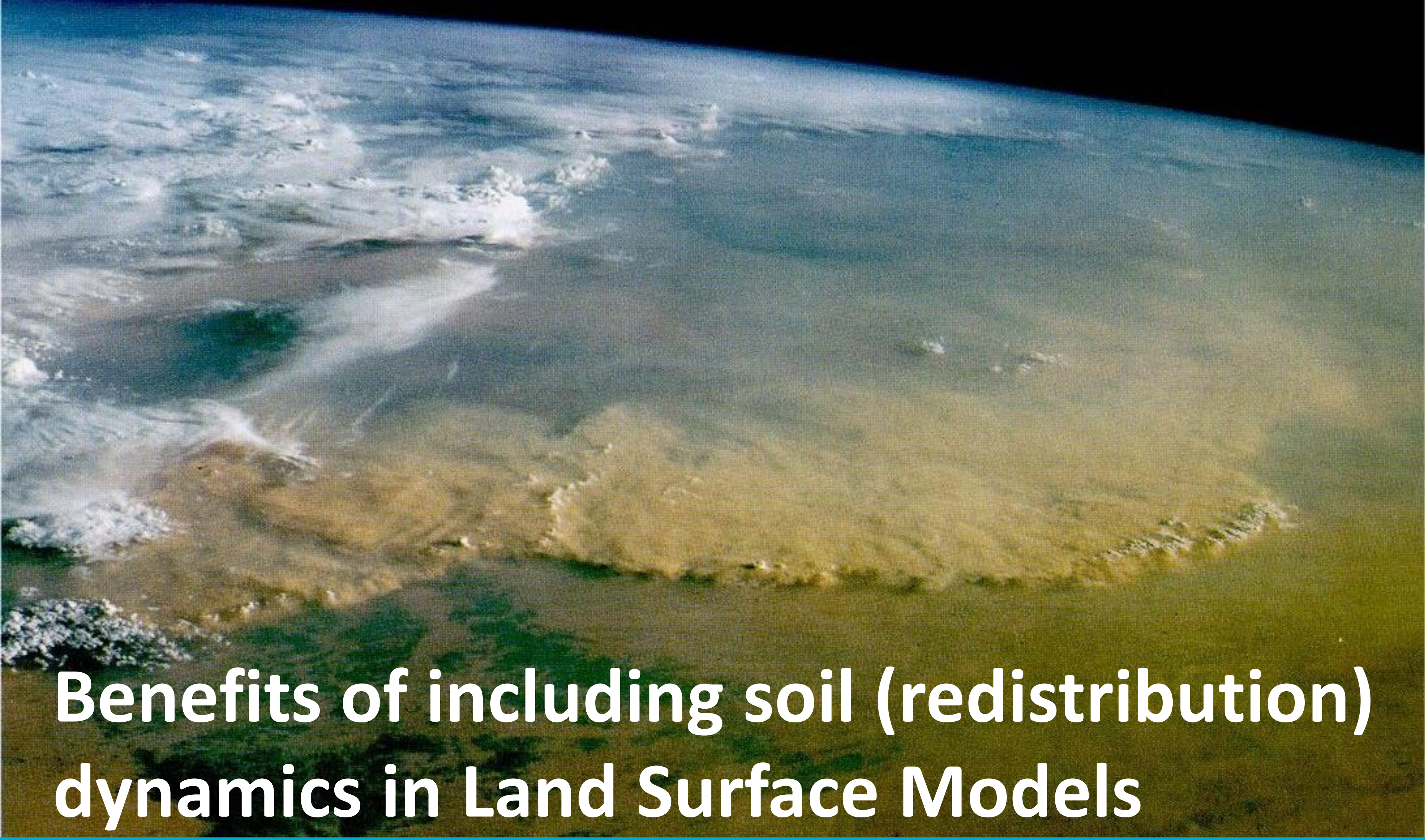
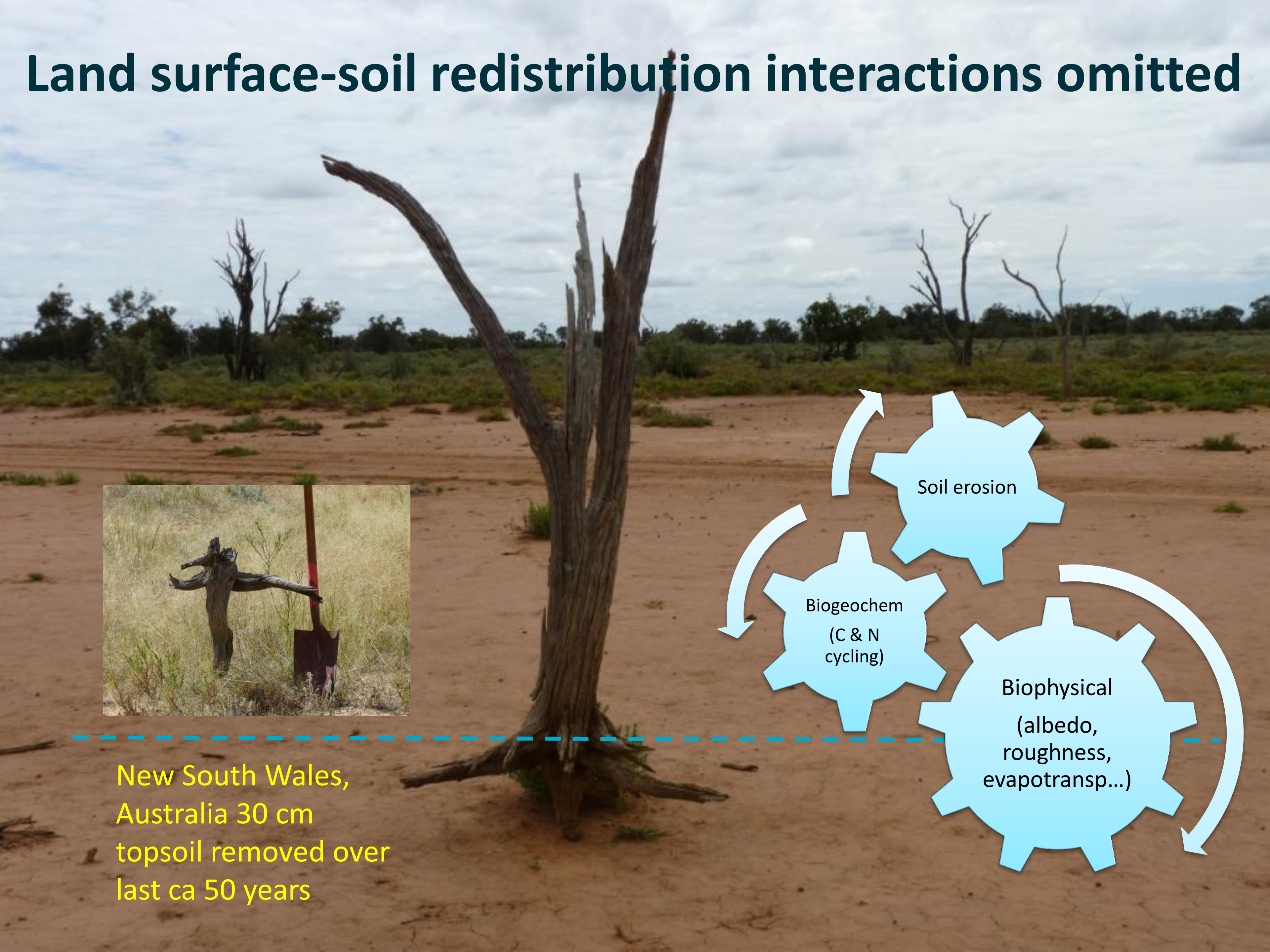


Benefits of including soil (redistribution) dynamics in Land Surface Models

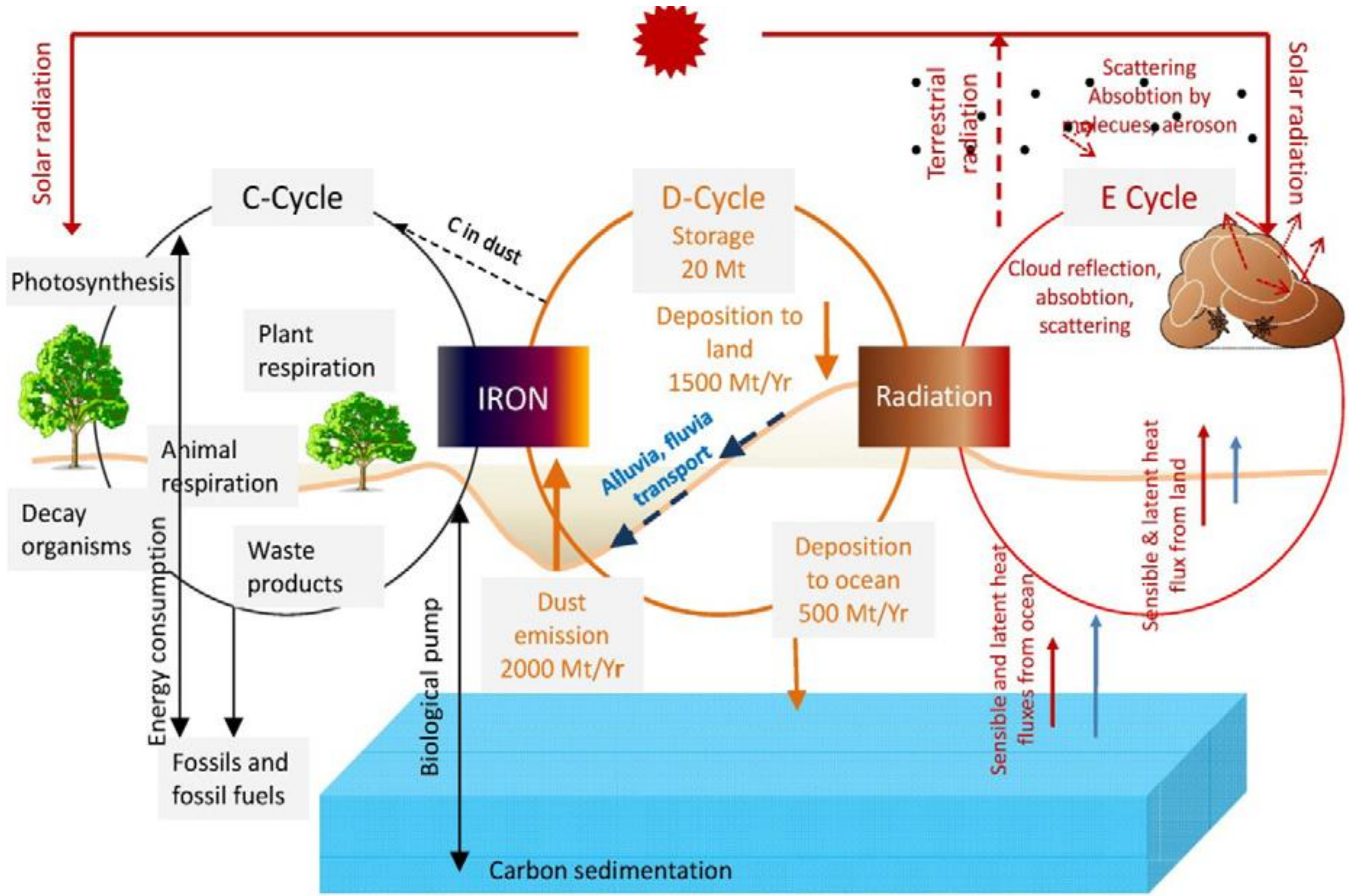
ADRIAN CHAPPELL, CSIRO LAND & WATER
www.csiro.au

Land surface-soil redistribution interactions omitted

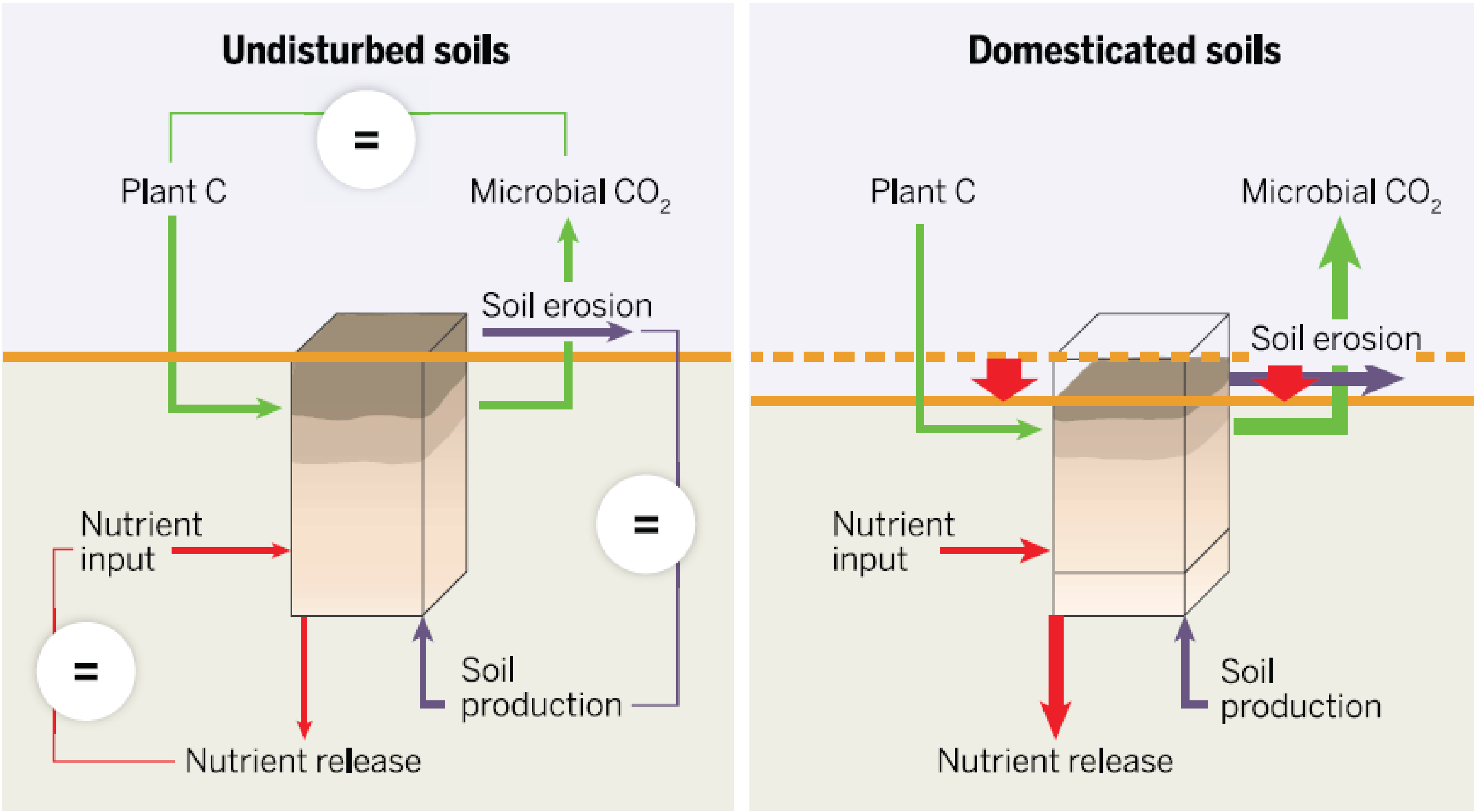


New South Wales, Australia 30 cm topsoil removed over last ca 50 years

Dust cycle in Earth System Modelling

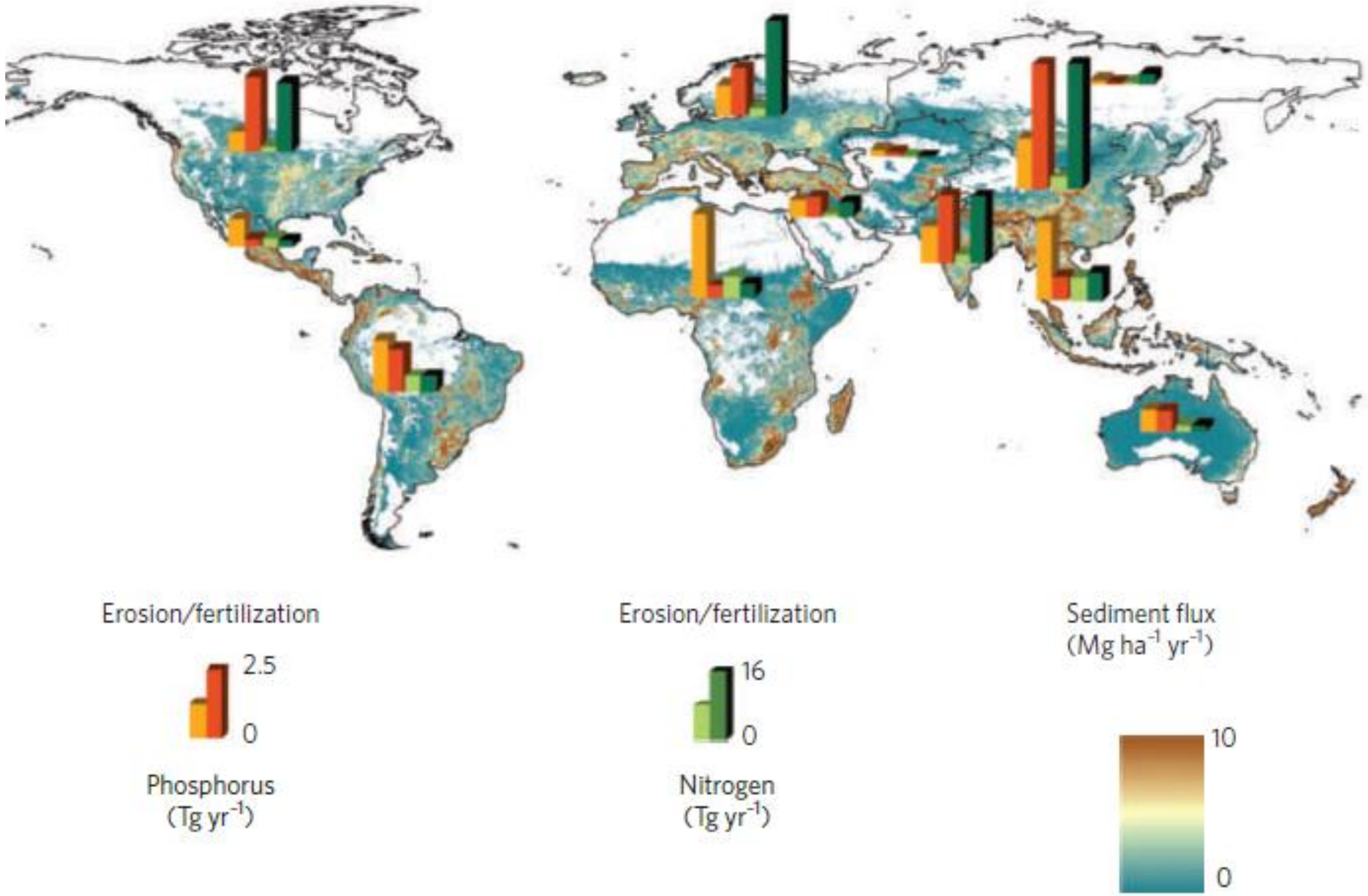


Human impact - accelerated soil erosion



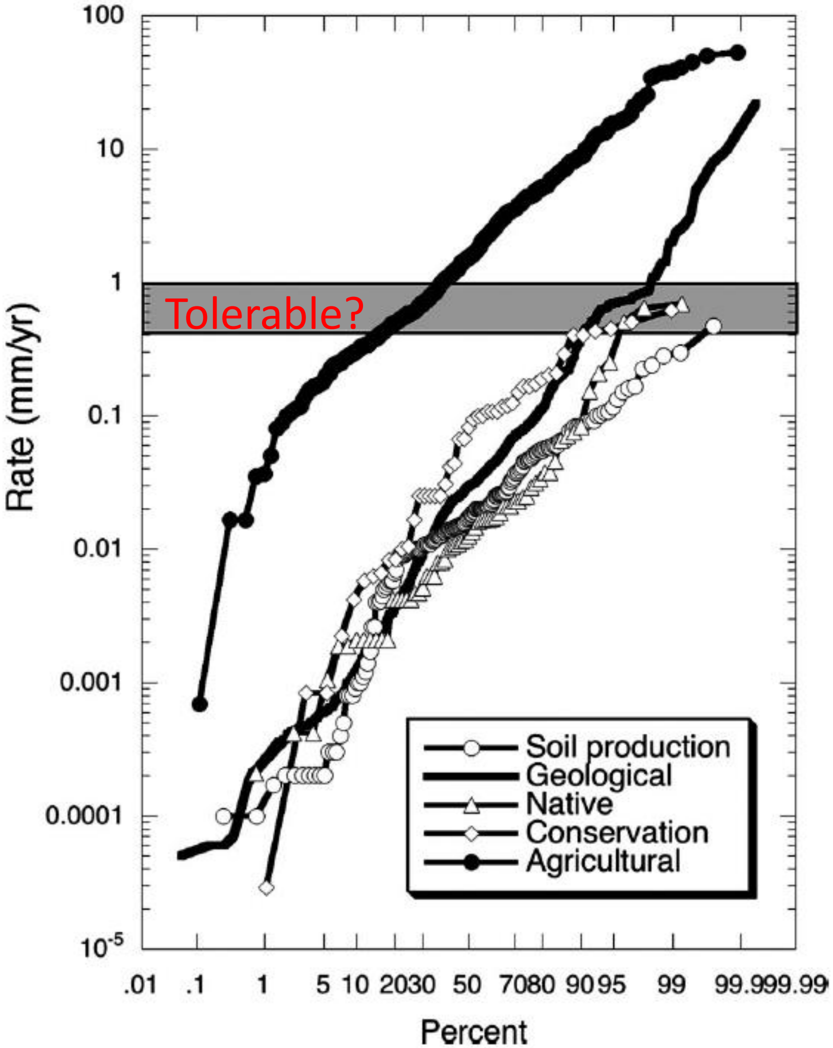
Amundson et al. (2015) Science

Soil erosion and biogeochemical cycling

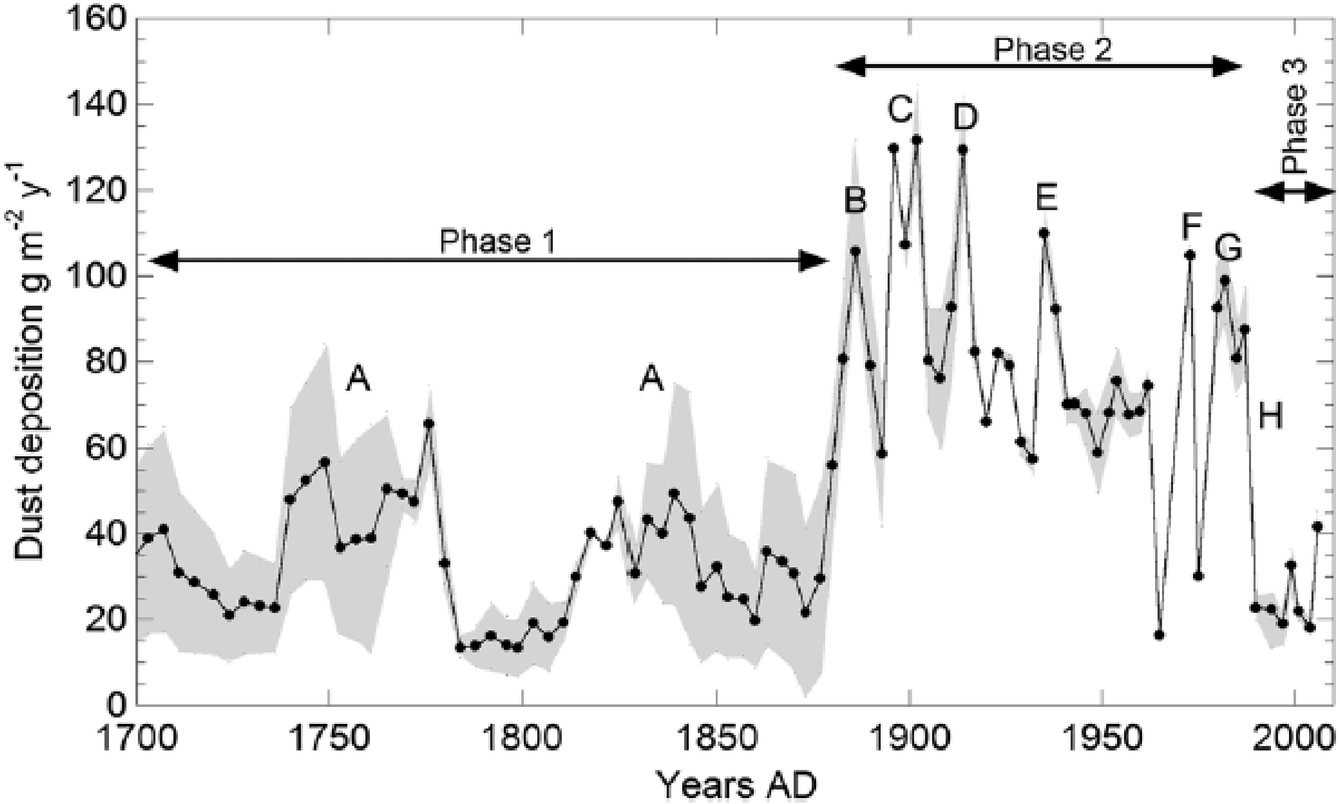


Global soil erosion dynamics

- Older, ploughed agriculture: soil erosion 1-2 orders greater than
- recent, conservation agriculture similar to native and geological
- Indicates global erosion dynamics (phases over time)



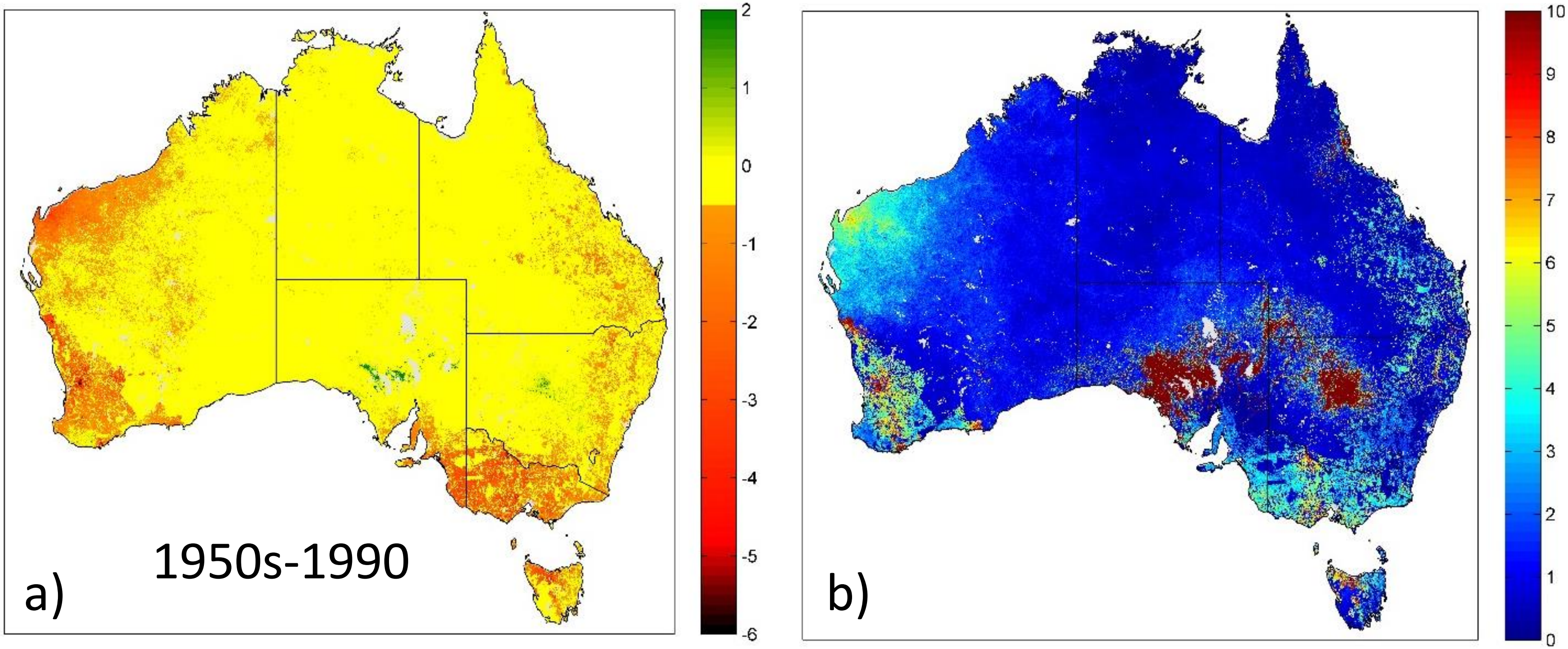
Australian gross soil erosion history?



Three main phases: (1) pre-European 1700–1879, (2) agricultural expansion (**B**) agriculturally-induced wind erosion e.g., MDB 1880–1989, and (3) agricultural stabilization (**H**) 1990 to present.

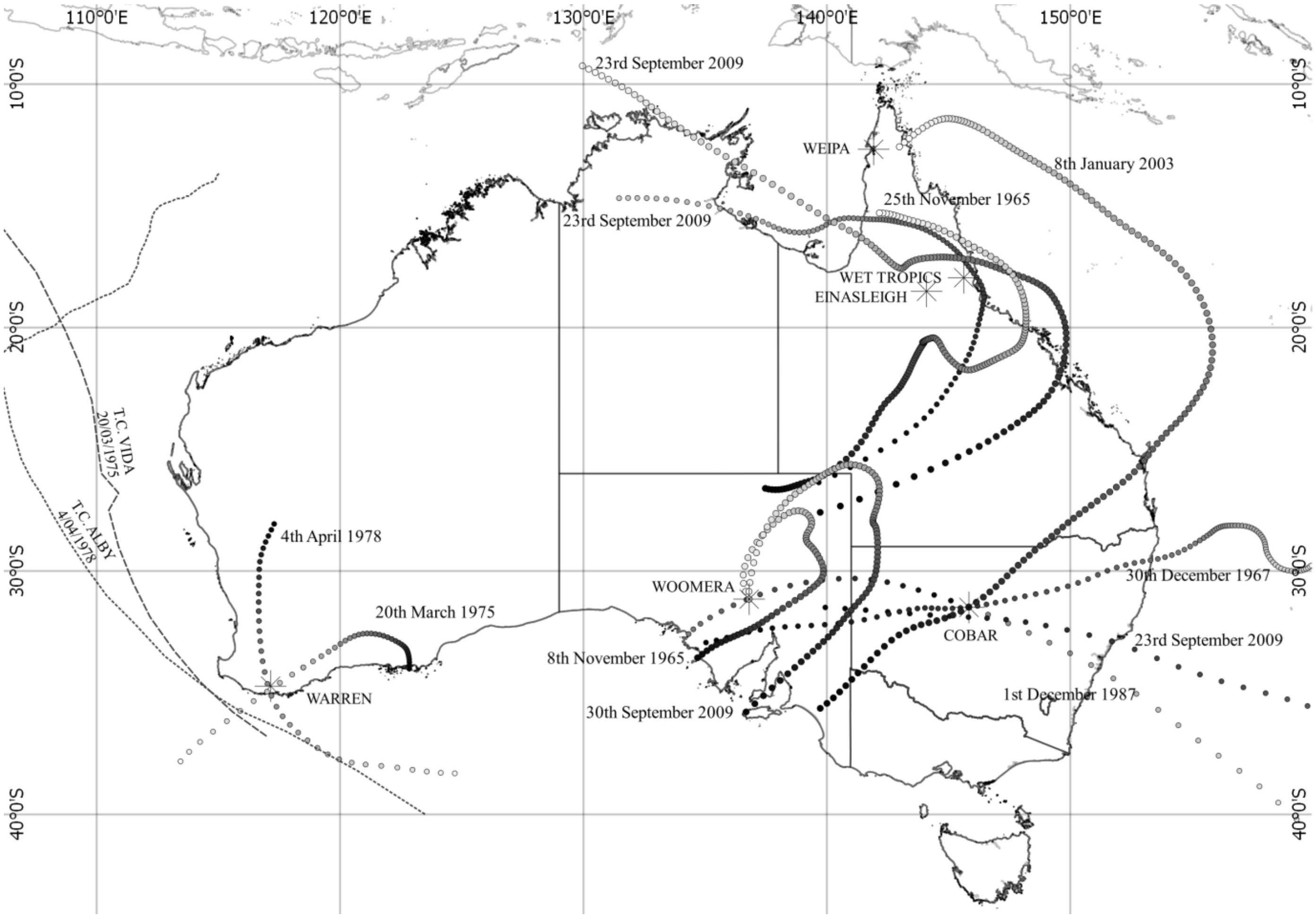
Droughts = Federation (C; 1895–1903), 1911–1915 (D), Dust Bowl era (E), early 1970s (F) and 1980s (G).

NSR under 'ploughed' agriculture

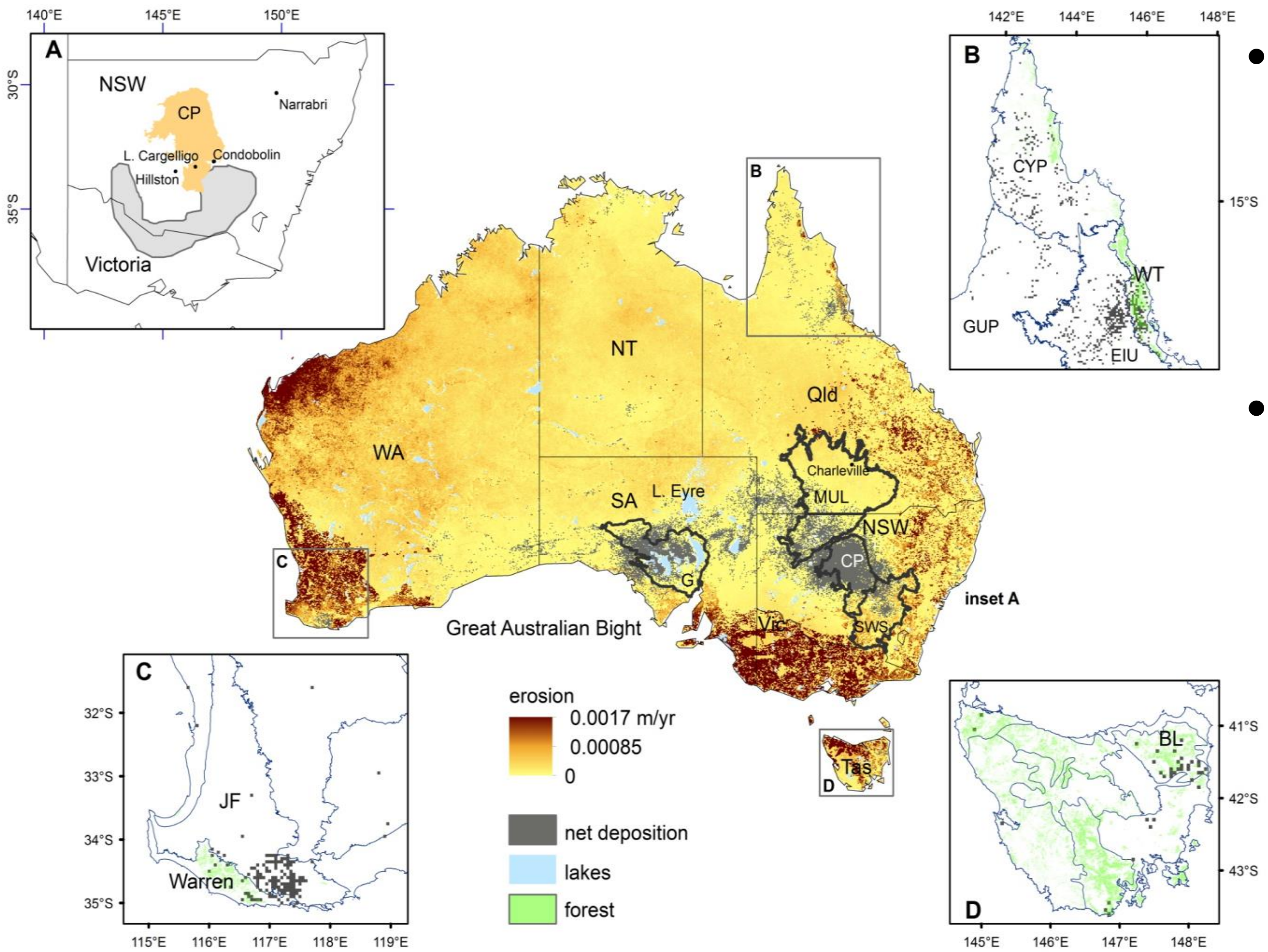


- Nearly five times more soil was lost from cultivated (−4.3 to +0.2 t ha^{-1} yr^{-1}) than from uncultivated (−0.9 to +0.1 t ha^{-1} yr^{-1}) land
- Multiple realisations used to map median (a) and IQR uncertainty (b)

Dust trajectory modelling (>1965)

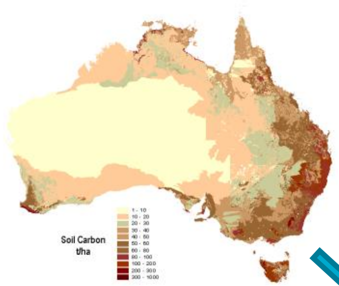


Dust nutrient redistribution

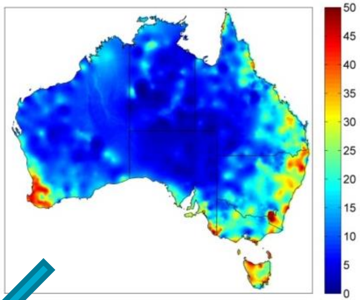


- Dust is a source of nutrients for tropical rainforests growing on ancient weathered soils
- Fluvial and aeolian interaction and biogeochemical cycling between Australia's arid interior and its coastal forests

Soil organic carbon redistribution



Native or recent?



$$C_{eros} = E \times OC_e \times P_e$$

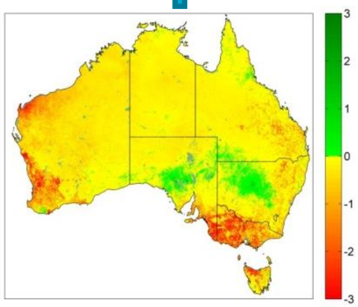
(tC ha^{-1} y^{-1})

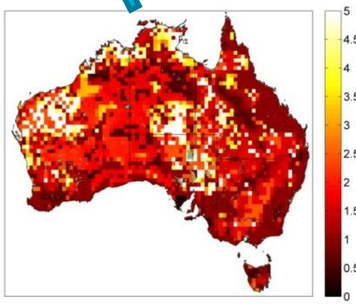
Enrichment:

- Property dependent
- Soil approx. P_e=1.5

Erosion rate dynamics:

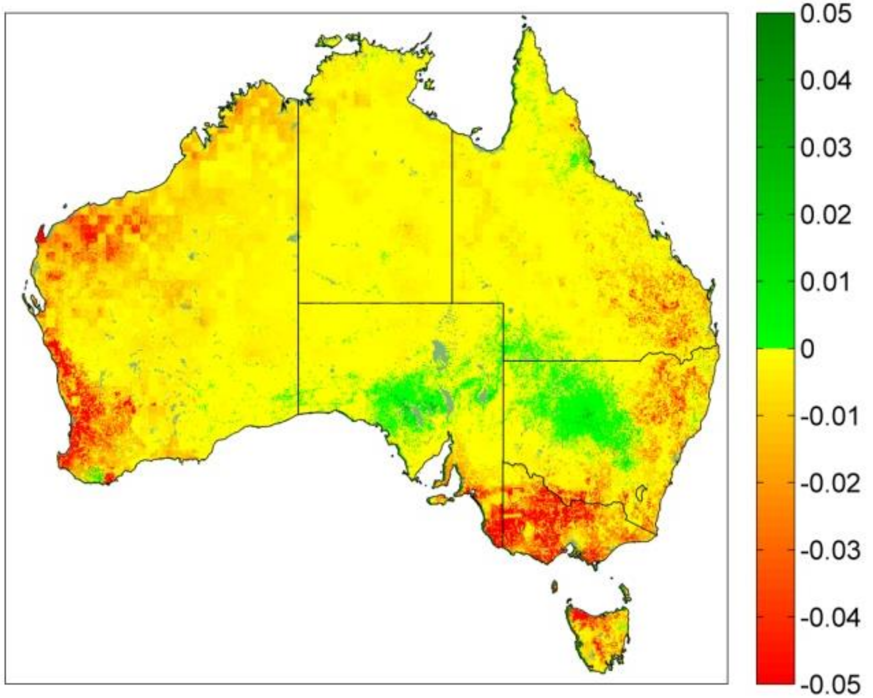
- Pre-European,
- Ag expansion,
- Ag stabilisation?





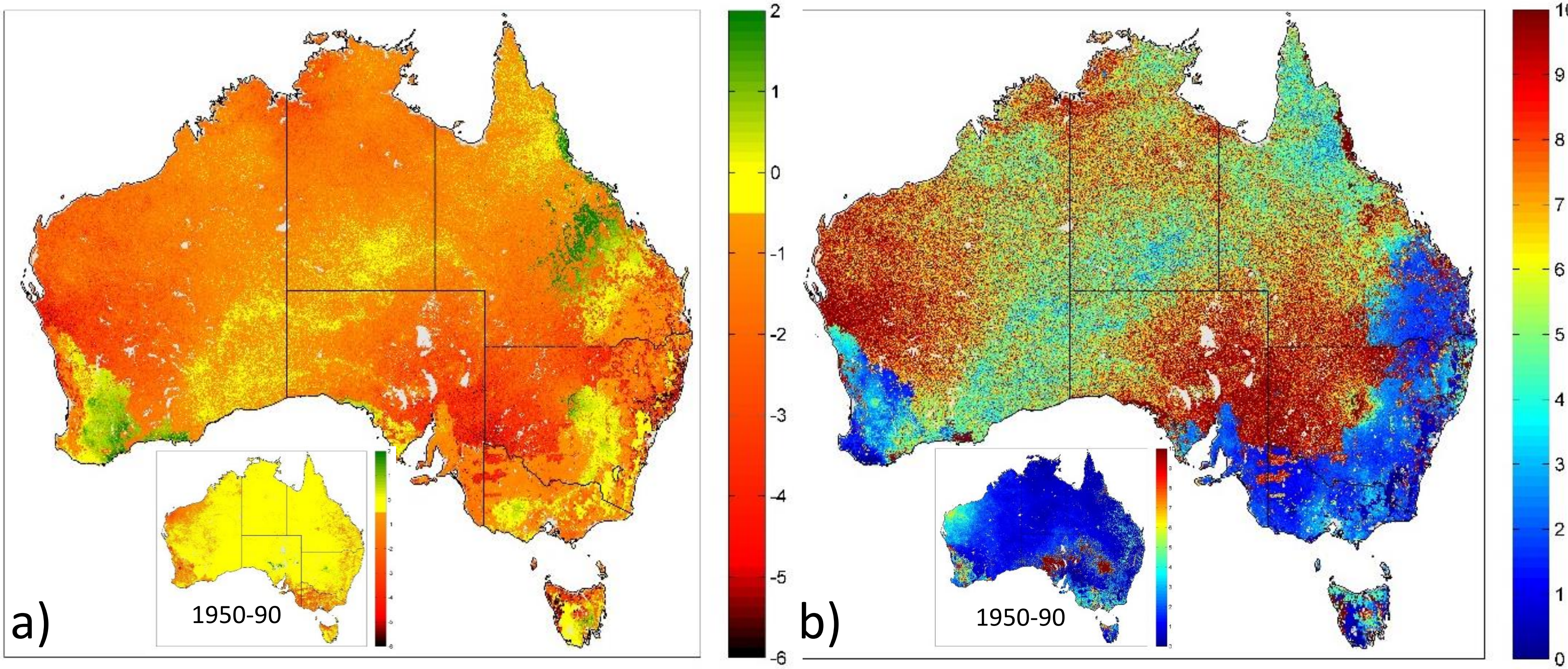
Australian net soil organic carbon redistribution

- Agricultural land
  - Soil erosion -1.5 t ha^{-1} y^{-1} predicts SOC erosion 0.033 tC ha^{-1} y^{-1}
  - Area 53.6 Mha, total SOC erosion 1.8 TgC y^{-1}
- Rangeland
  - Soil erosion -0.2 t ha^{-1} y^{-1} predicts SOC erosion 0.005 tC ha^{-1} y^{-1}
  - Area 666 Mha, total SOC erosion 3.2 TgC y^{-1}
- Australia was net (1950s-1990) eroding
  - Difficult to avoid conclusion that soil erosion is C source



tC ha^{-1} y^{-1}

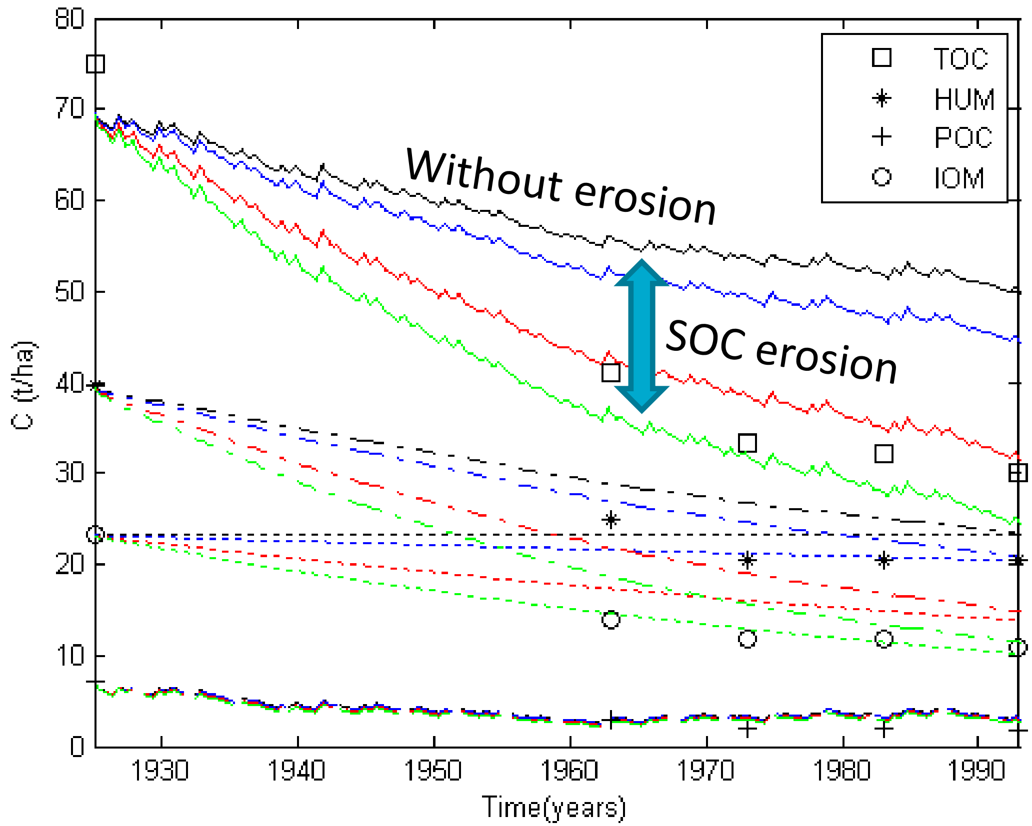
Soil erosion under conservation agriculture



^{137}Cs-derived net (1950s-2010) soil redistribution (t ha^{-1} y^{-1}; a) and its uncertainty (t ha^{-1} y^{-1} ; b) estimated using the 1990 ^{137}Cs reference inventory decayed to 2010 and the 2010 ^{137}Cs sample inventory based on mapped SOC.

Chappell et al. (Unpublished)

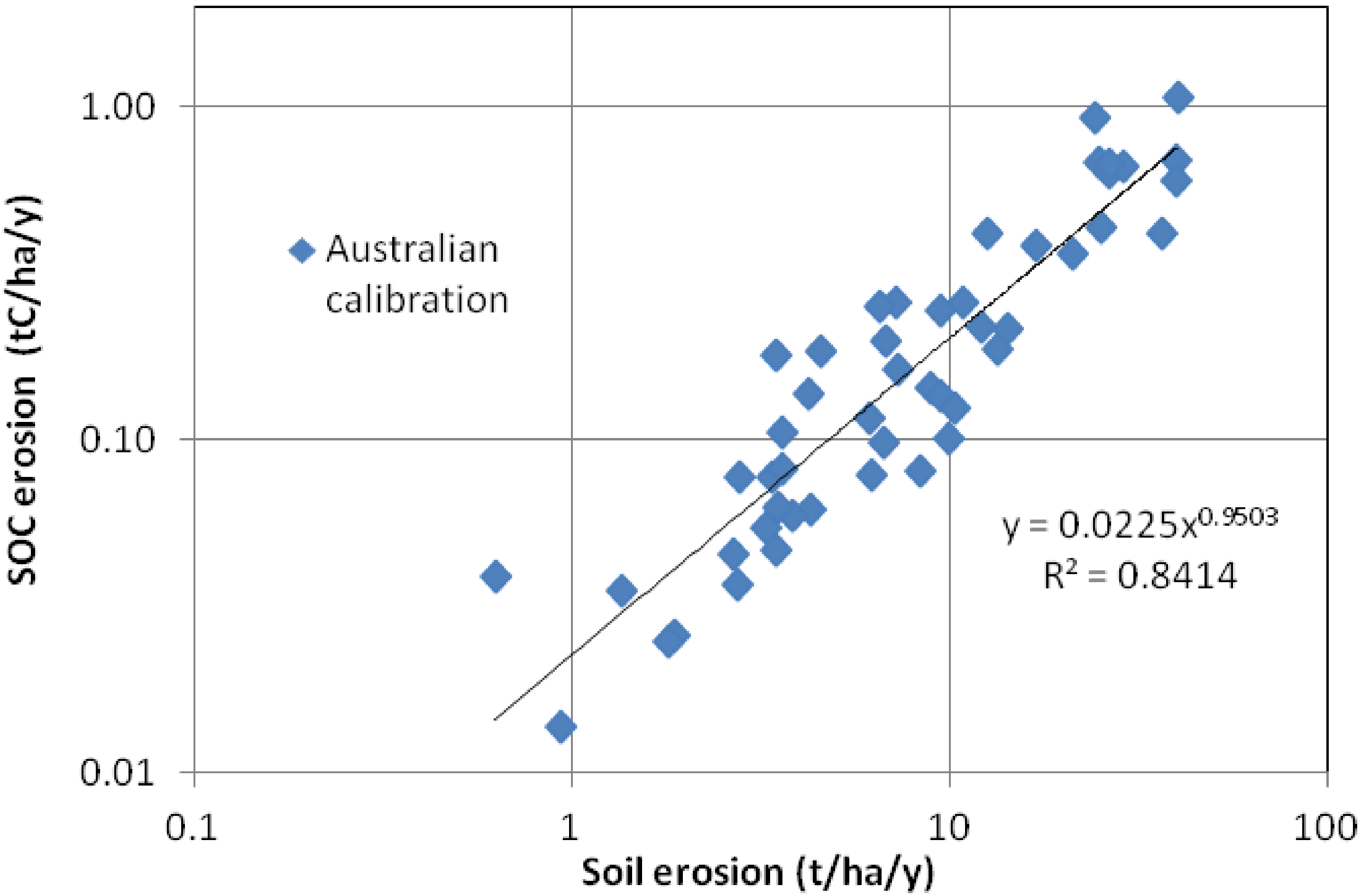
RothC fitted with/out soil erosion



- Represented conceptual pools
- Long-term Waite trial
  - Measured C fractions
  - Measured ^{137}Cs to estimate soil erosion
- With/out soil erosion fitted RothC
  - used established values for Australia
  - to measured SOC using three soil erosion models

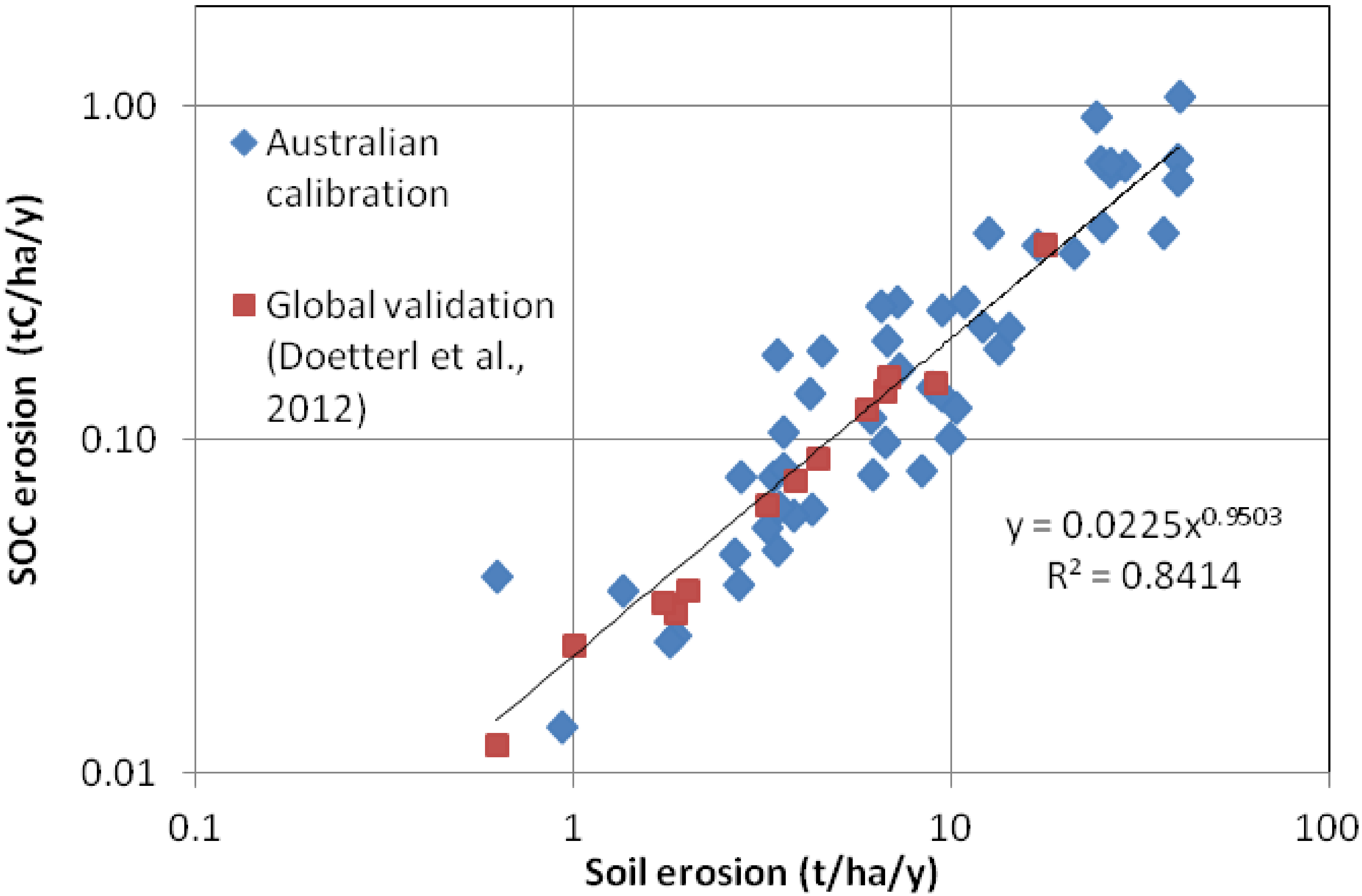
102 trials for 26 different geographical locations in Australia

Australian long-term plot C measurements



102 trials for 26 different geographical locations

Validation with 'catchment' scale



Global SOC erosion by water

	Min – max* water erosion (t ha^{-1} y^{-1})	SOC erosion (tC ha^{-1} y^{-1})	Water eroded area (ha x 10^6)#	Total SOC erosion (TgC y^{-1})	SOC erosion with 20% oxidation (TgC y^{-1})	Terrestrial C flux (PgC y^{-1})+	Difference (%)
Africa	3.7 – 12.9	0.08 – 0.26	1000	78.0 – 255.6	62 – 204	-0.1, -1.9	62.4 – 10.8
Asia	4.3 – 16.6	0.09 – 0.32	1550	138.2 – 503.5	111 – 403	-0.21, -0.49	52.6 – 82.2
S. America	5.7 – 22.1	0.12 – 0.43	510	59.9 – 217.4	48 – 174	-0.18, -1.82	26.6 – 9.6
N. America	4.4 – 12.3	0.09 – 0.24	430	39.7 – 105.0	32 – 84	-0.22, -0.85	14.4 – 9.9
Europe	6.7 – 13.4	0.14 – 0.27	300	41.0 – 79.5	33 – 64	-0.05, -0.45	65.5 – 14.1
Oceania	1.7 –9.5	0.04 – 0.19	460	17.5 – 87.9	14 – 70	0.04, -0.46	35.0 – 15.3
Global	4.1 – 15.2	0.09 – 0.30	4250	369.0 – 1269.6	295 – 1016	-1.67, -3.82	17.7 – 26.6

*Minima and maxima water erosion estimates for these regions were taken from Doetterl et al. (2012) and from Lal's (2003) collation of sediment yield estimates, respectively.
#Estimates of land area affected by water and tillage erosion were taken from Doetterl et al. (2012).
+The terrestrial flux (negative away from land) provided is the range of long-term mean (2000-2010) of the land surface model estimates available from the Global Carbon Atlas. Difference is the mineralised proportion of the eroded SOC relative to the maximum value of the terrestrial flux to provide a conservative estimate.

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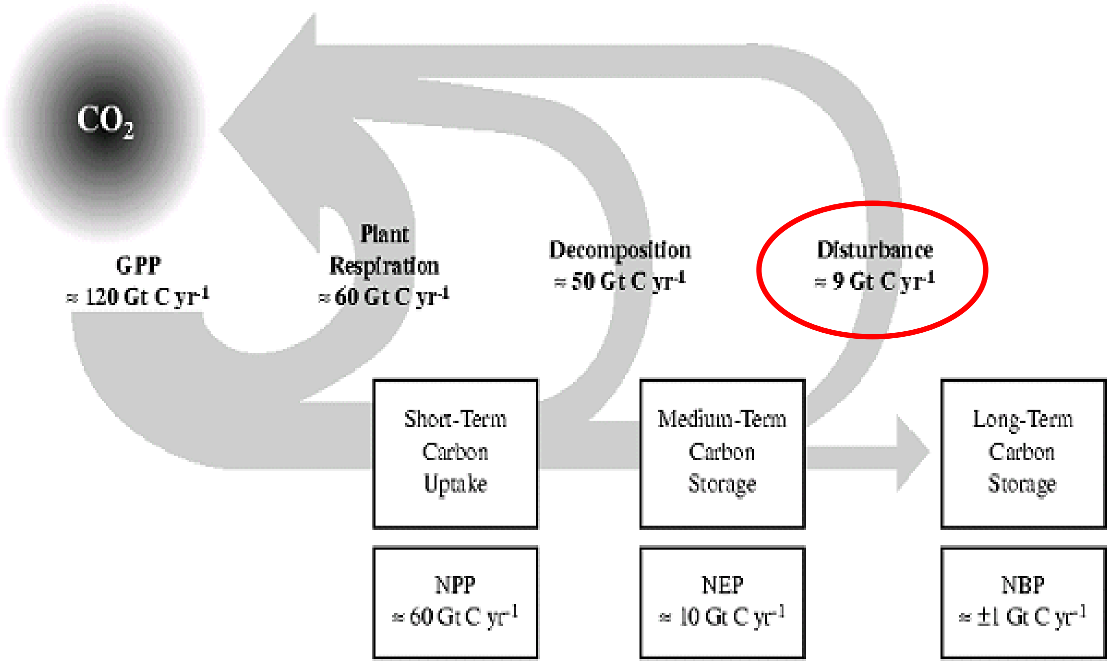
Global significance

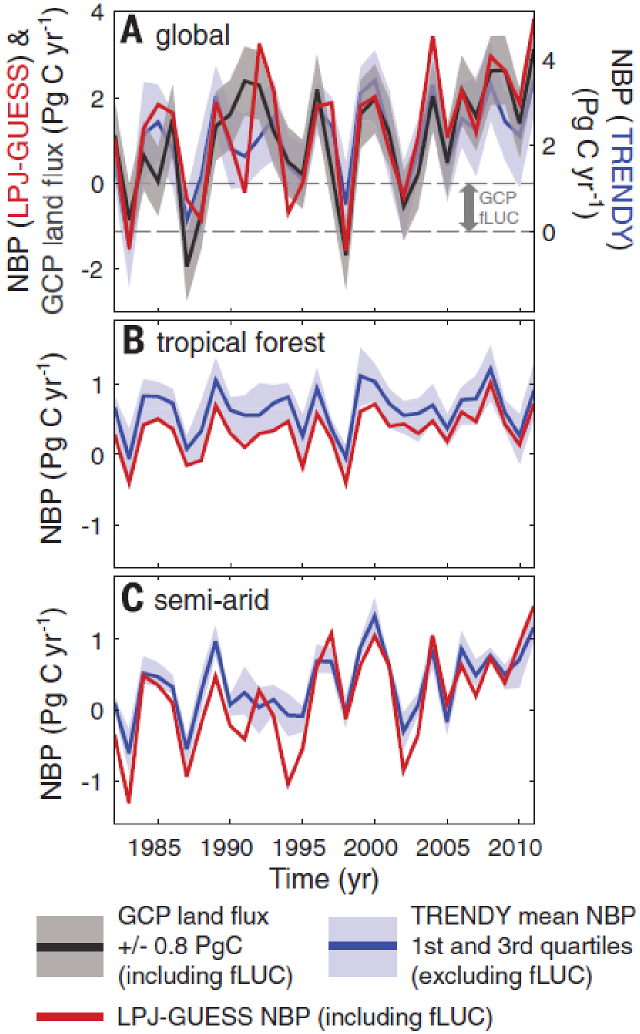
- SOC erosion omitted process (Relative to Global Carbon Atlas, 2012)
  - Globally 0.3-1 PgC y^{-1} (18-27%)
  - Between global regions 0.1-0.4 PgC y^{-1} (+35 to -82%)
  - Dominated by (area) water erosion



- Global direct effect up to 1 Pg C y^{-1} significant for 9 Pg C y^{-1} Disturbance (IPCC)

Misguided interpretations / mitigation?

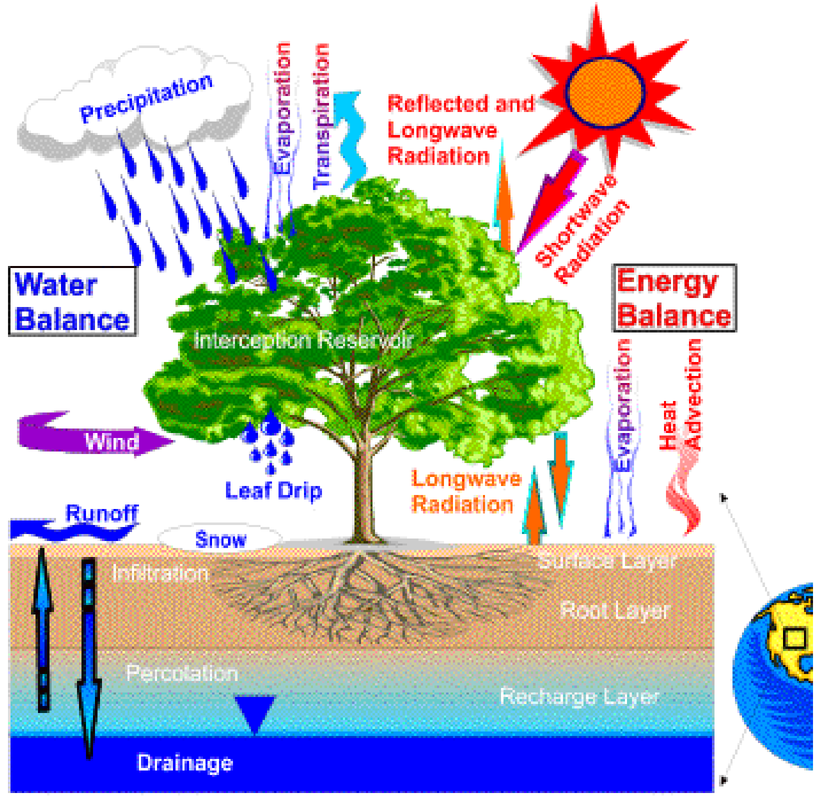
- Misguided interpretations about CO_2 flux
  - Misguided by omission of SOC erosion (up to 1 PgC y^{-1} uncertainty)
- National greenhouse gas inventories
  - Over-estimates net C flux from cropland by up to 40%
- Over-estimated SOC sequestration
  - Total SOC erosion in Australian cropland is estimated at up to 0.17 PgC which suggests that up to 17% of the potential SOC increase may be removed by soil erosion
- Implications
  - Reduce uncertainty in system dynamics by modelling soil erosion
  - Change interpretations (increased uncertainty)?



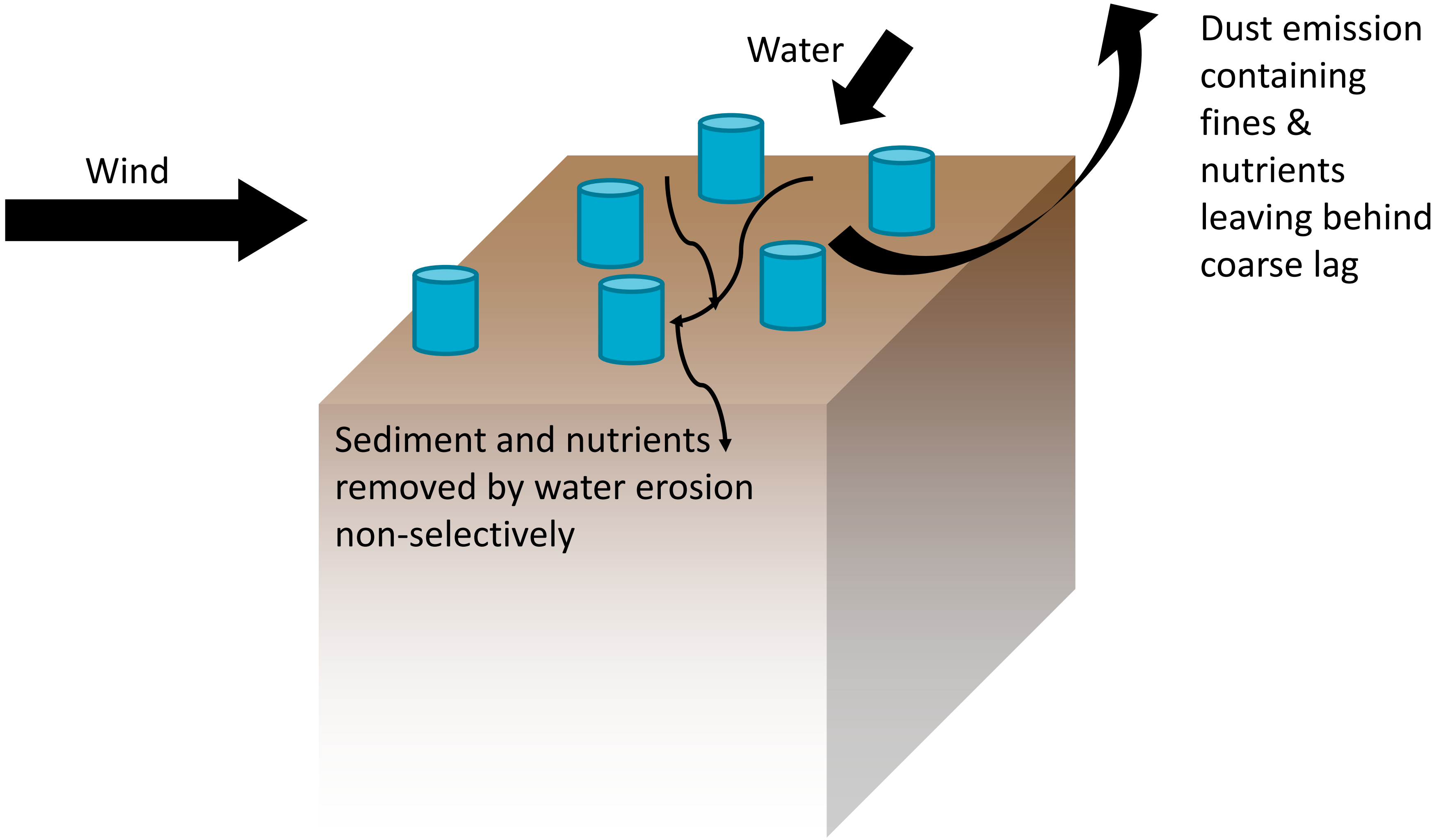
Ahlstrom et al. (2015) Science

Influences of soil redistribution on LSM

- Wind and water drivers of erosion
  - Introduce erosion component and couple dust emission
  - Link erosion (surface lowering) to energy and C / nutrient cycling
  - Develop feedbacks between water and wind erosion
- Erosion dynamics (space and time)
  - Global historical dynamics omitted - clearing native veg increased erosion; reduced ‘conservation’ agriculture.

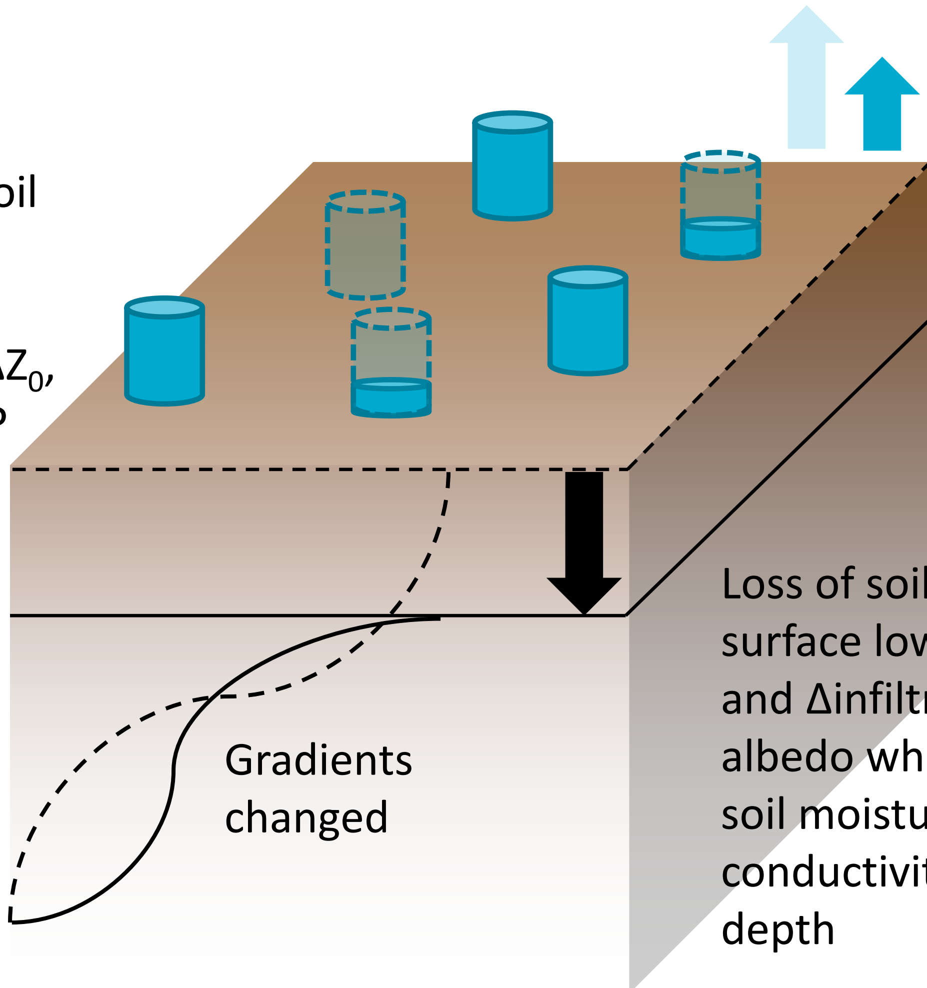


Soil erosion feedbacks in ORCHIDEE



Soil erosion feedbacks in ORCHIDEE

Δsoil moisture and soil fertility Δvegetation structure and composition which ΔZ_0, ΔE_t and ΔE and ΔNPP



Δsoil moisture and temperature (and rooting depth) ΔC decomposition and balance with ΔNPP for ΔCO_2

Loss of soil nutrients and surface lowering Δtexture and Δinfiltration rate, Δsoil albedo which Δgradients of soil moisture and hydraulic conductivity and rooting depth

Opportunities

- New sediment transport by water (driven by rainfall / runoff) = erosion and deposition
- Implementing Yaping Shao's wind erosion – dust emission scheme
  - New drag partition scheme from MODIS albedo to estimate R_t (friction velocity ratio) and driver $U*/U_h$ and improve Z_0 and evapo-transpiration
  - Predict drag partition from intrinsic albedo dynamics (within LSM) for improved prospective dust emission
  - Couple Shao's scheme to LSM (use existing 10 m wind speed U_h)
- Changed soil characteristics at eroded / depositional pixels at different points in time changes biophysical and biogeochemical processes
- Every process of LSM is influenced by soil redistribution; its omission therefore increases uncertainty.

Thank you

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