RAPIDC
Regional Air Pollution In Developing Countries

SEI STOCKHOLM ENVIRONMENT INSTITUTE

Potential Risk of Acidification in South Asia

Lecture 1

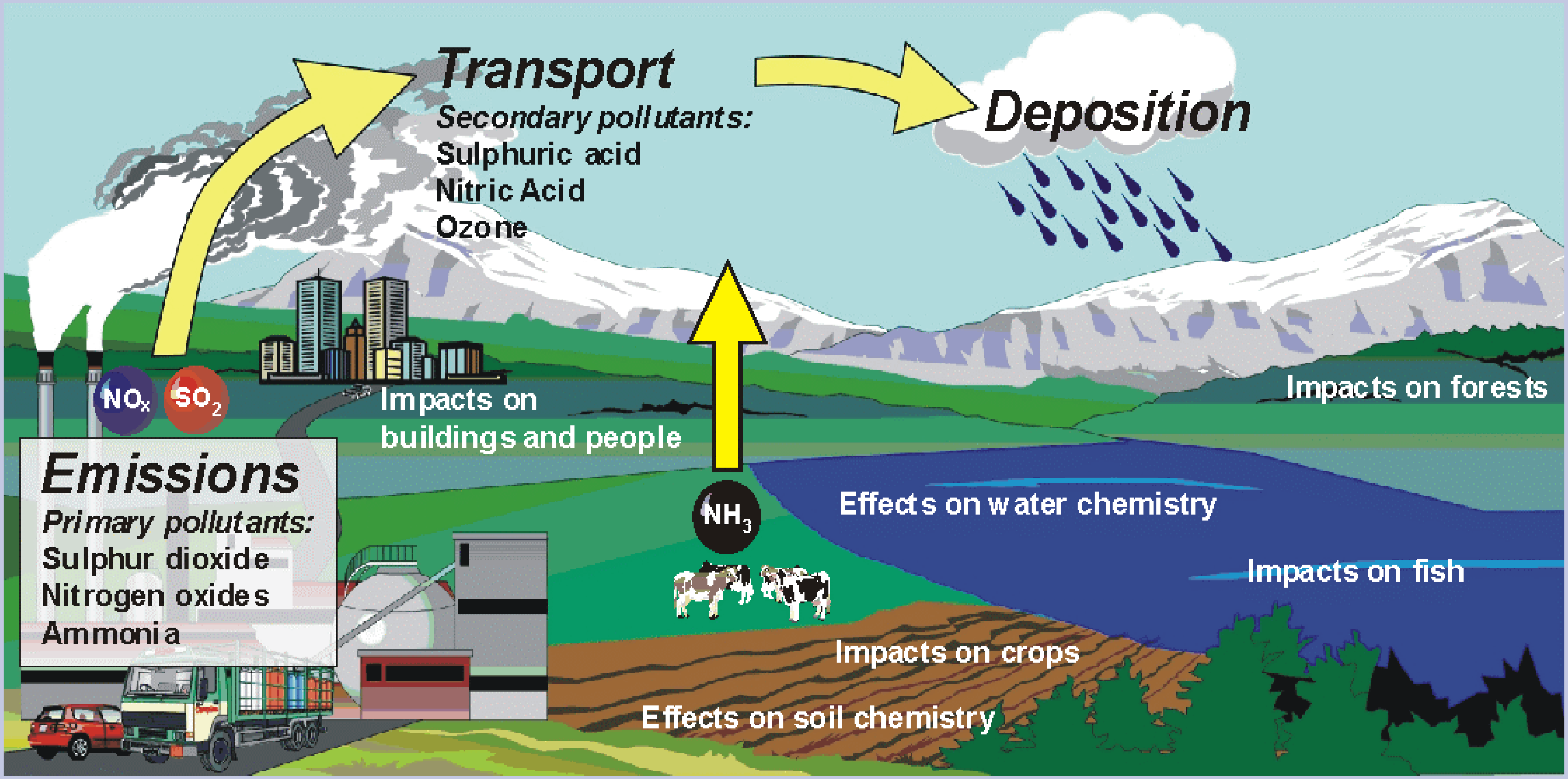
Kevin Hicks

Stockholm Environment Institute (SEI)

khicks@york.ac.uk

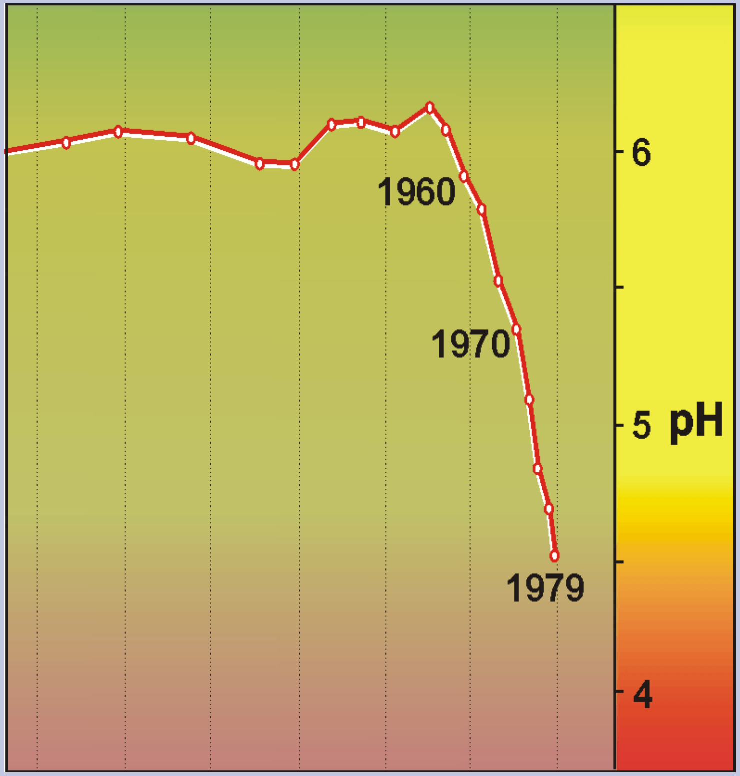
Aims

- Describe European experience of acidification
- Explain acidification processes and consequences
- Illustrate the dynamics of acidification over time
- Describe methodologies that could be used to promote national efforts to assess risk of acidification damage in South Asia

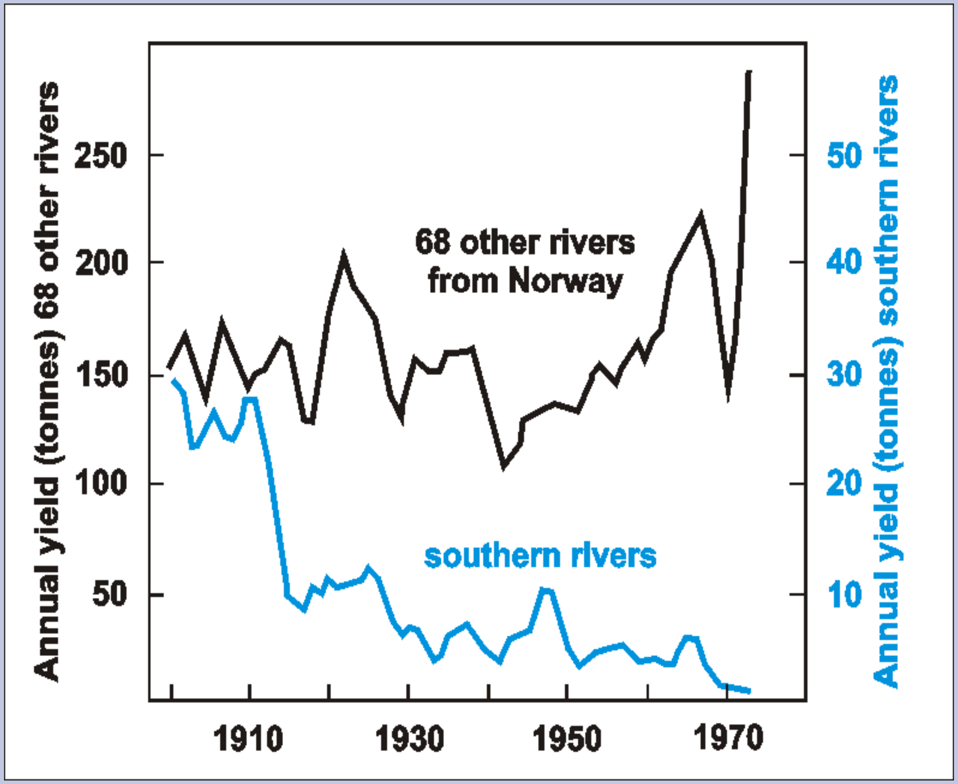


- Health impacts caused by gases, particulates and heavy metals
- Environmental effects (acidification, eutrophication, global climate change, ecosystem and material damage)
- Economic loss (crop yields, corrosion of materials, lost work days)

Effects of ‘Acid Rain’ in Europe

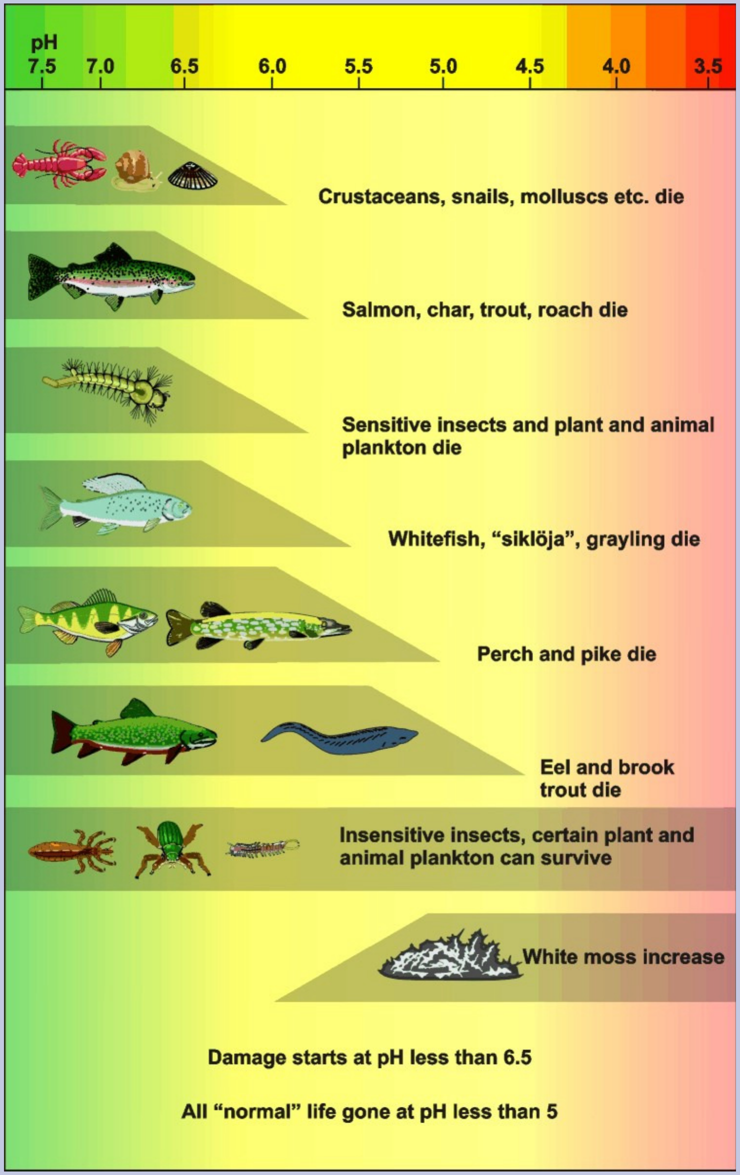


The pH of lake Gårdsjön, SW Sweden



Salmon decline in the acidified waters of southern Norway

The sensitivity of aquatic organisms to a lowered pH in freshwater



Lake and river acidification in Europe

85% of all acidified lakes and watercourses in Europe and North America are in six countries: Sweden, Norway, Canada, U.S.A., Scotland and Finland.

In Europe, about 50 000 – 100 000 lakes have been affected by acidification

This occurred in acid-sensitive regions where the soils have a low ability to neutralize continuous inputs of strong acids

RAPIDC
Regional Air Pollution In Developing Countries

Widespread forest decline in C Europe

Forest damage in Germany

Forest Decline

Forest decline experienced in many countries of central Europe and in eastern United States in the late 1970s and early 1980s

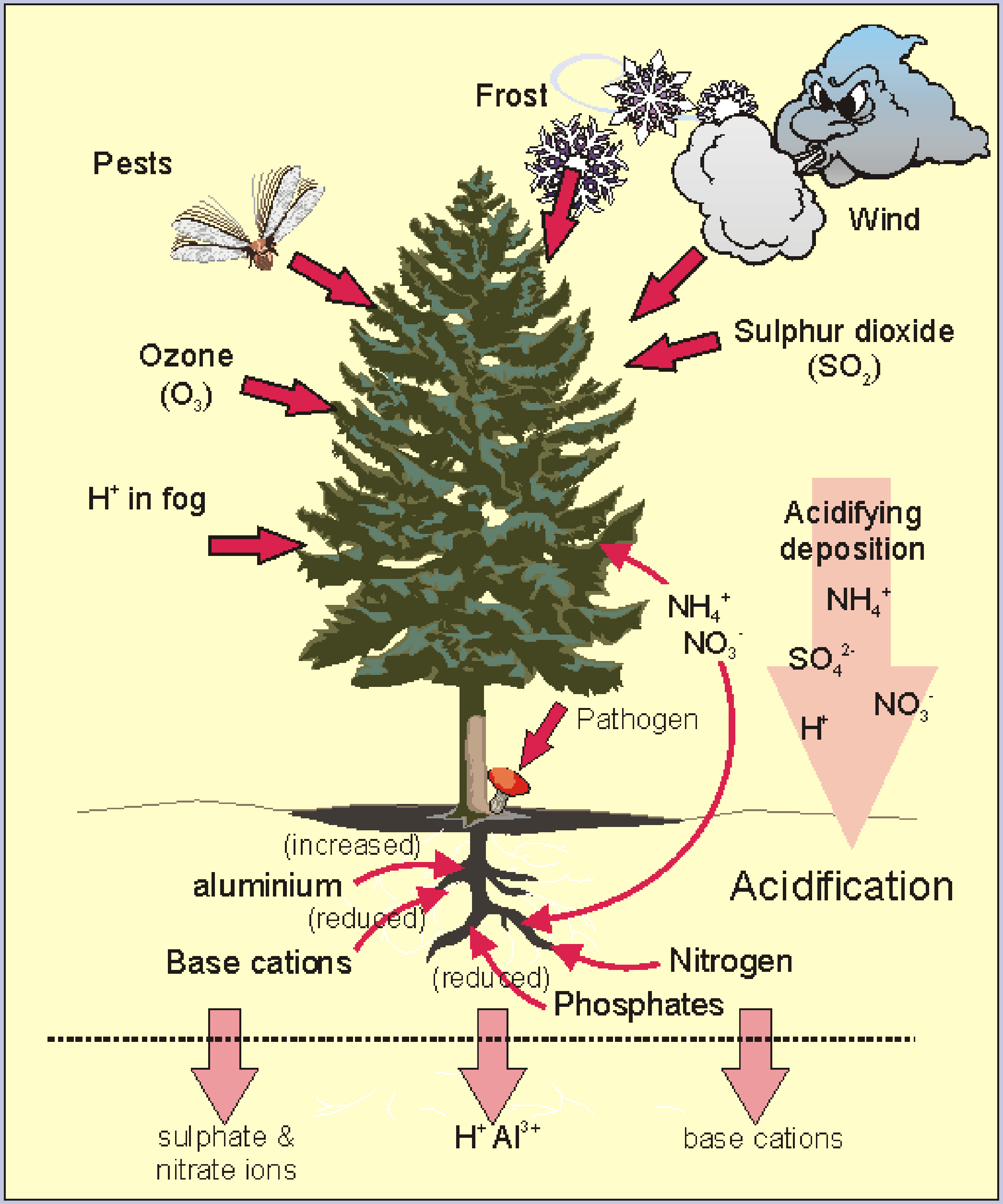
The main air pollution hypotheses were:

• direct effects of gaseous pollutants and acidic rain, alone or in combination

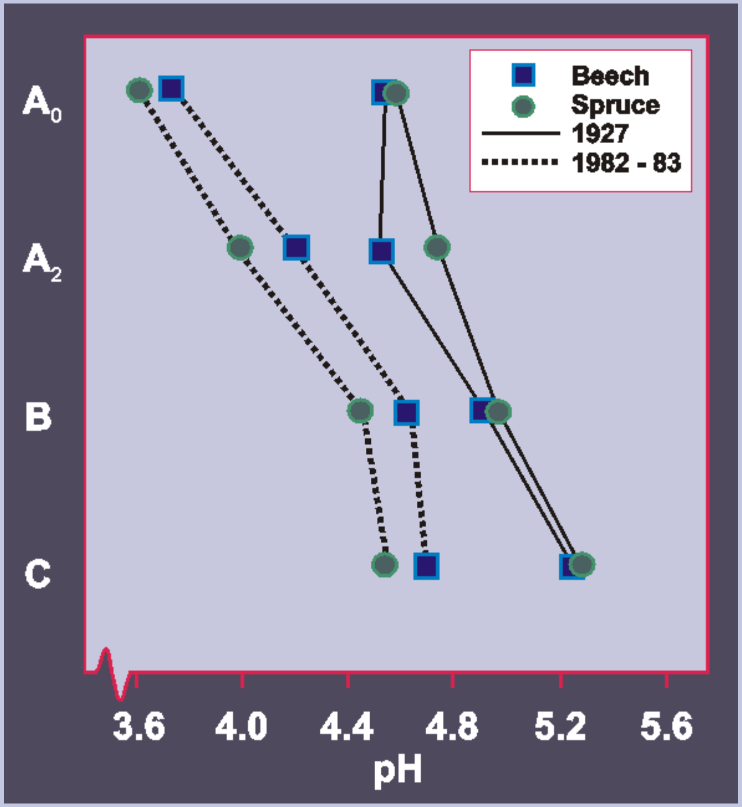
• indirect effects via soil acidification (e.g. reduced availability of certain plant nutrients (Ca, Mg etc) and/or toxic effects of aluminium)

• excess availability of nitrogen (+ve and –ve effects)

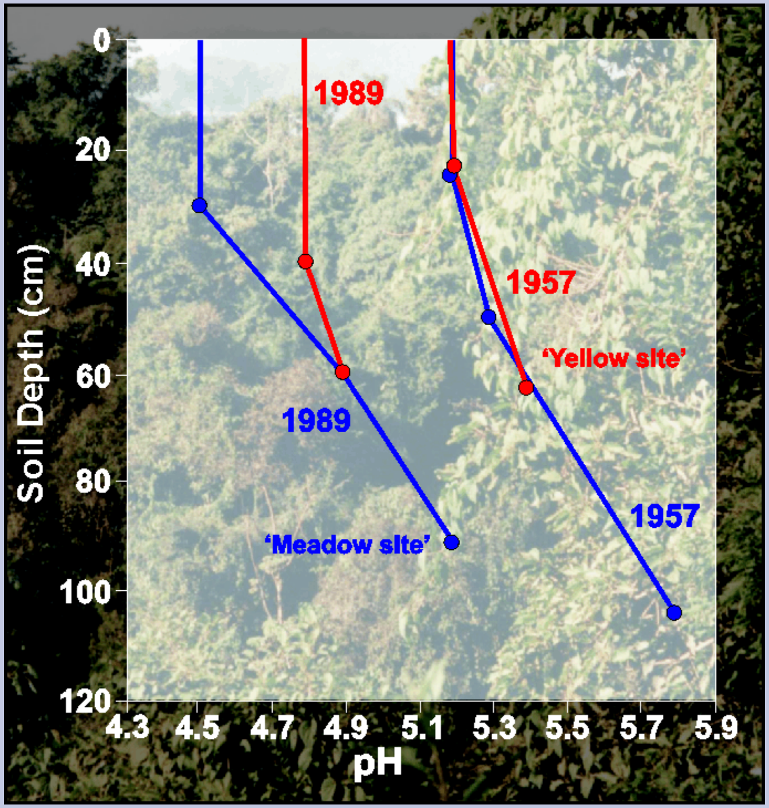
Various factors contributing to forest decline



Evidence of Soil Acidification in Europe and southern China



The decrease in soil pH between 1927 to 1982-83 in a beech and spruce forest in southern Sweden (Hallbäcken and Tamm, 1985).



Soil acidification at Mt. Lu in southern China (Zhao, 1996)

Evidence of soil acidification in South Asia?

- Few studies on acidification
- Evidence of potential acidification of waters surrounding industry in India
- Studies of water catchments in Nepal – no strong acidification seen
- Critical Load approach applied to soils in India, showing no 'exceedance'
- There is a need to collate all available studies and data on acidification in South Asia

Some definitions of terms commonly used in soil acidification work

Acidity is defined as:

pH: -log [H^+] or [H^+] = 10^{-pH}

pH 7 neutral [H^+] = [OH^-]
>pH 7 alkaline
<pH 7 acidic

[H^+]	pH	Example
1	0	Concentrated HCl
0.1	1	Battery acid
0.01	2	Lemon juice
0.001	3	Vinegar
0.0001	4	Soda, Coffee, Beer
0.00001	5	Natural rain
0.000001	6	Milk
0.0000001	7	Pure water
0.00000001	8	Sea water, egg whites
0.000000001	9	Baking soda
0.0000000001	10	Antacid tablets
0.00000000001	11	Ammonia
0.000000000001	12	Hydrated lime – $Ca(OH)_2$
0.0000000000001	13	
0.00000000000001	14	Concentrated NaOH

[H^+] in moles per litre

Examples

pH 5.6 is value for pure water in equilibrium with atmospheric CO_2
pH of acid rain in Europe has been < pH 4
pH of rain in S Asia = 5.3 - 7.2

RAPIDC

Regional Air Pollution In Developing Countries

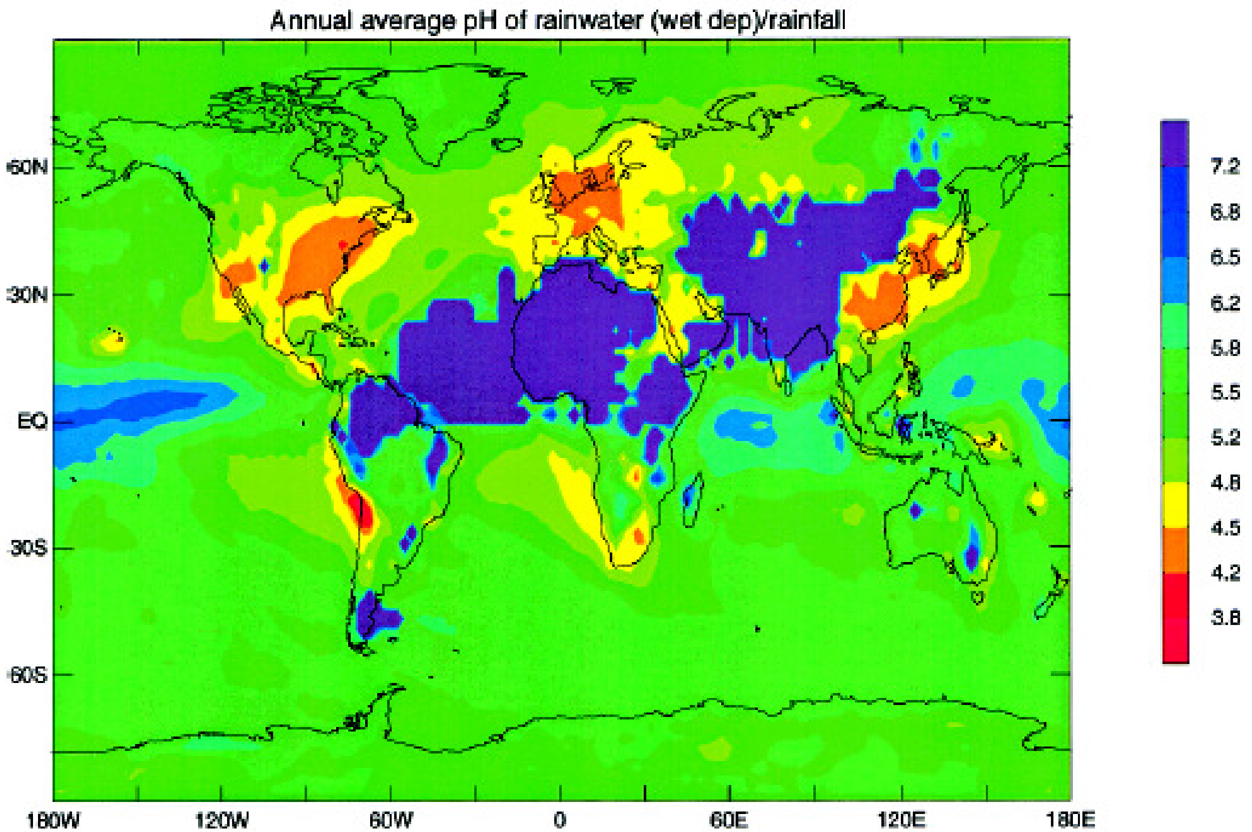


FIGURE 2. Annual average pH of precipitation calculated from volume weighted averages of H^+ according to eq 1. The most acidified regions occur in eastern North America, Europe, and China. The maximum in South America is associated with emissions from a smelter in northern Chile coupled to low amounts of rainfall in that region.

Some definitions of terms commonly used in soil acidification work

Weathering rate (WR) - rate of buffering of acidity by the chemical weathering of soil minerals

Cations – positively charged ions

Base cations = Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}
Acid cations = H^{+} Al^{3+}

Cation exchange capacity (CEC) – measure of the capacity of the soil to bind cations to soil particles

Base saturation (%BS) = sum of base cations/CEC

Soil acidification can be defined in different ways

- Increase of soil acidity or decrease in soil pH

- Decrease in base saturation

- unbalanced availability of elements in the root environment

- Decrease in the acid neutralising capacity (ANC) of the soil

ANC (van Breemen et al. 1986) – the total capacity of a given soil to neutralize acidic inputs, includes all elements capable of neutralizing H^+

- means pH may stay the same while buffering capacity is consumed by added H^+

Soil acidification is driven by an input of H^+ to the soil system

Natural Acidifying processes

- Decomposition of organic material
- Mineral weathering and leaching
- Dissolution of CO_2 (above pH 6)
- Cation uptake by vegetation
- Nitrogen fixation
- Leaching

Human induced Acidification

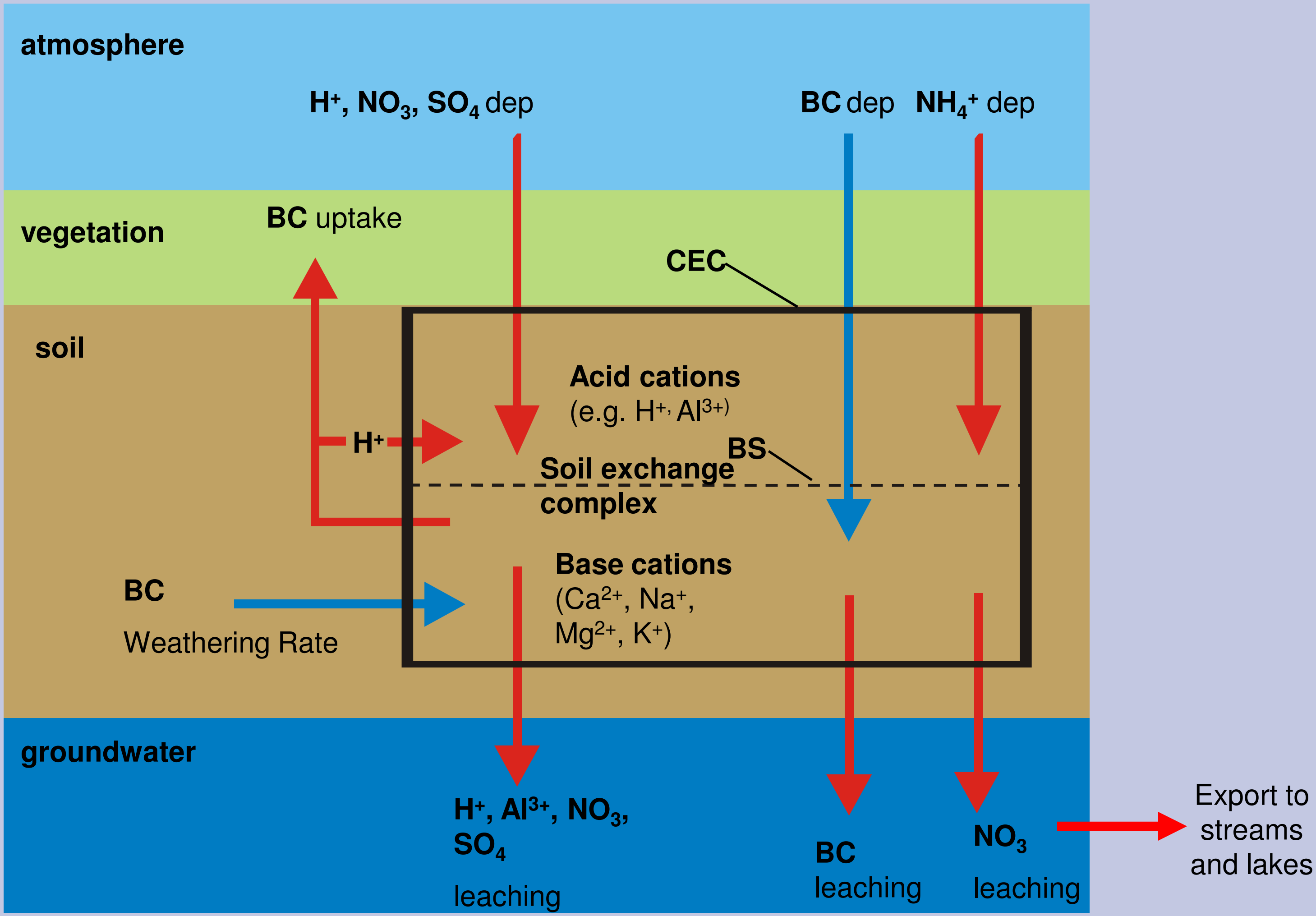
- *Acid producing fertilizers*
- *Drainage of some coastal wetlands*
- *Land use and harvest*
- *Acid Deposition*

Fertilizer	Chemical formula	Acidity equivalent
Elemental sulfur	S	300
Anhydrous ammonia	NH_3	148
Ammonium sulfate	$(NH_4)_2SO_4$	110
Urea	$CO(NH_2)_2$	84
Diammonium phosphate	$(NH_4)_2HPO_4$	70
Monoammonium phosphate	$NH_4H_2PO_4$	65
Ammonium nitrate	NH_4NO_3	59
Gypsum	$CaSO_4 \cdot 2H_2O$	0
Single superphosphate	$Ca(H_2PO_4)_2 \cdot CaSO_4 \cdot 2H_2O$	0
Triple superphosphate	$Ca(H_2PO_4)_2$	0
Potassium chloride	KCl	0
Potassium sulfate	K_2SO_4	0
Potassium nitrate	KNO_3	-26

Characteristics of soils susceptible to acidification:

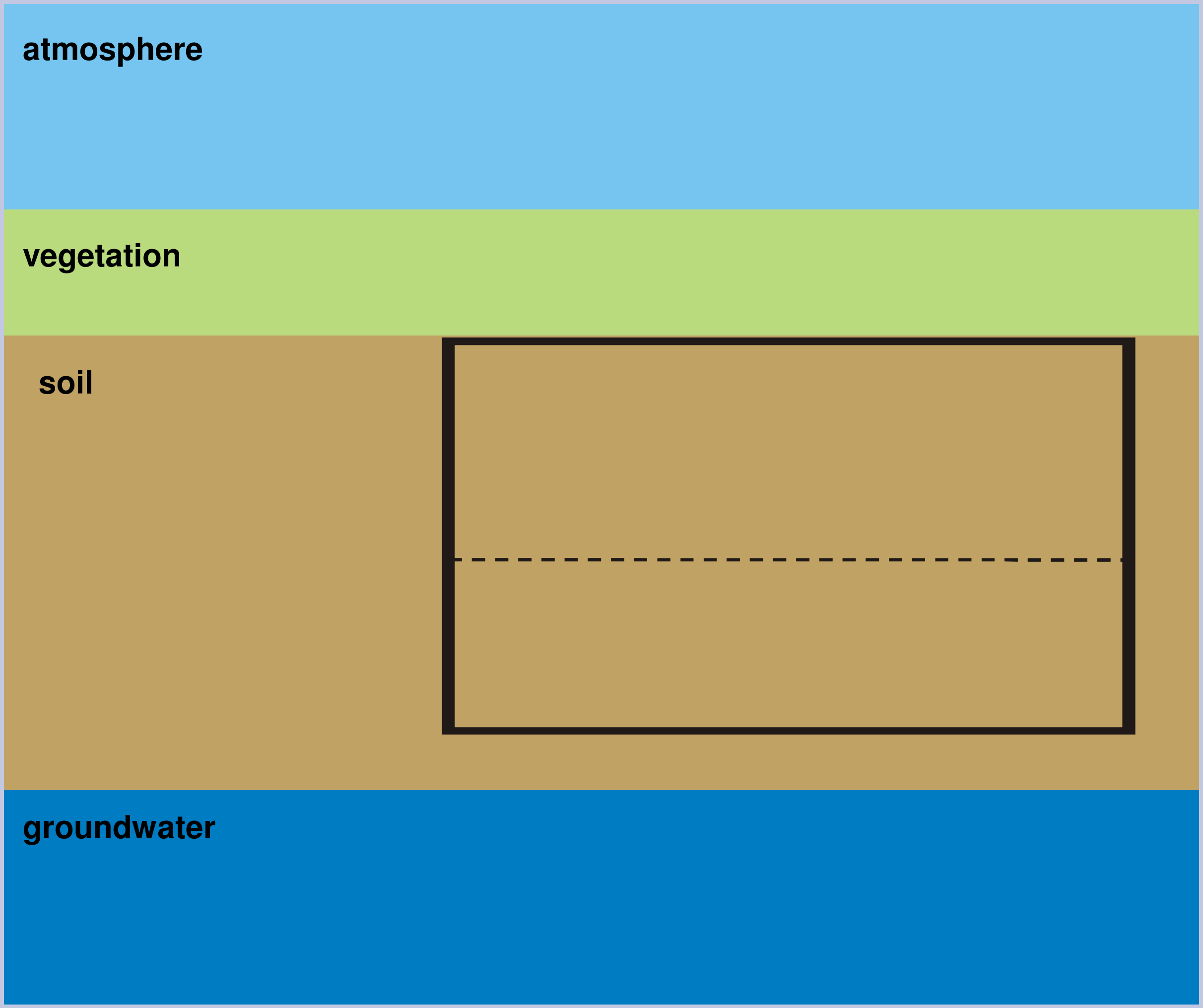
- Low soil depth
- Low amount of weatherable minerals
- low cation exchange capacity
- Moderate pH
- Low capacity to absorb sulphate
- Located in regions with high deposition of acidic compounds

The soil acidification process

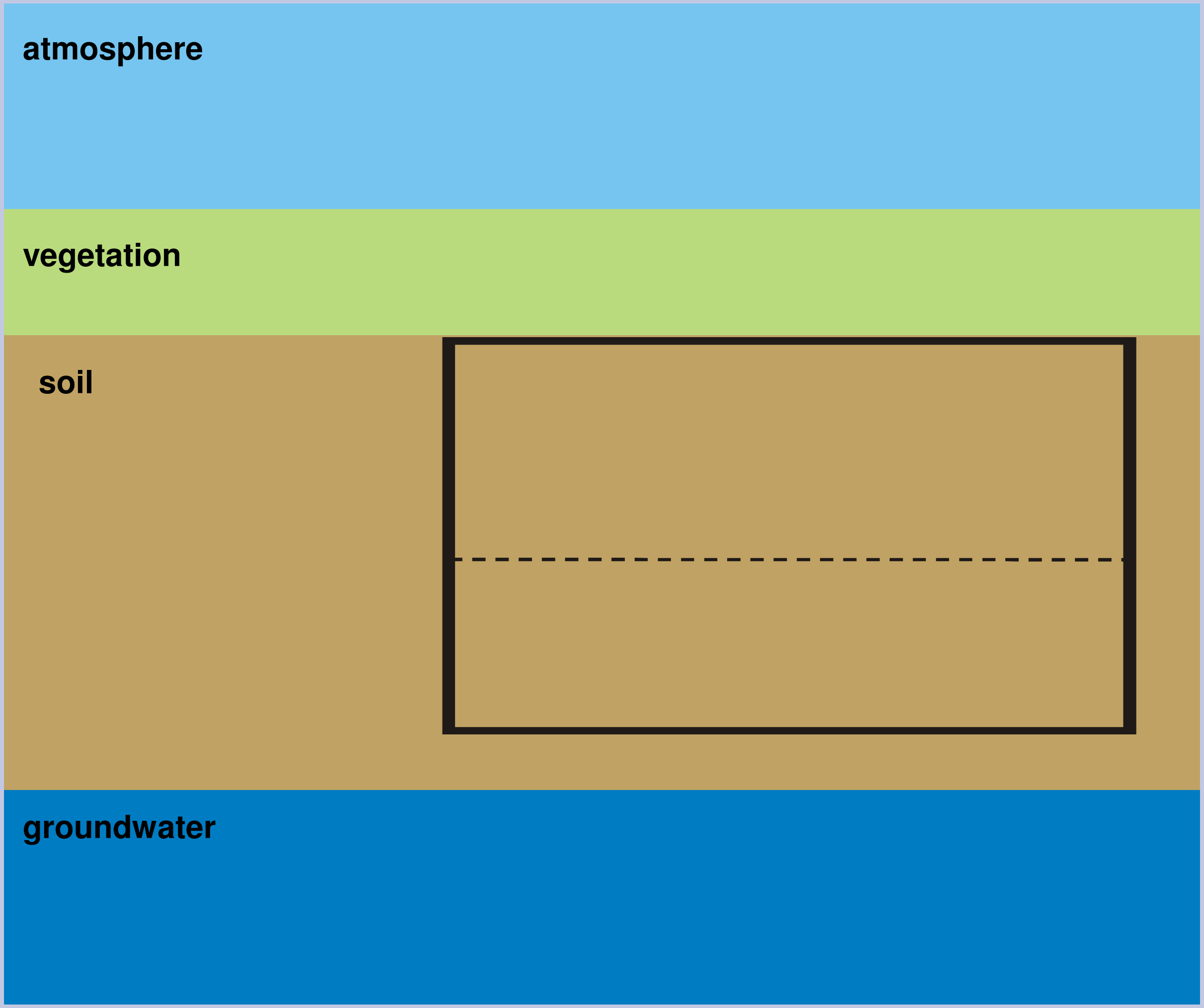


RAPIDC
Regional Air Pollution In Developing Countries

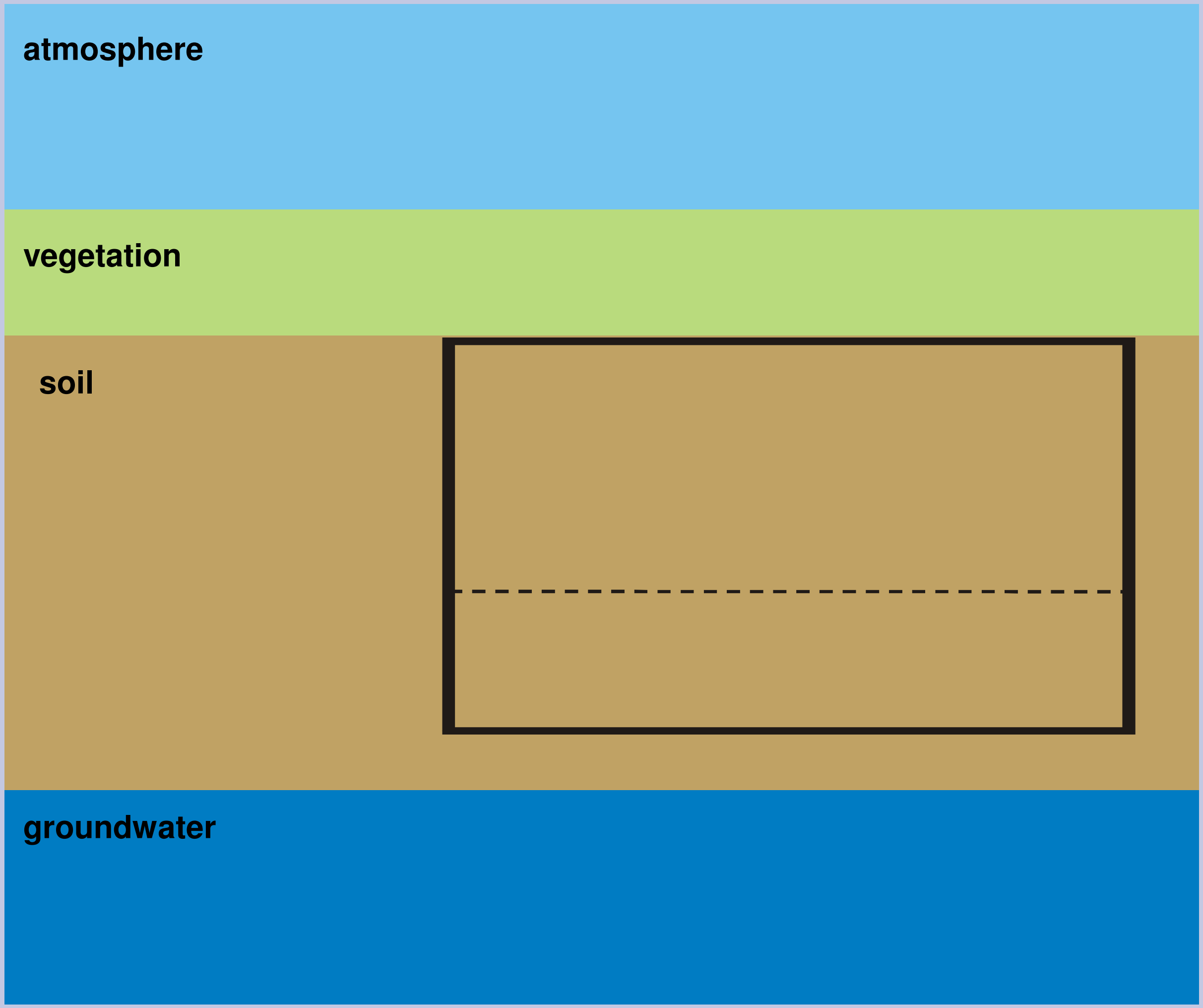
The soil acidification process



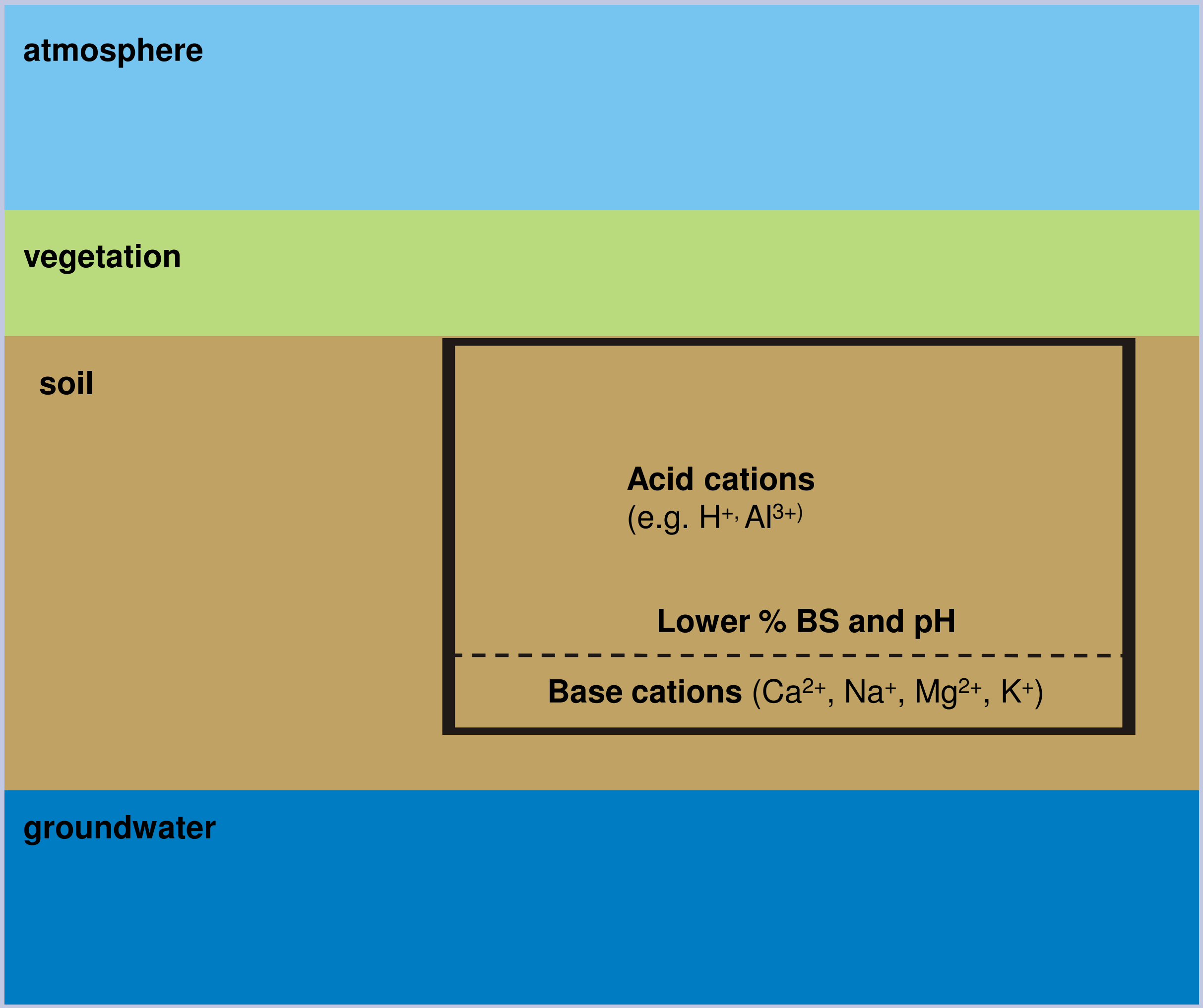
The soil acidification process



The soil acidification process

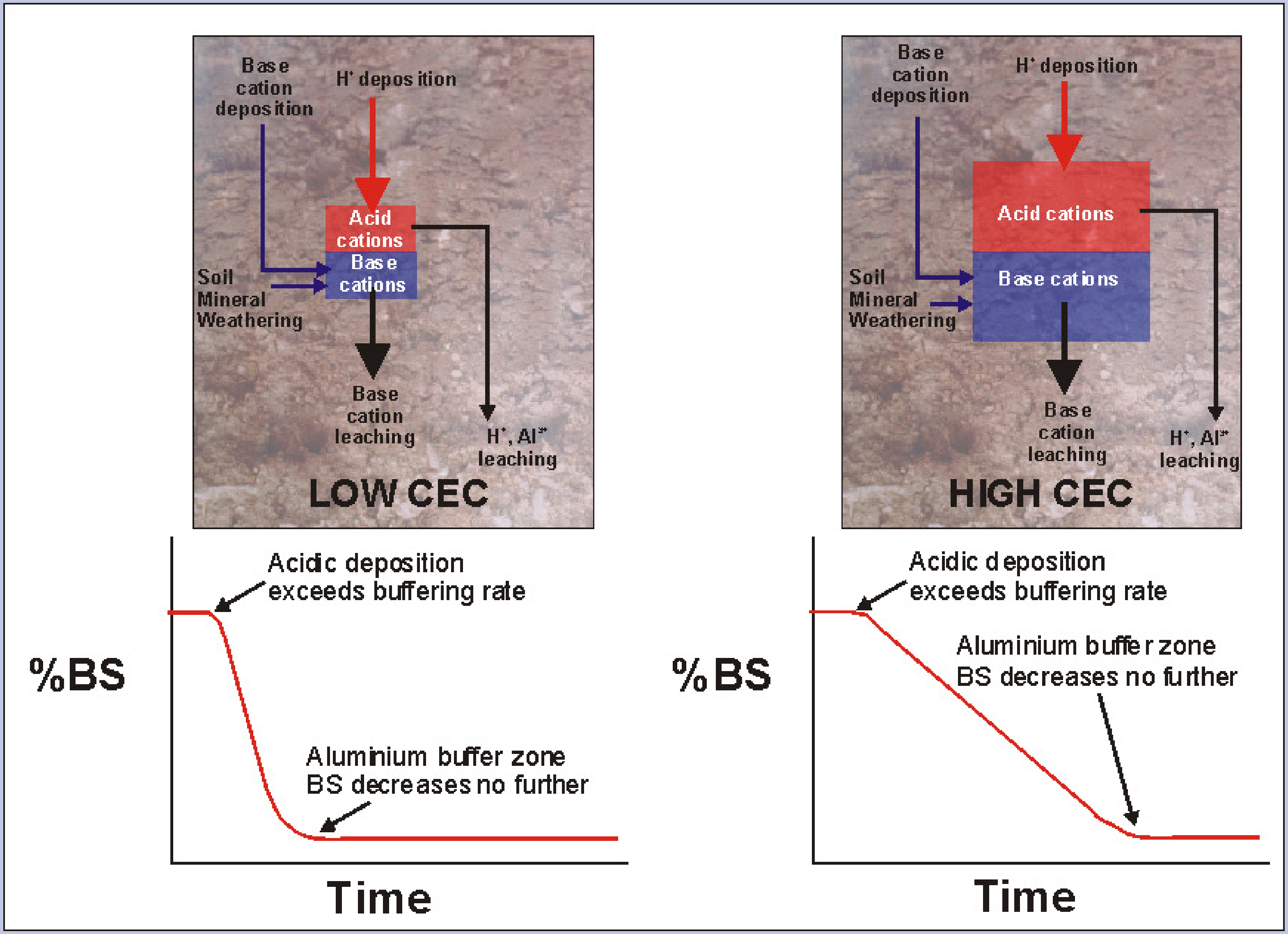


The soil acidification process



RAPIDC
Regional Air Pollution In Developing Countries

The Role of CEC and Aluminium in Soil Acidification



The soil acidification process summary

- Acid deposition (S, NOx and NHx) can increase acidity and reduce buffering capacity of soils

- pH drops and toxic aluminium ions can be released into the soil (toxic to plants) and can be leached to streams and lakes (toxic to fish)

- Acidity of rain water, measured by pH, is one measure of acid rain inputs but not the whole story

- The ‘potential’ acidity is released if ammonium is transformed to nitrate in the soil and leached

What is the risk of soil acidification?

Crucial Questions:

What is the acidic input to the soil from atmosphere and vegetation growth?

How much of the potential acidity in deposition is released?

How well can the soil buffer the acidic inputs?

Acidity and ‘potential’ acidity of rain

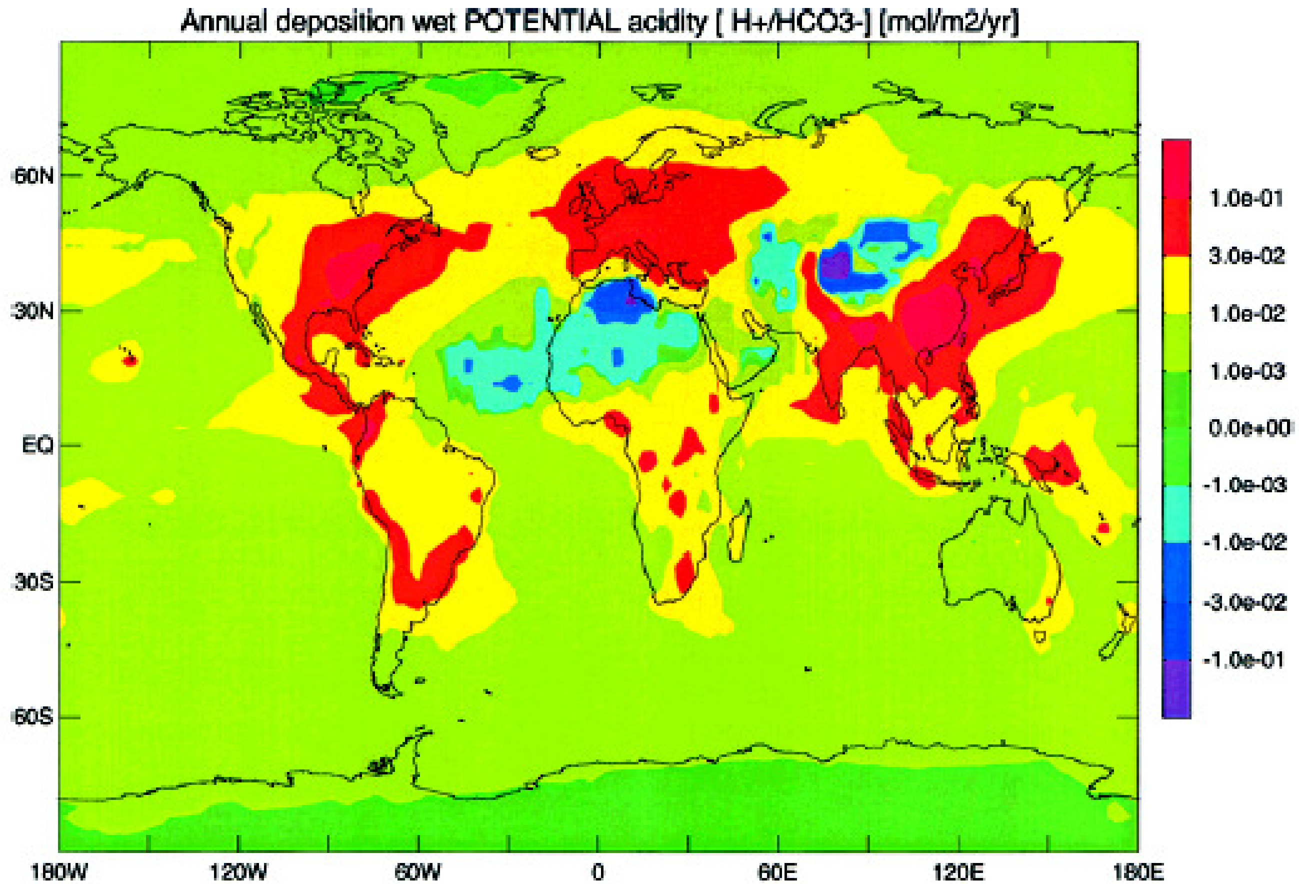


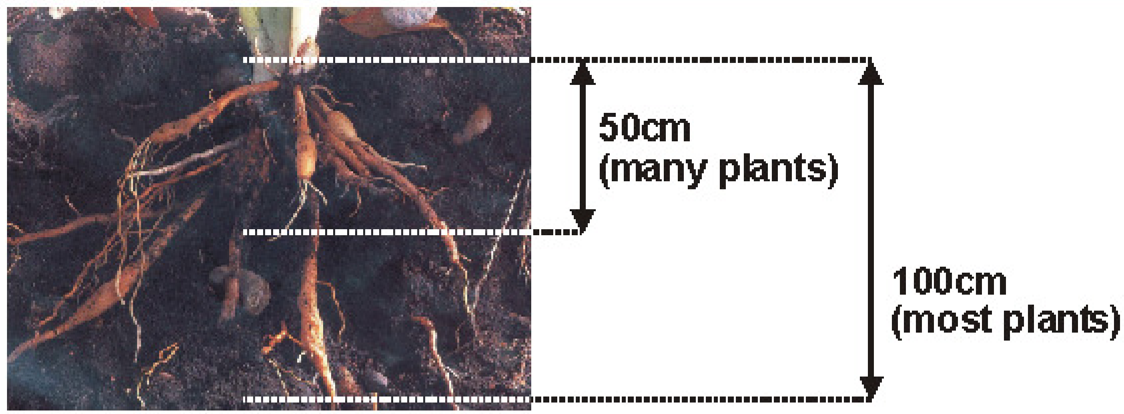
FIGURE 5. Annual wet deposition of potential acidity onto nitrogen saturated ecosystems according to eq 2. Positive values refer to H^+, negative to HCO_3^-. The same color code is used as in Figure 4. The difference between the deposition of potentail acidity (Figure 5) and acidity (Figure 4) is most pronounced in regions with high deposition of NH_x, e.g. India and parts of South America. Unit: mol m^{-2} a^{-1}.

Ammonia neutralizes acidity in the atmosphere but may contribute to soil acidity when deposited to the plant /soil system

SEI terrestrial ecosystem sensitivity to acidic deposition mapping method

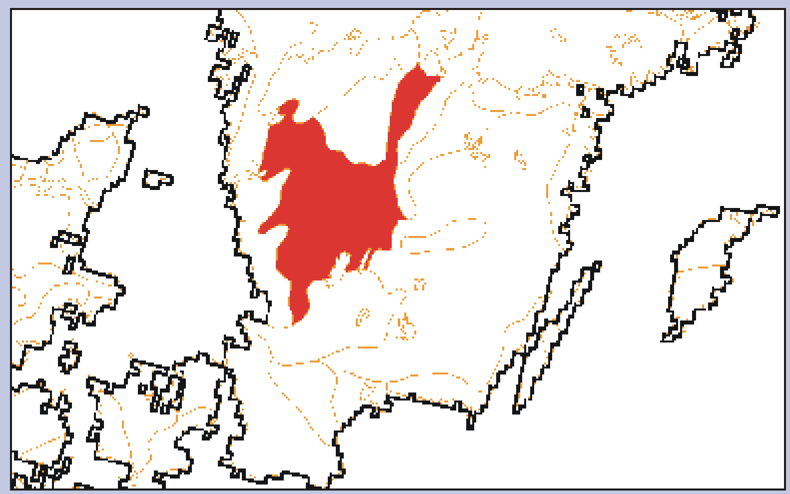
Kuylenstierna *et al.* 2001

CEC (Meq/100g)	Base Saturation % (mean over depth d) 0-20	20-40	40-60	60-80	80-100
10	1	1	2	3	5
25	1	2	3	4	5
>25	2	3	4	5	5

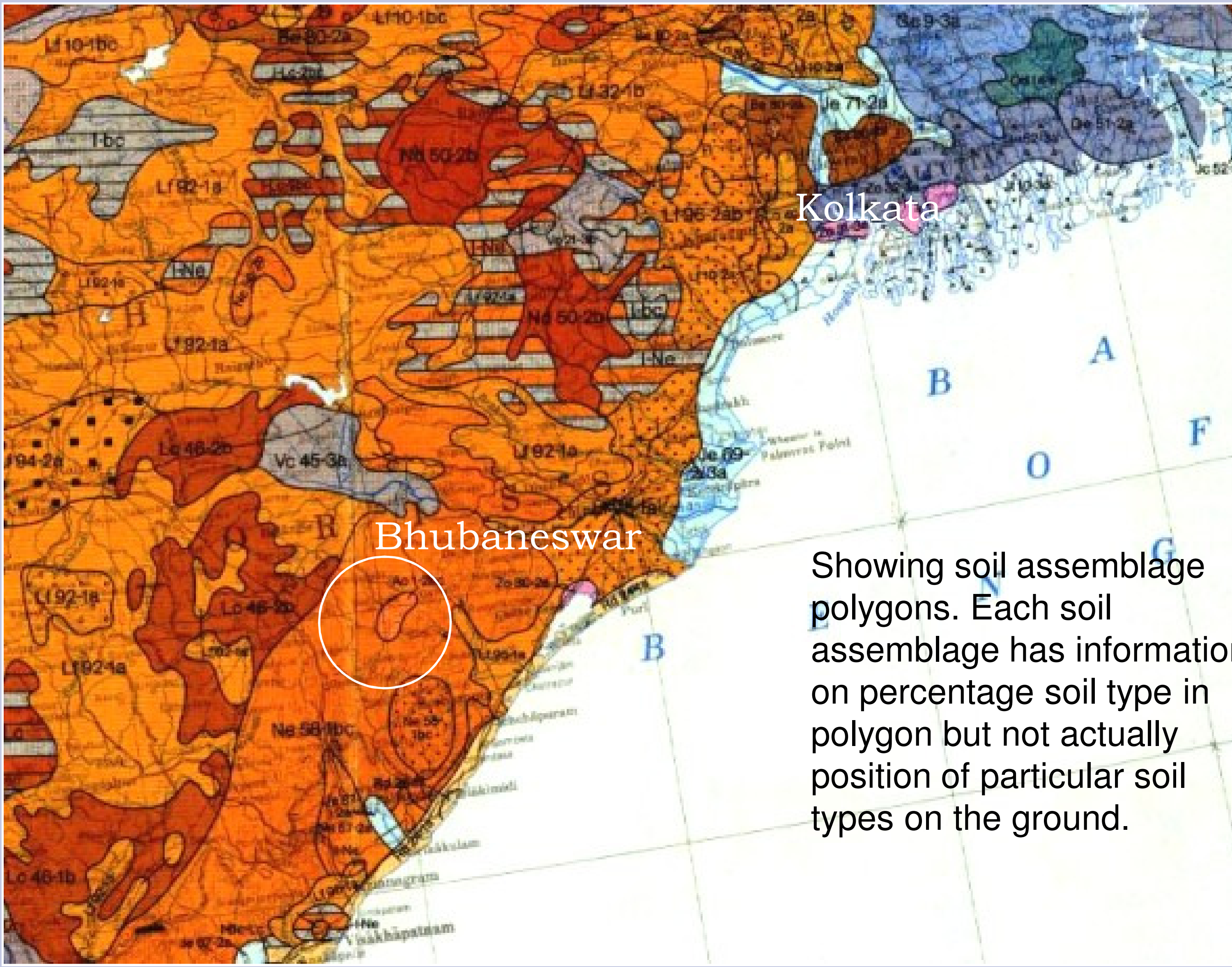


Soil Type	Sensitivity class	Cover %
Po	1	60
Be	5	20
Od	2	20

Table shows soil assemblage information for polygon shown in map on right. The area weighted mean sensitivity class shown on the map is 2 [calculated as (1*0.6)+(5*0.2)+2*(0.2)]. Note: the map could also be drawn with the most sensitive (Po) or the least sensitive soil (Be) depending on the use for the finished map.



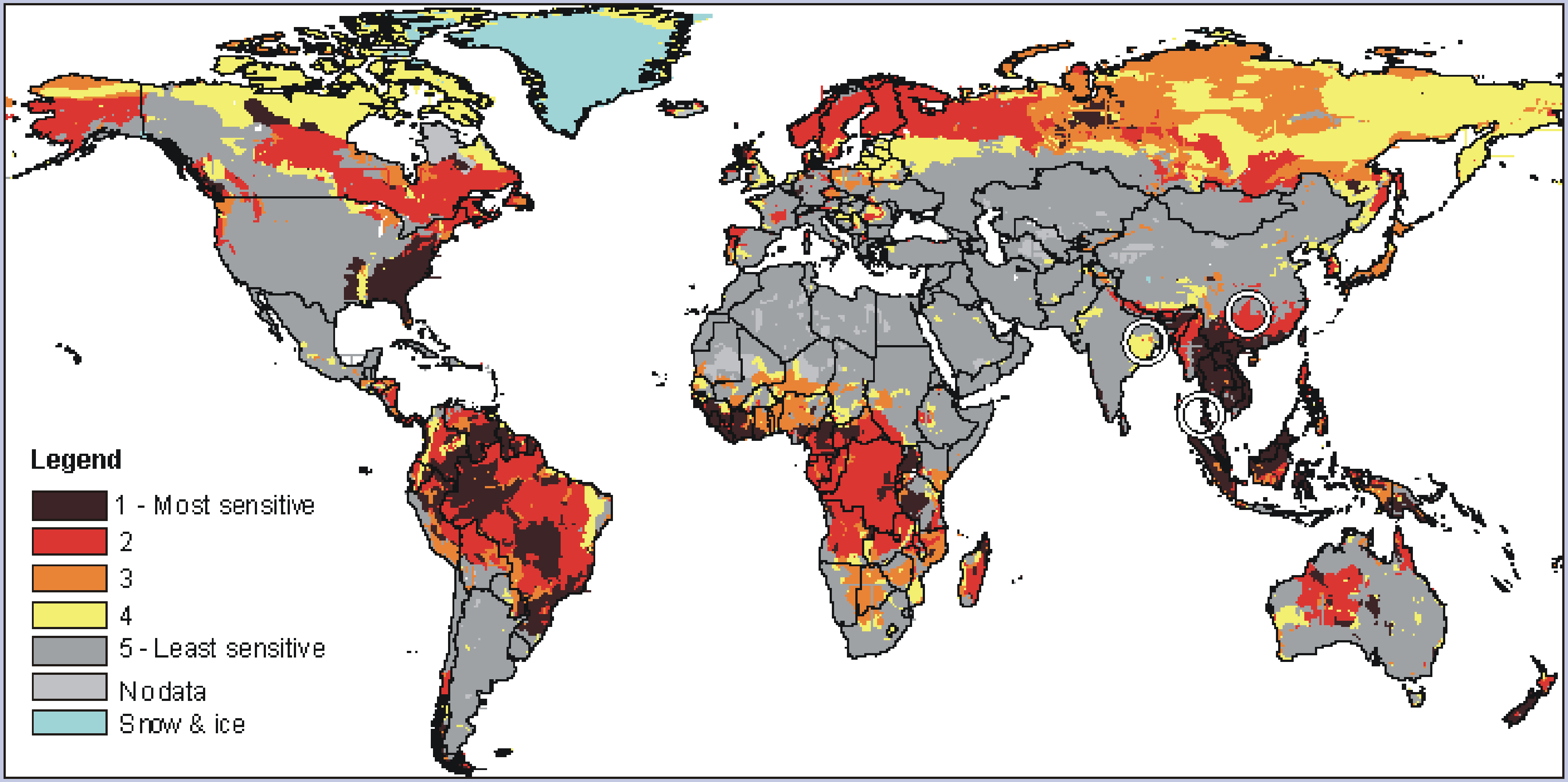
FAO Soil Map of the world for NE India



Showing soil assemblage polygons. Each soil assemblage has information on percentage soil type in polygon but not actually position of particular soil types on the ground.

RAPIDC
Regional Air Pollution In Developing Countries

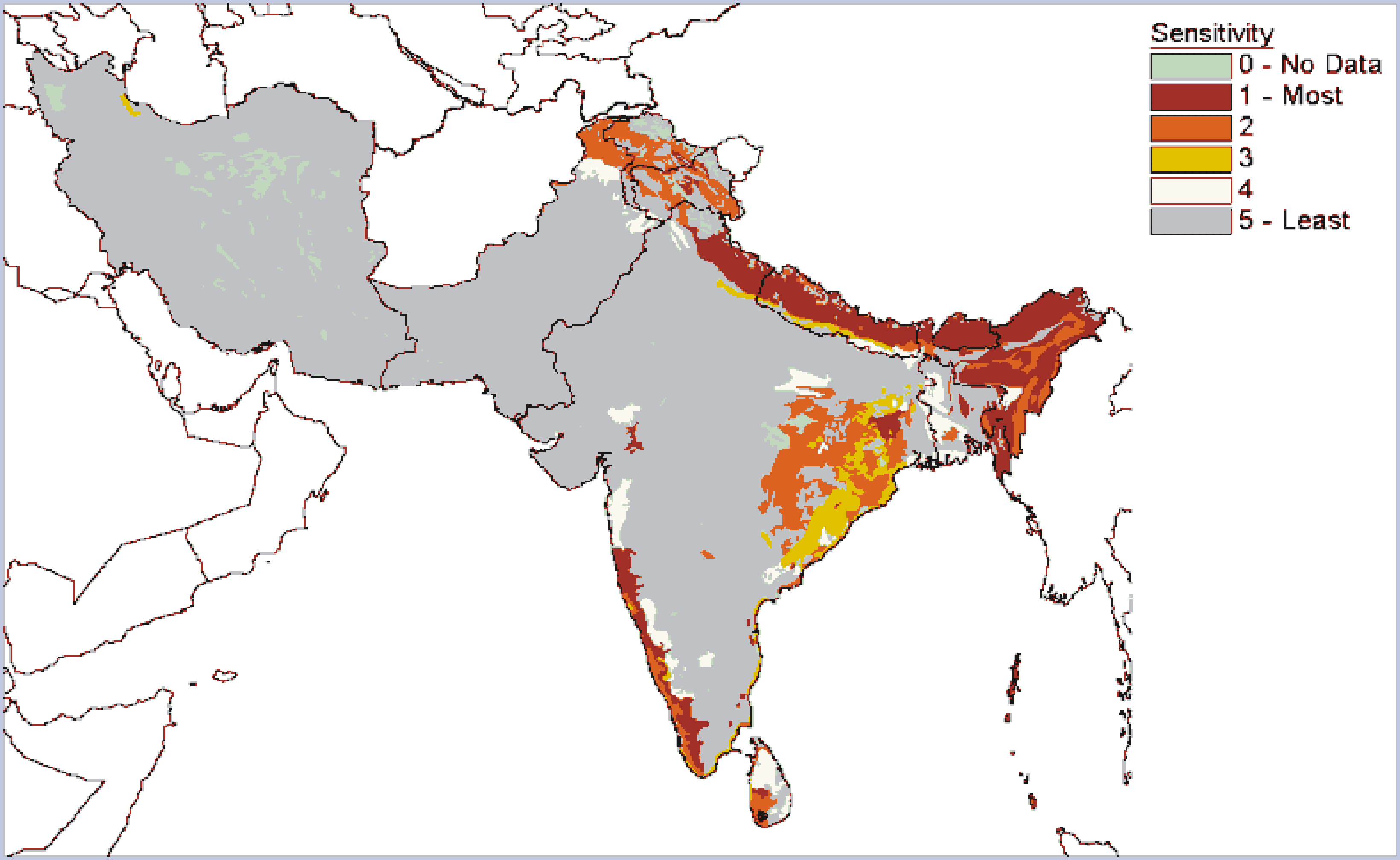
Global Map of Terrestrial Ecosystem Sensitivity to Acidic Deposition



Source: Kuylenstierna *et al*. 2001

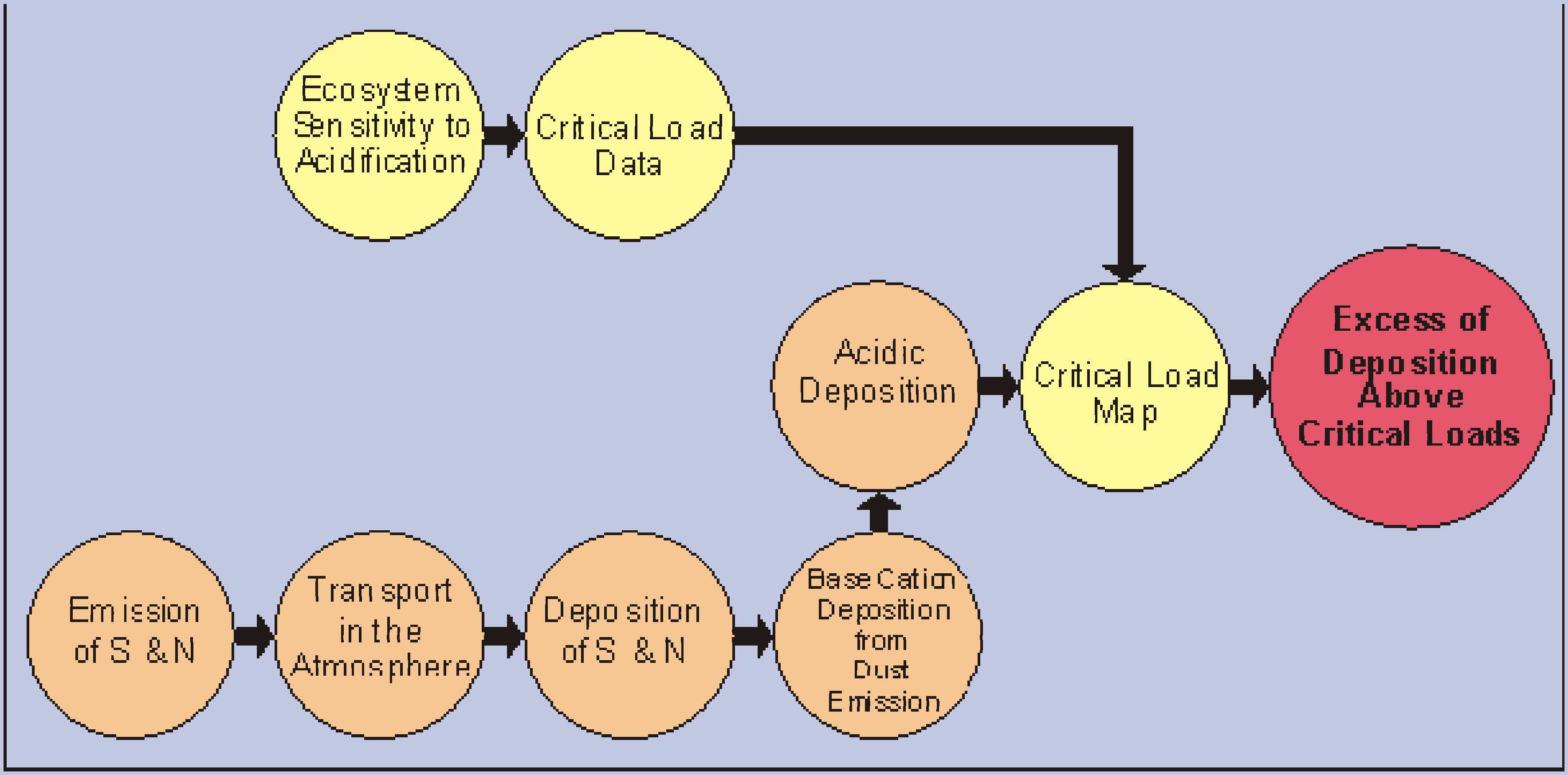
RAPIDC
Regional Air Pollution In Developing Countries

Terrestrial Ecosystem Sensitivity to Acidic Deposition in South Asia

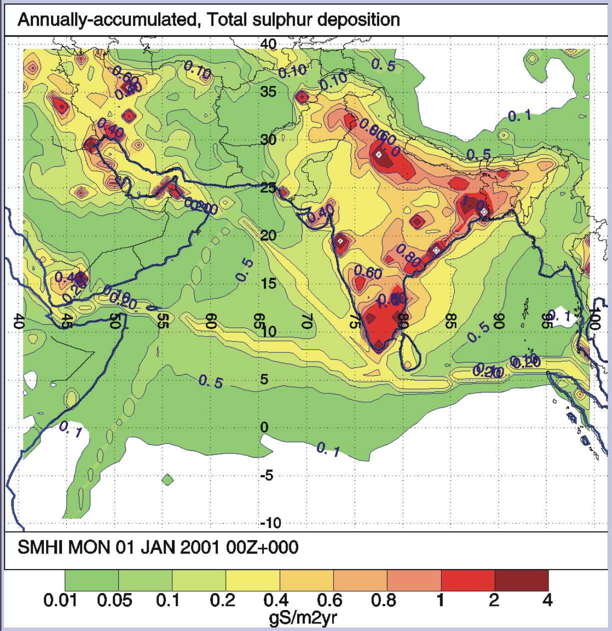


Source: Kuylenstierna *et al*. 2001

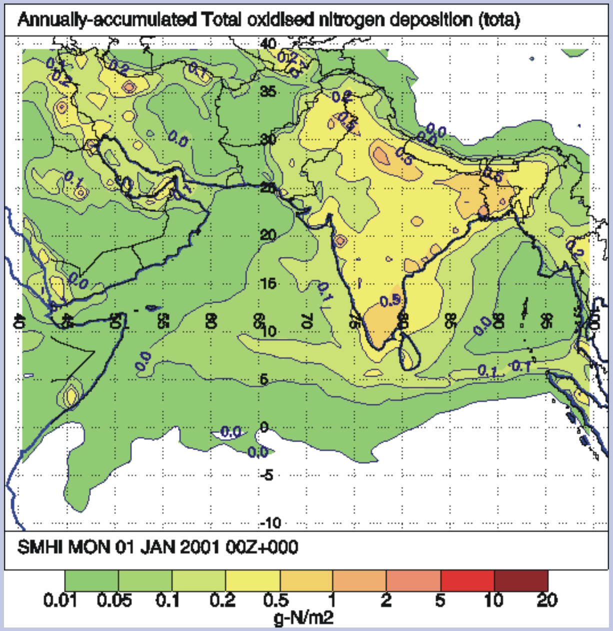
Calculating Risk of Ecosystem Damage Using the Critical Load Approach



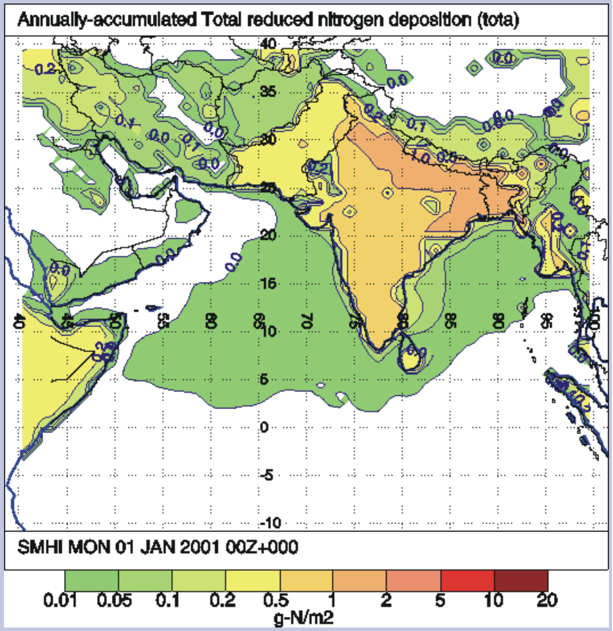
Acidic deposition in South Asia during 2001 using the MATCH model



Sulphur



Oxidized Nitrogen

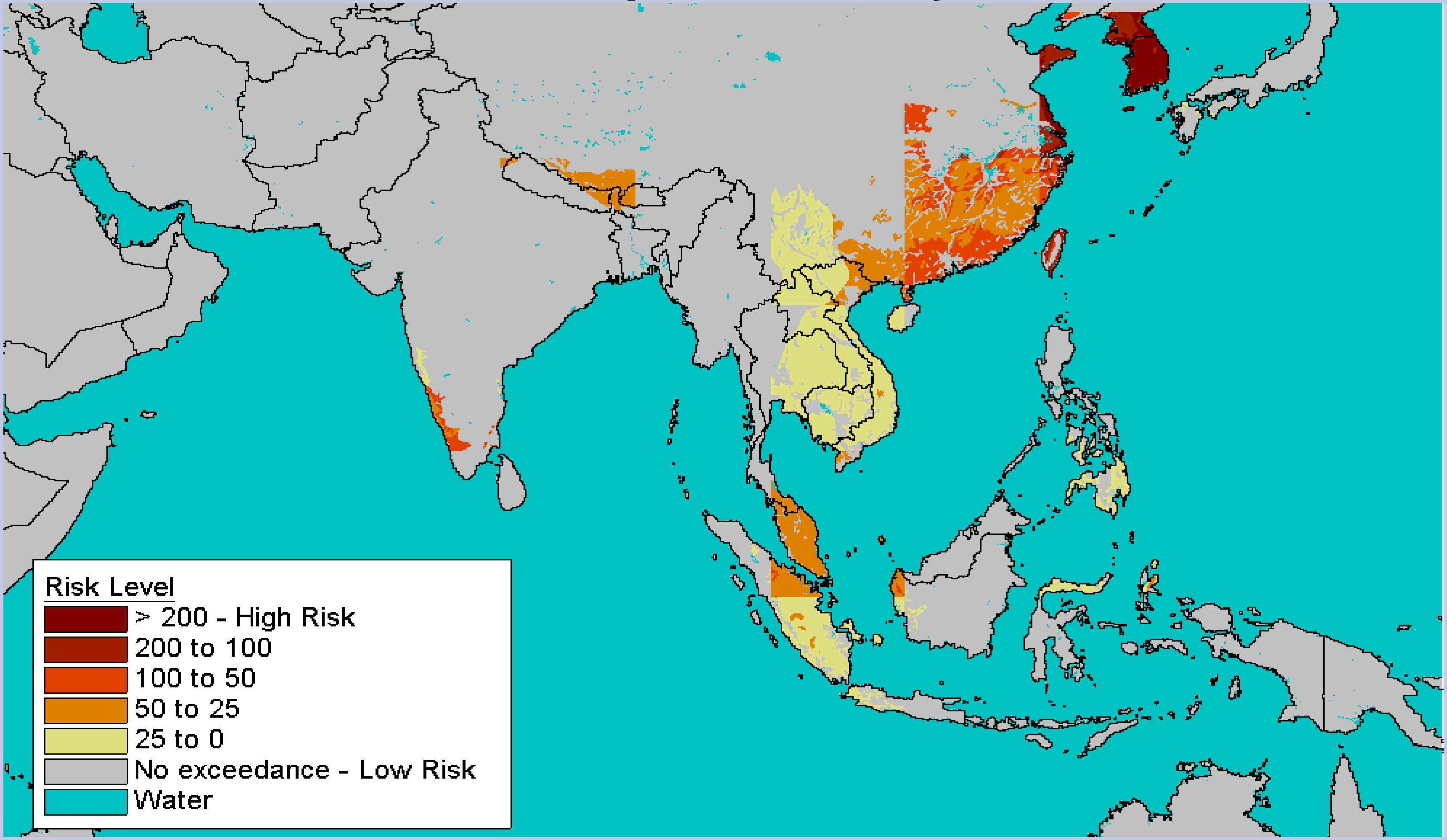


Ammonium

RAPIDC

Regional Air Pollution In Developing Countries

Estimated Risk of acidification for S deposition only



Acidification in South Asia?

1. No evidence of acidification effects yet
2. Potential areas at risk: e.g. Western Ghats, NE India, Himalayas, Bangladesh, wet zone of Sri Lanka have sensitive soil types
3. Areas of high ammonium deposition may be especially at risk e.g. NE India
4. Whether acidification potential is realised or not depends on air pollution emission trends, soil properties and management

What actions can be taken?

Soils potentially at risk in each country must be identified and:

- relevant soil parameters measured
- pollutant load and its origins determined
- fate of nitrogen deposition in soil plant system and leaching determined
- management of the site studied e.g litter removed?

Next steps in Malé process?

1. Research required at national level on sensitive soils
2. Manual will be distributed in near future through NIAs

In Europe extensive and expensive liming was carried out to maintain buffering capacity of ecosystems

RAPIDC

Regional Air Pollution In Developing Countries

Sida funded RAPIDC Programme

For more information visit:

WWW.RAPIDC.ORG

RAPIDC
Regional Air Pollution In Developing Countries

Chinese proverb:

'A **clever** man learns from his mistakes….

….a **wise** man learns from other people's'