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The incidence of wind erosion as related to soil properties and geomorphic history in south-western Australia

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Introduction

Wind erosion is a major form of land degradation in the dryland farming systems of south-western Australia, with severe erosion events recurring every few years (Select Committee into Land Conservation 1990).

The relationships between soil properties and wind erosion have been poorly developed in this region. Moreover, there is little soil survey information at scales suitable for farm management to allow the extension of wind erosion models at the farm scale. If, however, relationships can be deduced between wind erosion and soil properties or geomorphological features, those attributes, and hence wind erosion hazard, can be identified and mapped by landholders or consultants. Appropriate management systems can then be devised for soils according to their susceptibility to erosion, rather than by applying uniform management procedures across all soils.

The most extreme episodes of wind erosion since land development occurred near Jerramungup, Western Australia, in 1980 and 1981 with the extent estimated by a Landsat MSS remote sensing analysis (Carter and Houghton 1984). In that study, soil and geomorphological information was unavailable, this preventing an understanding of the relationships between these attributes and the incidence of wind erosion. A detailed soil and geomorphological survey has since been undertaken and estimates made of the rates of wind erosion using the ^{137}Cs technique (Harper and Gilkes 1994). In this paper we assess the relationships between the incidence of wind erosion, soil properties and geomorphic history.

Methods

This study was undertaken in an area of 5 200 ha adjacent to Lake Cairlocup, 400 km south–east of Perth, Western Australia. The annual rainfall of 350 mm, is mostly received in winter. Farms were developed from mallee (*Eucalyptus* spp.) woodland in the period 1964-74, and farming involves annual rotations of cereal or legume crops with pasture.

A general-purpose soil survey, using the free survey technique, was undertaken at a scale of 1:12 500. Approximately one site was examined every three hectares, with the sampling intensity varying over the study area. Six geomorphic surfaces, based upon geomorphic process and parent materials, were identified, with these comprised of 21 major soils (Fig. 1). These surfaces can be considered in terms of the following three groups:

1. Deeply weathered granitic ridges and slopes: Two geomorphic surfaces were defined in deeply weathered granitic terrain, based on the degree of landscape dissection. Unit UDL occurs where landscape dissection has been minimal. Sandy surfaced, texture contrast soils occur within these areas (Petroferric yellow Sodosols, Eutrophic yellow Kandosols, Ferric hypernatric grey Sodosols (Isbell 1996); Plinthoxeralfs, Natrixeralfs (Soil Survey Staff 1994)).

Unit PDL occurs where the pallid zone, a deeper horizon of the former lateritic profile has been exposed. Sandy surfaced texture contrast soils also occur within these areas (Calcic yellow Sodosols, Natrixeralfs), often containing calcrete nodules or concretions.

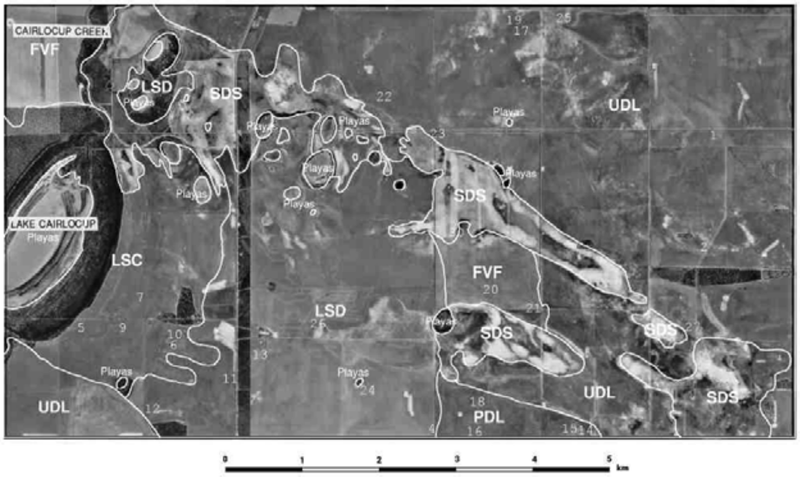

Fig. 1**. Aerial photograph with overlay showing the major geomorphic units.**

2. Valley floor: The valley floors are poorly drained and comprise sequences of Quaternary sediments dominated by Lake Cairlocup, a 200 ha hypersaline playa. This is bounded by a series of source bordering lunettes (clay or parna dunes) that extend 5 km to the southeast (Harper 1994). The lunettes and associated swales have been separated into two geomorphic surfaces — those comprised of loamy soils (Hypernatric grey sodosol, Regolithic calcic Calcarosols; Xerochrepts), which occur immediately adjacent (0-2 km) to Lake Cairlocup (Unit LSC), and those with sandy texture contrast soil profiles (Mesonatric brown Sodosols, Natrixeralfs), some distance (2-5 km) from Lake Cairlocup (Unit LSD). A third small geomorphic surface (Unit FVF) was defined for those areas of the valley floor, without playas or lunettes. This contained texture contrast soils with carbonate nodules at depth (Calcic yellow Sodosols, Natrixeralfs)

3. Sandy aeolian deposits: Unit SDS occurs as a discontinuous, NW-SE oriented, strip ~10 km long and 2 km wide, directly southeast of the ephemeral Cairlocup Creek. Quartzose sands, generally >100 cm deep (Mesonatric grey Sodosols, Typic Quartzipsamments) overlie a range of substrates and landscape positions. This feature represents former quartzose aeolian deposits, derived from the drainage line during former arid periods.

Samples were taken from each of the 21 major soils. Each of the 219 samples comprised 20–30 cores taken from a depth of 0-10 cm. For 133 soils with a sandy E horizon paired samples were taken from 0-10 and 10-20 cm.

A Landsat MSS analysis was used to interpret wind erosion patterns in 1980 and 1981 (Carter and Houghton 1984). This classification was superimposed onto the field mapping polygons, using ArcView, with sampling sites classified as eroded or non-eroded on the basis of this classification. Two categories were derived – those areas eroded in either year, to give a maximum extent of erosion and those areas eroded in both years, this category indicating areas most prone to erosion.

Results and Discussion

Severe wind erosion affected 1385 ha or 27% of the arable soils in the study area in 1980 or 1981, or 474 ha (9%) in both years. As a first order approximation, this resulted in a loss of soil carbon of around 4,900 t C from a total of 90,000 t in the top 20 cm. Although this carbon has been lost from the farms, it is not certain if it can be considered a net carbon emission as it may have been deposited elsewhere.

The incidence of erosion was estimated from the proportion of the different mapping units eroded across the study area. Despite strong evidence in this landscape of relict aeolian activity, the incidence of contemporary wind erosion was only partly related to past geomorphological processes (Fig 2a). Quartzose dune sands (Surface SDS) were particularly susceptible to erosion (47% eroded in either year, 18% in both years), whereas texture contrast soils formed on clayey, wind-formed lunettes (Surface LSD) were variably eroded (16%, 5%). Similarly, soils formed on deeply weathered regolith (Surface UDL) were also variably eroded (34%, 11%). Soils formed on stripped laterite (Surface PDL) and on loamy lunettes and swales close to playas (Surface LSC) were not affected by erosion. There were marked differences in the amounts of erosion within each geomorphic surface (Fig. 2b). Within Surface UDL the proportion of erosion ranged between 31 and 55% for different soils in either year (6-16% in both), in Surface LSD 0-41% (0-18%) and Surface SDS 25-75% (9-32%), with the most erodible soils being old dune systems. Overall, the incidence of erosion tended to be greatest on sandy surfaced soils and those with sand horizons deeper than 60 cm.

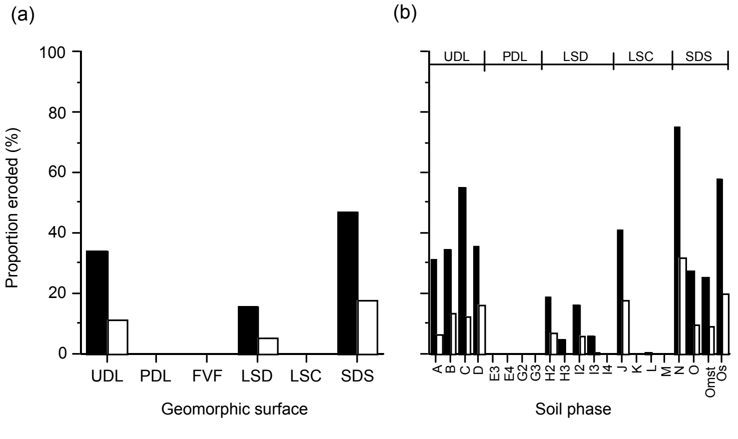

Fig. 2 Proportion (%) of mapping units wind eroded in either (■), or both (□) years for (a) geomorphic surfaces and (b) soils.

The risk of wind erosion was better predicted from surface soil properties, such as clay and silt contents and sand horizon depth. The contemporary particle size properties of the surface horizon of the soils may as much reflect the results of erosion, as the intrinsic properties of the soil. Therefore, samples from 10-20 cm depth were used as a diagnostic horizon as this is below the depth of cultivation in this area (mean depth 9.2 cm).

The incidence of erosion was compared for classes based on 1% increments of clay content derived from the 10-20 cm deep sample, for two surface horizon depth classes (shallow <60 cm and deep >60 cm) (Fig. 3a). Two major trends are apparent. The first is the systematic decline in the proportion of samples that were wind eroded with increasing clay contents and the marked difference in erodibility between soils with shallow and deep sandy horizons. The proportion of sites eroded thus decreased from 45% for the 1-2% clay class to 16% for the 4-5% clay class. No site with >5% clay was eroded. There is thus a large range of wind erosion within soils that are considered as "sands", with small differences in clay content having marked effects on erodibility. A similar trend is apparent with declining erosion with declining contents of silt, in this case erosion is confined to soils with <3% silt.
Wind erodibility is explained in terms of the strength of the soils, which is in turn related to clay content, and amount of plant cover (related to fertility and water storage). The soils that are most erodible have been pre-sorted by wind or water. Assessment criteria commonly used in field surveys, such as field texture and consistence, can indicate the likely risk of wind erosion, however these are less predictive that methods based on soil analysis.

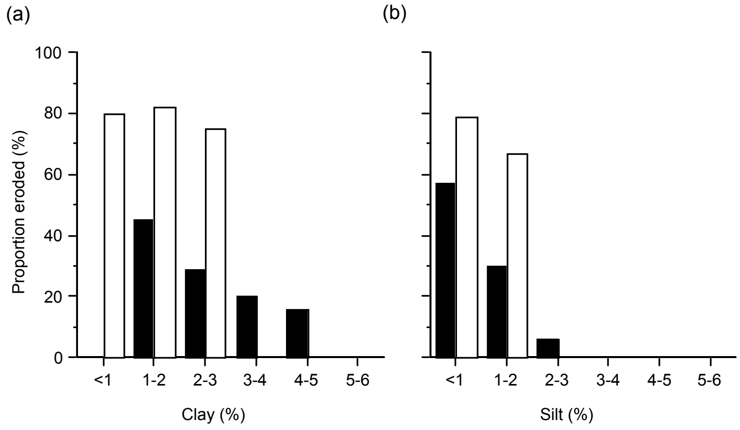

Fig. 3 Proportion of sandy texture contrast soils eroded by wind for different classes based on physical analysis of the 10-20 cm layer. Soils with shallow (<60 cm) (☐) and deep (>60 cm) (■) sandy surface horizons. (a) Clay (%), (b) silt content (%). n = 134.

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