Joint Research Centre (JRC)

Tolerable versus actual soil erosion rates in Europe
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Tolerable soil erosion in Europe

Objective

To review tolerable soil erosion for European conditions

- Need for scientifically sound and robust threshold values against which to appraise monitoring data

Structure

1. Concept (definition, history and assumptions)
2. Rates (weathering + dust deposition)

Boundary conditions

1. Mineral soils (on hard rock/consolidated sediments)
2. Hillslopes

Definition

Many terms

- Soil loss tolerance
- Permissible soil loss
- Acceptable rates of soil erosion
- Allowable soil loss
- Etc.

Two Themes

- Maintaining biomass (crop) production function
- Maintaining soil quantity (volume or mass)

Definition

Definition/interpretation	Reference
The maximum volume of erosion-removed topsoil that provides high, or economically feasible, fertility for a long time	Patsukevich et al., 1997.
Soil loss balanced by soil formation through weathering of rocks	in Roose (1996)
Erosion that does not lead to any appreciable reduction in soil productivity	in Roose (1996)
The maximum rate of soil erosion that permits an optimum level of crop productivity to be sustained economically and indefinitely	ISSS (1996)
The average annual soil loss a given soil type may experience and still maintain its productivity over an extended period of time (permissible soil loss)	Kok et al. (1995)
The maximum permissible rate of erosion at which soil fertility can be maintained over 20-25 years	Morgan (2005)
(i) The maximum average annual soil loss that will allow continuous cropping and maintain soil productivity without requiring additional management inputs. (ii) The maximum soil erosion loss that is offset by the theoretical maximum rate of soil development which will maintain an equilibrium between soil losses and gains	SSSA (2001)
Rate of soil erosion is not larger than the rate of soil production (acceptable rates of soil erosion)	Boardman and Poesen (2006)

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Linking to soil functions

Primary soil functions	Components
Habitat	Refugium function; nursery function; medicinal resources; gene pool; seed bank
Information	Cultural information (archaeological and palaeontological); science and education; spiritual and historic; recreation; aesthetic information
Production	Food; fodder; fibre; raw materials; renewable energy
Engineering	Technical, industrial and socio-economic structures
Regulation	Gas regulation; climate regulation; disturbance resistance; disturbance resilience; water supply; water filtering; pH buffering; biotransformation of organic carbon; soil retention; soil formation; nutrient regulation; biological control; waste and pollution control

Blum, 1993; Sombroek and Sims, 1995; Brady and Weil, 2002; De Groot et al., 2002; Blum, 2005; Nikitin, 2005; and the European Commission, 2006a,b)

Definition

Tolerable rate of soil erosion

'Any actual soil erosion rate at which a deterioration or loss of one or more soil functions does not occur'

Actual soil erosion: 'the total amount of soil lost by all recognised soil erosion types'

Intergenerational equity argument

future generations should have the same rights to natural resources as those enjoyed by the current generation

Assumptions

Soil formation rate = tolerable soil erosion rate

Soil erosion can generally be judged not to deteriorate soil functions as long as soil erosion does not exceed ‘natural’ or ‘geological’ (or ‘normal’) erosion rates

Desert dust also forms soil

‘when dust is deposited onto a soil from a desert source area, it may be regarded as ‘more valuable’ for soil functions in its new location’ Simonson (1995)

- Accept, as long as the amount deposited is of an order of magnitude that enables the soil to incorporate it (i.e. not buried by it)

Weathering Rates

- **Slow process, difficult to measure experimentally**

- **Large scale methods**
  - Mass balance
  - In situ cosmogenic nuclides
  - Continental sedimentation

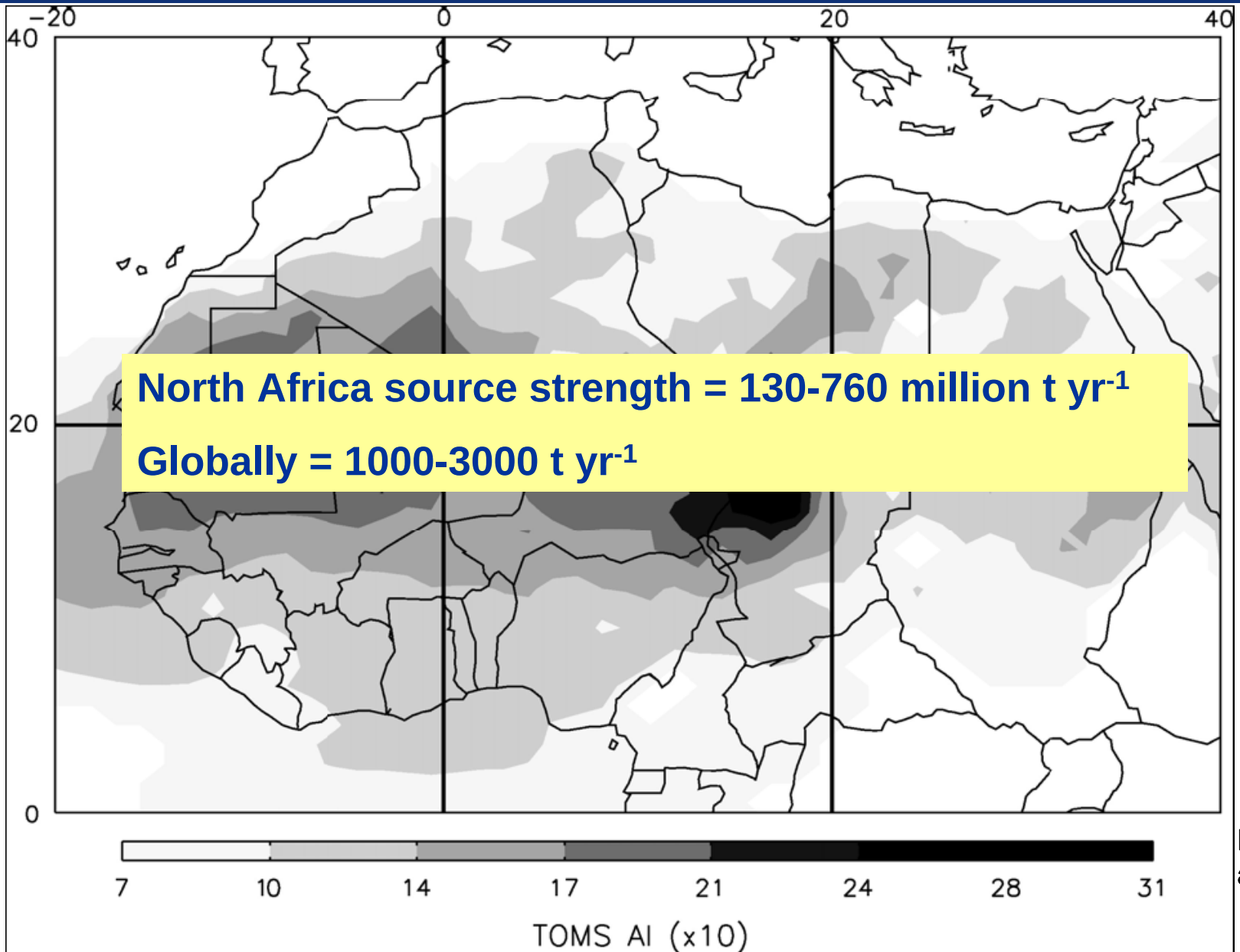
Weathering Rates

Methodology	Spatial scale	Temporal scale	Lower limit	Upper limit	Reference
Mass balance (Si)	Non-carbonate; non-arable; North America, Europe, Australia (Victoria), Zimbabwe	na	0.02	1.27	Alexander (1988a)
Mass balance (Al, Fe, Ca, K, Mg, Na, Si)	Global		0.37	1.29	Wakatsuki and Rasyidin (1992)
In situ cosmogenic ^{10}Be and ^{26}Al	Northern California	na	0.39	0.91	Heimsath et al. (1997)
In situ cosmogenic ^{10}Be	Middle European rivers	10-40 Kyr	0.26	1.3	(Schaller et al. (2001)
Continental scale erosion/sedimentation	Global	542 Myr	0.4	1.4	Wilkinson and McElroy (2007)
Na	USA	na	0.3	1.1	Bennett (1939)

Dust Deposition Rates

- Much improved understanding in last 15-20 years
- TOMS AI – Total Ozone Mapping Spectrometer Aerosol Index

Dust sources

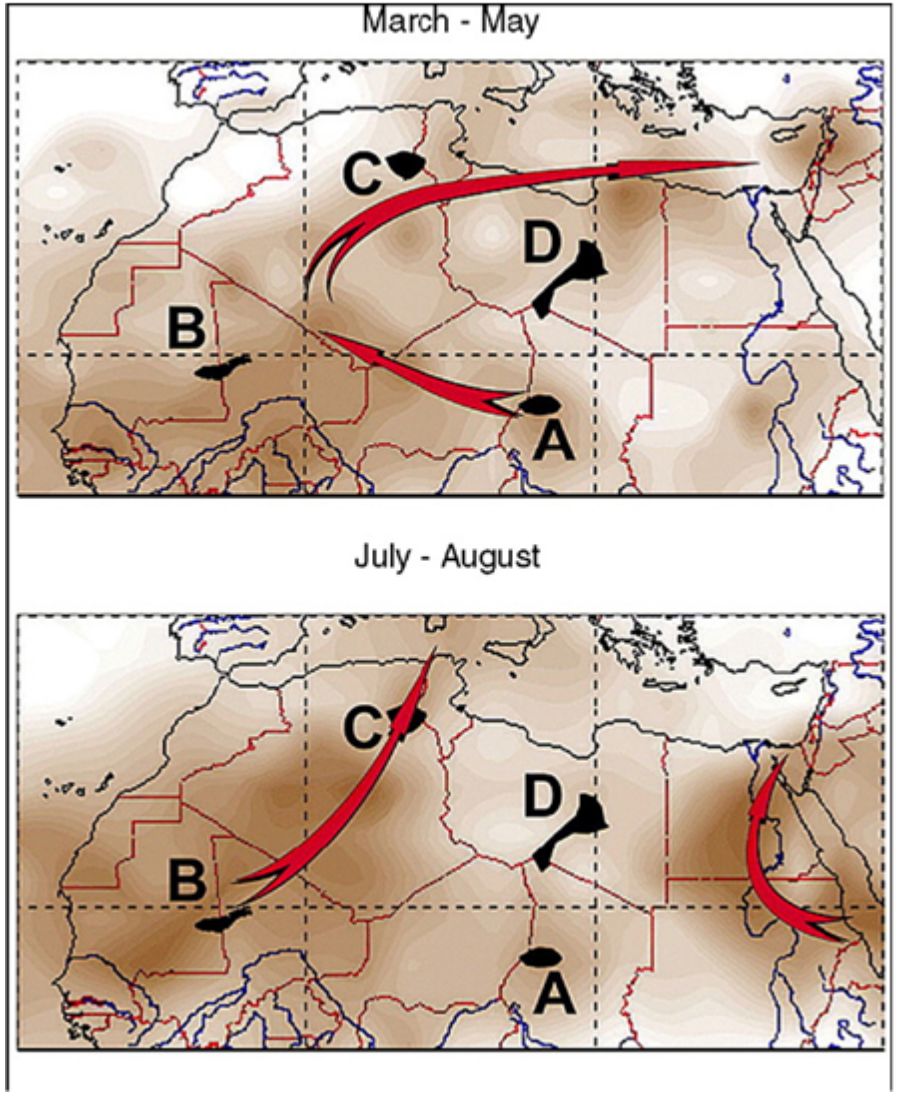


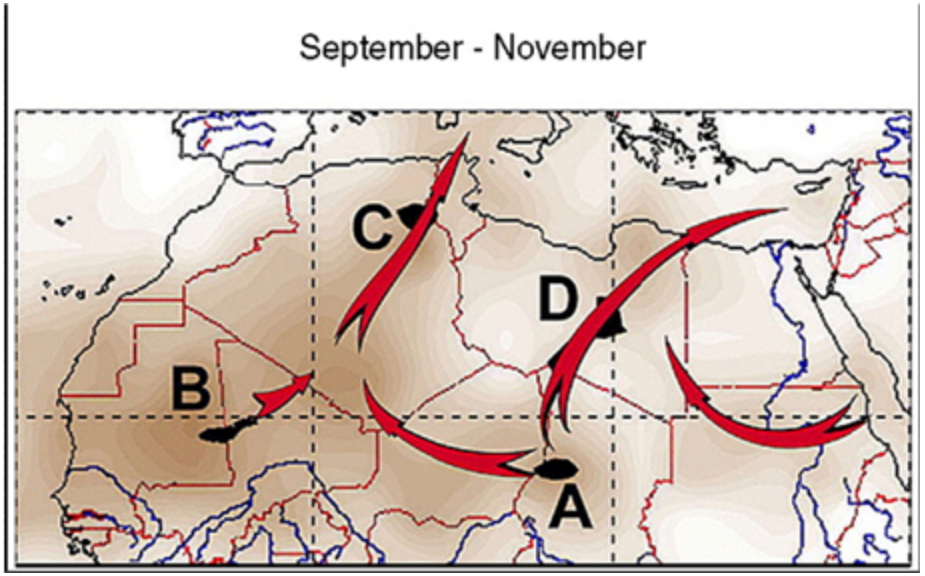
North Africa source strength = 130-760 million t yr^{-1}

Globally = 1000-3000 t yr^{-1}

Engelstaedter et al., 2006

Dust pathways





Dust supply to Europe is variable

20 – 120 t yr^{-1}

Engelstaedter et al., 2006

Dust deposition

Location	Dust deposition ($t\ ha^{-1}\ yr^{-1}$)
Aegean Sea	0.112 - 0.365
Southern Sardinia	0.06 – 0.13

Mediterranean = 0.05 – 0.39 t ha yr^{-1}

North of Med = < 0.01 t ha yr-1

Corsica	0.12
Corsica	0.125
Central France	0.01
Crete	0.1 – 1.0
Crete	0.195
Pyrenees	0.30 – 0.39

Contrast and compare

- 0.04 – 0.16 t ha^{-1} yr^{-1} Southern Nevada/SE California (Reheis and Kihl, 1995)
- 0.3 t ha^{-1} yr^{-1} Average for SW California (Reheis and Kihl, 1995)
- ~3.0 t ha^{-1} yr^{-1} between Rockies and Mississippi (Simonson, 1995)

Key Findings - Concept

Tolerable rate of soil erosion:

'Any actual soil erosion rate at which a deterioration or loss of one or more soil functions does not occur'

Actual soil erosion: 'the cumulative amount of soil lost by all recognised soil erosion types'

Assumption 1: tolerable soil erosion=soil formation

- **Can we relate (components of) soil functions with soil erosion?**
- **e.g. USDA uses target of 1 t ha^{-1} yr^{-1} to maintain water quality**

Assumption 2: soil formation=weathering + dust deposition

- **Dust deposition can be a relevant factor**
- **Is the value really greater where it is deposited?**
  - **1-50% of dust is estimated to be caused by anthropogenic factors**

Key Findings – Tolerable rates

- Review largely supports the 1 t ha^{-1} yr^{-1} blanket threshold for tolerable soil erosion
  - 0.3 – 1.4 1 t ha^{-1} yr^{-1}
  - Spatial structure?
  - some location soil lost 2x faster than formed

- More data needed to confidently differentiate rates by dominant factors (and soil functions)

- How will climate change affect soil formation?
  - Physicochemical
  - Biological
  - Indirectly by land use change

- Effect of soil depth?

- Other dust sources?
  - Volcanic ash?
  - Anthropogenic dust emissions?