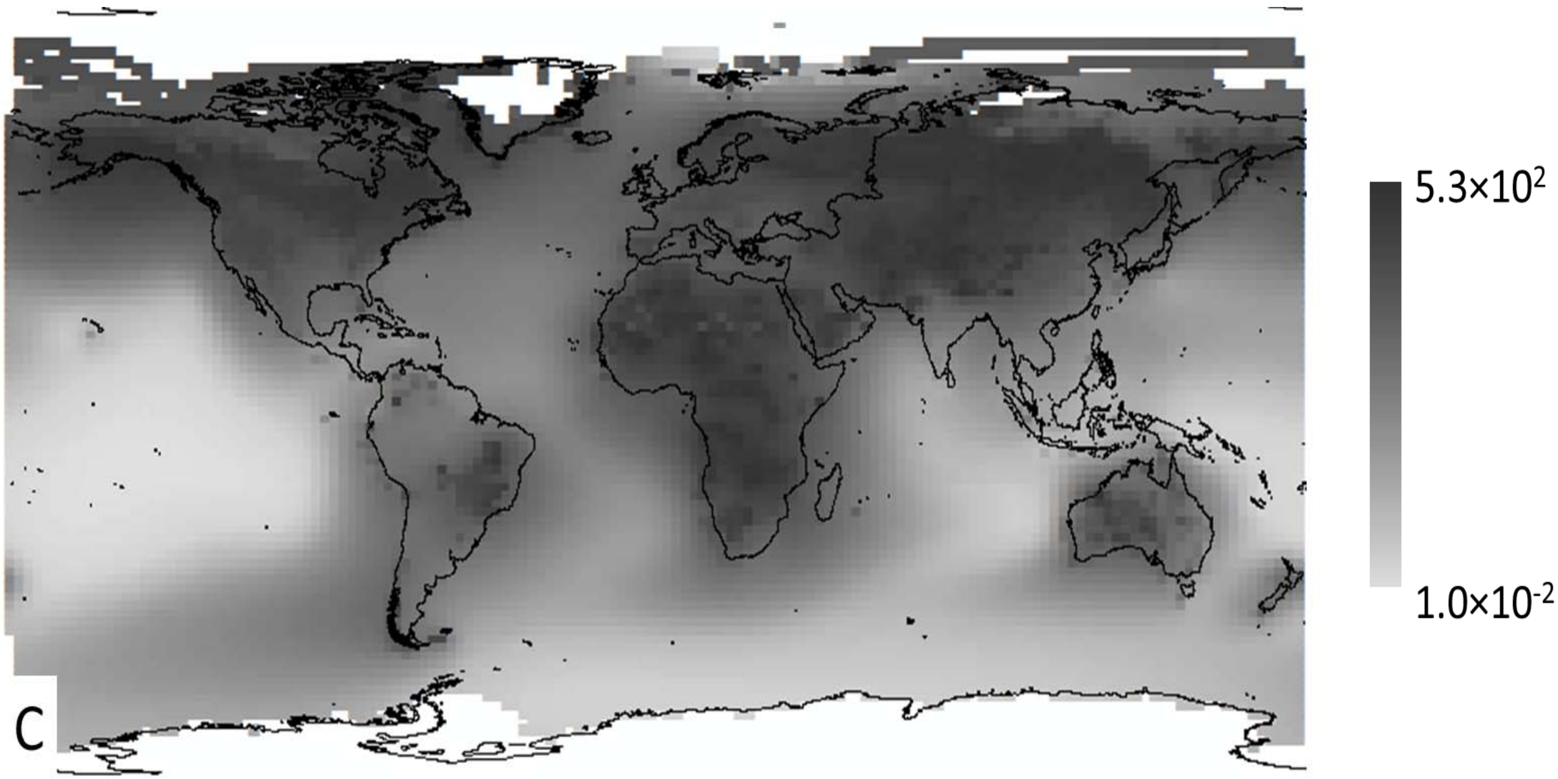
$$PNOF_j = \frac{1}{1 + \exp^{-\left(\frac{3.57 - pH_j}{0.63}\right)}}$$

*Grid j: in temperate biome*




*Azevedo et al. (Environmental Pollution)*

# 3. Worldwide characterization factors ($m^2 \cdot kg\ SO_2^{-1} \cdot yr$)




*Azevedo et al. (unpublished)*

# 4. Main differences between current interim and proposed methods: MIDPOINT

| Feature | Van Zelm et. al., 2007 (ES&T) | Roy et. al., (unpublished) |
|---|---|---|
| Coverage | Europe | Global |
| Resolution | 1/2° | 2.0° x 2.5° |
| Fate transport across continents | Not included | Included |
| Soil stressor | Base saturation | pH |
| Vegetation type | European forest species | World's biomes |

Improvement

# 5. Conclusions of lecture

- Terrestrial acidification is generally considered to be caused by N and S
- The sources of N and S are fossil fuel combustion, fertilizer volatilization, among others
- The effect of acidification is the decrease in species richness (or increase in the potentially not occurring fraction – PNOF – of species)
- The characterization factor is determined by a fate and an effect factor, both spatially-explicit