# SOIL ORGANIC CARBON DUST EMISSION: RECENT AUSTRALIAN COLLABORATIVE RESEARCH

N.P. Webb, A. Chappell, C.L. Strong, H.J. Butler, S.K. Marx, J.F. Leys, G.H. McTainsh, R. Viscarra-Rossel

## Magnitude and mechanisms of SOC enrichment of dust emissions

Soil erosion perturbs the carbon cycle by influencing the distribution of soil organic carbon (SOC) across landscapes and soil carbon emissions. Wind erosion selectively removes SOC from vast land areas and transports it quickly downwind (Fig 1).

We quantified SOC enrichment of dust sampled across Queensland, Australia and evaluated the mechanisms to inform new models of SOC erosion.

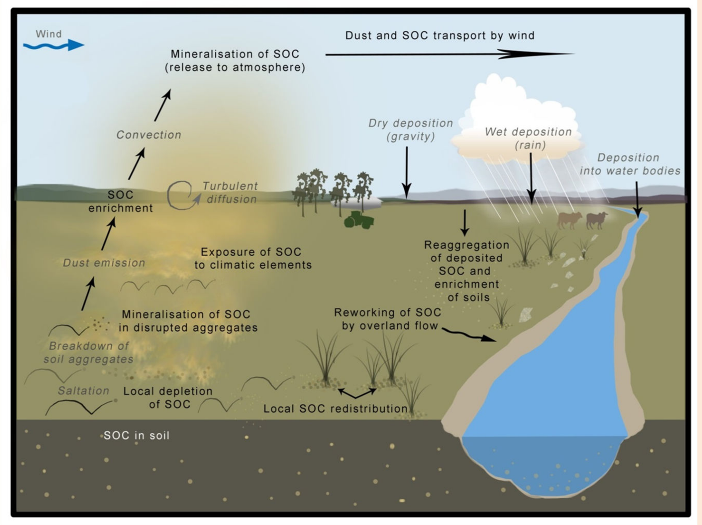

Fig. 1: Illustration of the impact of wind erosion on SOC flux. At eroding sites, soil aggregates containing SOC may be broken and SOC mobilized. Transport can lead to local SOC redistribution, while SOC may also be carried long distances and off-shore.

### Approach and Results

Five study sites were selected in areas representative of the major dust source areas in the Lake Eyre Basin (Fig. 2).

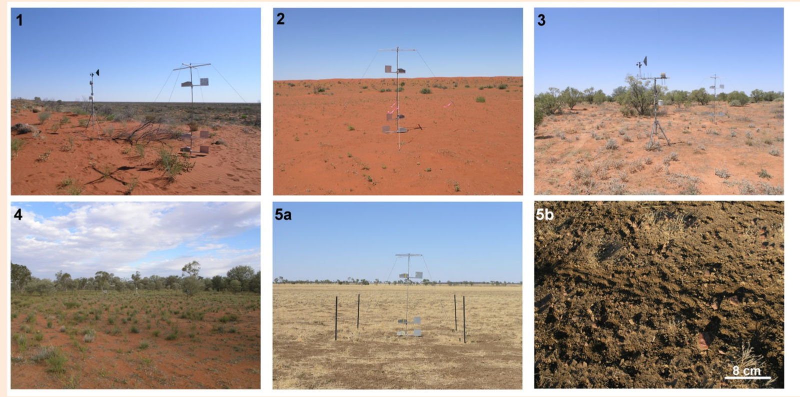

Fig. 2: Study sites in the Simpson Desert, dune crest (1) and inter-dune (2); sand plain bordering an ephemeral lake (3), Mulga woodland (4), and (5a,b) cracking clay soils of the Mitchell grasslands.

BSNE samplers were used to measure sediment flux at a monthly resolution over 3 years (2005-2007). Soil particle size distributions were analysed and the SOC content of local source area soils and sediment samples was measured by loss on ignition. SOC contents were used to calculate ratios of the enrichment of SOC in the dust (Table1).

Table 1: Statistics for soil particle size distributions, mean %SOC in soil and dust, and mean enrichment ratios (En).

| Site | Soil Particle Size | | | | Soil %SOC | Dust %SOC | Mean En. Ratio |
|---|---|---|---|---|---|---|---|
| | Median | Mode | d10 | d90 | | | |
| Site 1 | 240.35 | 250.19 | 159.74 | 306.27 | 0.12 | 0.85 | 7.09 |
| Site 2 | 131.20 | 572.91 | 65.70 | 316.72 | 0.32 | 0.97 | 3.02 |
| Site 3 | 231.22 | 265.23 | 73.64 | 410.19 | 0.54 | 1.96 | 3.63 |
| Site 4 | 190.62 | 259.90 | 56.38 | 376.91 | 0.93 | 4.47 | 4.81 |
| Site 5 | 27.35 | 184.19 | 2.88 | 176.57 | 4.23 | 7.06 | 1.67 |

### SOC enrichment characteristics

Larger SOC enrichment of dust was found to be associated with a large sand content and small SOC content of source area soils.

Sandy, particulate and quartz dominated (i.e. large particle densities) soils, are more efficient at releasing SOC and produce larger SOC En. than aggregated, clay-rich soils.

Results suggest large spatial variability in soil erodibility and SOC En. will determine patterns of SOC dust emission (Fig. 3).

## Australian SOC dust emission and the carbon budget

The contribution of wind erosion to rates of carbon release and sequestration is poorly understood. Here we quantified spatial patterns of SOC dust emissions from Australia and evaluated the potential significance of wind erosion for national carbon accounting.

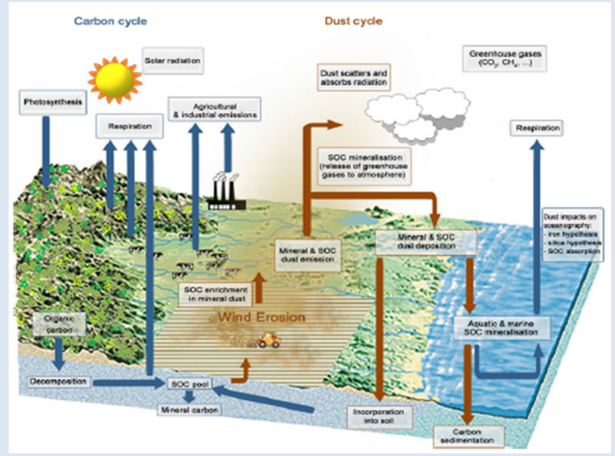

Figure 4: Illustration of key components of the national carbon budget, including wind erosion.

### Approach and Results

We developed a physically-based approximation of SOC enrichment to estimate SOC emissions with the Computational Environmental Management System (CEMSYS) national dust emission model (Fig 5).

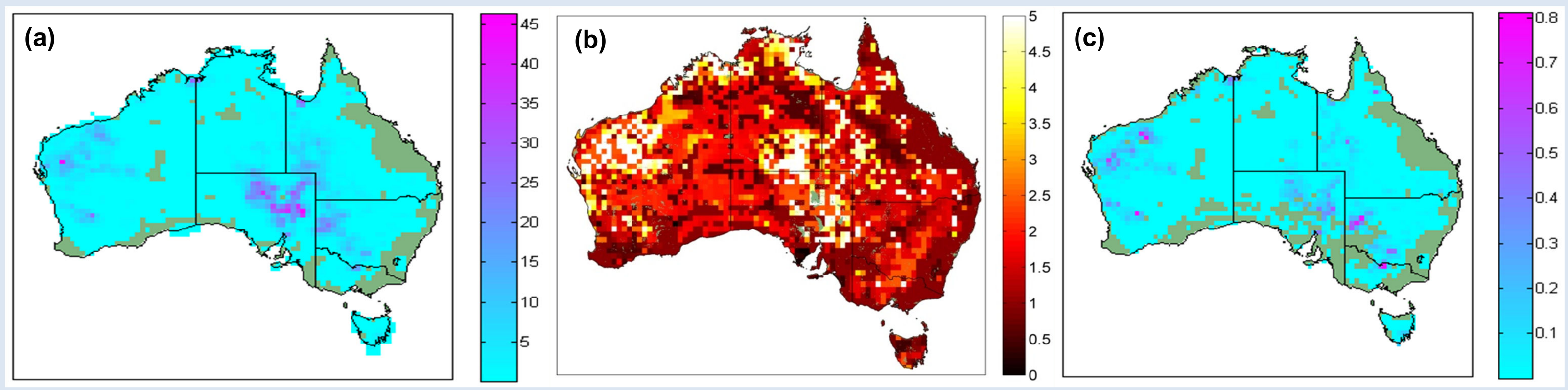

Figure 5: Maps showing the spatial distribution of (a) mean annual mineral dust emission (g $m^{-2}$ $yr^{-1}$); (b) modelled mean SOC enrichment factor for SOC dust <22 µm, capable of long-range transport off the Australian continent; and (c) mean annual soil organic carbon dust emission (g SOC $m^{-2}$ $yr^{-1}$). Maps show the mean annual emissions for the period 2000-2011.

We ran CEMSYS at a 50 km spatial resolution to calculate total monthly dust and SOC emissions for 2000–2011. We then evaluated the SOC emissions by land use to quantify sectoral contributions to existing components of the national carbon accounting system. The mean total mineral dust emission for Australia is 148 Tg $yr^{-1}$. The mean total SOC dust emission is estimated to be 1.59 Tg SOC $yr^{-1}$ (Table 2).

Table 2: Mineral and soil organic carbon dust emissions (<22 µm) by land use class for Australia (2000-2011).

| Land Use | Mean mineral dust flux (g $m^{-2}$ $y^{-1}$) | Mean SOC enrichment ratio | Mean SOC dust flux (g SOC $m^{-2}$ $yr^{-1}$) | Total SOC dust emission (Tg SOC $y^{-1}$) |
|---|---|---|---|---|
| Rangeland | 35.96 | 2.48 | 0.46 | 1.34 |
| Agriculture | 19.10 | 1.92 | 0.50 | 0.11 |
| Australia | 35.20 | 2.44 | 0.48 | 1.59 |

### SOC dust emission and the carbon budget

SOC dust emission is greatest in agricultural areas where soils are regularly disturbed.

The removal of SOC from vast rangeland soils produces the single largest source of SOC dust, from an area which has small SOC content and is highly sensitive to SOC change.

Assuming SOC dust emissions (<22 µm) are transported offshore, wind erosion of Australian SOC may result in a loss of ~5.83 Tg $CO_2$-equivalents $yr^{-1}$ and ~5% of the annual $CO_2$ emissions from the Australian rangelands.

## Australian net (1950s-1990) SOC erosion: an omitted $CO_2$ source

We used 'catchment' scale (~25 $km^2$) estimates of $^{137}$Cs-derived **net** (1950s-1990) soil redistribution of all processes (wind, water and tillage) (Fig. 6) to calculate the soil organic carbon (SOC) net redistribution across Australia. We included the selective removal of SOC at net eroding locations and SOC enrichment of transported sediment and net depositional locations, informed by national wind erosion modelling (Fig. 5).

### Approach and Results

The physically-based model of SOC enrichment by wind was applied to account for soil redistribution by all processes. The arising pattern (Fig. 5b) is complicated by the highly variable soil types and textures.

Nearly five times more soil was lost (1950s-1990) from cultivated regions than from the mainly uncultivated rangeland interior of Australia (Table 3).

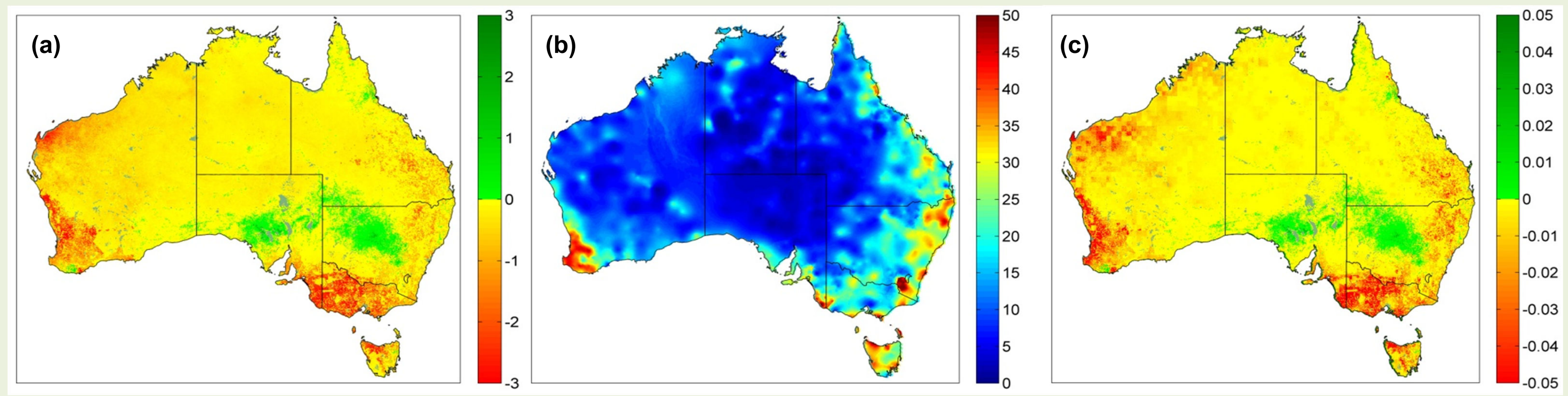

Figure 6: Maps of Australia for (a) $^{137}$Cs-derived median net (1950s-1990) soil redistribution (t soil $ha^{-1}$ $yr^{-1}$). Positive values represent sites of net gain, while negative values are those of net loss; (b) soil organic carbon (SOC) stocks (t $ha^{-1}$; 0-10 cm); and (c) net (1950s-1990) SOC redistribution (t soil $ha^{-1}$ $yr^{-1}$).

On average approximately 2% of the SOC stock (0-10cm) was removed from the Australian land surface by soil erosion over this ~40 year period.

Table 3: Net (1950s-1990) SOC redistribution and its proportion for land use classes across Australia.

| Land Use | Mean SOC (%) | Mean En. Ratio | Mean net soil redistribution (t soil $ha^{-1}$ $y^{-1}$) | Total net SOC redistribution (tC $y^{-1}$ x $10^6$) |
|---|---|---|---|---|
| Rangeland | 0.74 | 1.99 | -0.217 | -2.189 |
| Agriculture | 1.64 | 1.39 | -1.480 | -1.821 |
| Australia | 0.81 | 1.95 | -0.313 | -4.057 |

### Omission of Australian $CO_2$ source

Our estimated total SOC net redistribution for Australia is -4.06 Tg SOC $y^{-1}$.

Assuming this material is mineralised during transport, the net redistribution for Australia amounts to a loss of 14.87 Tg $CO_2$-equivalents $yr^{-1}$ from the terrestrial ecosystem.

.

Soil erosion amounts to 12% of the $CO_2$-equivalent emissions from all carbon pools in Australia (115-126 Tg $CO_2$-e). Until net soil erosion is included in the national carbon account, the impact of soil redistribution will remain a significant source of uncertainty.

Related publications:
1) Webb et al. 2012. Global Change Biology. doi:10.1111/j.1365-2486.2012.02780.x
2) Webb et al. 2013. Earth Surface Processes and Landforms. doi:10.1002/esp.3404
3) Chappell et al. 2013. Global Change Biology. doi:10.1111/gcb.12305
4) Chappell et al. 2014. Biogeosciences Discussions. doi:10.5194/bgd-11-6793-2014

contact: Nicholas Webb, USDA
phone: +1 575-646-3584
email: nwebb@nmsu.edu
web: http://jornada.nmsu.edu