than for other methods. There is a clear advantage in using both methods involving combinations of kriging with regression on those variables which have low correlation with the geomorphic attributes: RMSEs for all the soil variables are much lower than those resulting from multi-linear regression (with the exception of topsoil gravel), ordinary kriging, universal kriging or cokriging.

A notable advantage of multi-linear regression models, each of which requires p+2 parameters to be estimated (p being the number of predictor variables to be used), is that there are fewer or equal number of parameters to be estimated in comparison with other methods excepting ordinary kriging. In a cokriging example, if m is the number of random variables, then 3 x parameters are required. Thus four random variables used in cokriging of the topsoil gravel required 3 parameters (nugget, sill and range) from each of the =10 semivariograms (including cross-variograms), meaning a total of 30 parameters. Based on the topsoil gravel, only 3 parameters are required for ordinary kriging, 6 for universal kriging based on REML, 9 for regression-kriging model A, 12 for regression-kriging model B and 6 for multi-linear regression. A drawback of the multi-linear regression method is that it cannot be used for undersampled situation where those points that need to be predicted have no observation of any of the predictor variables (ie., where nothing has been measured or observed).

Regression-kriging model B may be considered as a special case of GLM-kriging where GLM is a generalised linear model and in that context is similar to Voltz and Webster's (1990) approach in which the GLM is a one-way analysis of variance model. The regression-kriging model B is inconsistent in that it assumes, for estimating the GLM, that the predicted values and the residuals are uncorrelated but subsequently uses the correlation to improve the prediction. The relative sensitivity of the two components is unknown. Further information regarding these methods may be found in Odeh et al. (1993). From a statistical point of view a generalised linear spatial model needs to be developed.

In applying the prediction methods in the wider sense, the cost-benefit performance may determine the best method, ie., whether an increase in precision (of prediction) is more than compensated by the cost of analysis (computing charge and time) and additional sampling. For example, if, as in our study here, we want to spatially predict the topsoil gravel where the DEM (used to derive the geomorphic attributes) at high intensity is readily obtained at reasonable cost, multi-linear regression of the gravel content with the attributes could be used in preference to other methods. However, if increase in precision in predicting topsoil gravel is less than compensated by increased cost of obtaining the DEM at a higher density, kriging methods that take advantage of spatial correlation (eg. cokriging or regression-kriging model B) may be preferable to multi-linear regression. Each case should be examined carefully before deciding on the best method.

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SOILS AND GEOMORPHOLOGY OF THE CAIRLOCUP AREA, WESTERN AUSTRALIA, AND RELATIONSHIPS WITH CONTEMPORARY WIND EROSION - Richard Harper

Introduction

Many farms have been developed in the semi-arid areas of south-western Western Australia in the last 30-40 years, and various forms of contemporary land degradation are now evident. Consequently I attempted to relate the distribution of this land degradation, and particularly wind erosion, to the distribution and properties of the soils in an area with a history recurrent severe wind erosion [1]. A study area of 5 000 ha, near Cairlocup 400 km south-east of Perth, was selected as being representative of the wider area, and the soils and

1. Under the supervision of Assoc. Prof. Bob Gilkes, with many discussions with Dr Maurice Mulcahy. Their help, and funding from the (then) WA Grain Legumes Research Committee and Barley Research Committees is much appreciated.

geomorphology mapped at a scale of 1:12 500. Although salinity is a major problem in Western Australia, it was not considered in this study.

The landscape of much of inland Western Australia, is comprised of broad trunk valleys, containing playas and lunette sequences, bounded by uplands dominated by deeply weathered ("laterite") profiles derived from basement granitic rocks (McArthur 1991). Soil distribution is strongly controlled by geomorphology (Mulcahy 1960, Bettenay and Hingston 1964, Churchward 1970). Consequently it was considered that understanding the geomorphology and moreover the dominant geomorphic processes of the study area would provide clues as to the distribution of soil parent materials, the properties of contemporary soils and therefore the distribution of contemporary land degradation. As elsewhere, the dominant soil-geomorphic model in this region stresses the water-borne re-distribution of materials in the landscape (Mulcahy 1960), although this water borne model was consequently modified (Bettenay 1962, Bettenay and Hingston 1964) to incorporate aeolian processes, such as deposition of parna downwind of playas.

Aeolian influences on the distribution and properties of soils

There is strong evidence of an aeolian influence on the nature and distribution of soils in the study area. Clayey lunettes occur as concentric sequences up to 5 km from the present playa shores, whereas linear quartzose dunes occur in a discrete, 2 km wide strip which extends 10 km to the south-east of an ephemeral creek line. Together with elliptically shaped playas these features suggest that the geomorphologically most active winds have been from the north-west.

Other features suggest that the aeolian influence may be more extensive in the landscape:

- Deep sandy soils are often more extensive on slopes with south-easterly as compared to north-westerly aspects. This pattern occurs in areas with quite distinct geology (lunettes and lateritised ridges) and it is thought that these features are shadow dunes formed on the lee side of ridges, due to the effects of topography on wind flow and hence sand transport
- Duplex soils with alkaline B horizons overly acidic subsoils, and ferricretes in upland areas are often cemented by calcretes. It is suggested that this is due to the accession of aeolian dust. Discrete layers of parna are not apparent and it appears the imprint of aeolian dusts has been more subtle.

This aeolian influence, from both saltation and suspension transport, means that the application of catenary soil-landscape models may result in errors in predicting the soil pattern. As a similar catenary assumption is made in recent approaches which have predicted the distribution of soil attributes using terrain

Association	n	Clay (%)	OC	pH	EC (dS m^{-1})
Sand Dunes and Sheets (SDS)	24	1.2	0.46	6.0	0.03
Undissected Laterites (UDL)	59	2.6	0.72	5.8	0.05
Partially Dissected Laterites (PDL)	20	6.0	1.30	6.0	0.11
Lunettes and Swales - Distant (LSD)	73	3.0	0.72	6.0	0.09
Lunettes and Swales - Close (LSC)	42	22.1	2.20	8.0	0.30

Table 1. Major attributes of Ap (0-10 cm) horizons of soils within Soil Associations

Association	n	Proportion of class eroded in 1980 or 1981 (%)
Sand Dunes and Sheets (SDS)	24	80
Undissected Laterites (UDL)	59	41
Lunettes and Swales - Distant (LSD)	73	19
Partially Dissected Laterites (PDL)	20	0
Lunettes and Swales - Close (LSC)	42	0

Table 2. Proportion of each Soil Association affected by wind erosion.

Ap horizon clay class (%)	n	Proportion of class eroded in 1980 or 1981 (%)
0-1	11	100
1-2	38	63
2-3	49	35
3-4	25	12
4-5	21	14
>5	75	0

Table 3. The incidence of wind erosion decreases with increasing clay content in the surface (ap) horizon.

models (Skidmore et al. 1991, Moore et al. 1993), it is suggested that in some landscapes these models may have to be modified to account for aeolian saltation and suspension.

Distribution of land degradation

What does the soil and geomorphological mapping tell us about contemporary land degradation?

The soil mapping produced 28 soil mapping units, and these were combined to produce five Soil Associations, based on geomorphology and five Field Classes based on depth, texture and consistence of the soil surface horizons. Some 233 surface soil samples (0-10 cm) were taken across the study area. Only the results from the Soil Associations will be reported here, with median values of selected attributes summarized in Table 1. The distribution of contemporary wind erosion was assessed from a remote sensing analysis by Carter and Houghton (1984), in each of two years of severe erosion (1980 and 1981). Sampling sites were classified as eroded or non-eroded, according to this analysis. The proportion of erosion in each Soil Association is summarized in Table 2.

Contemporary wind erosion is most likely to occur on prior aeolian sand deposits, with 80% of Association SDS eroded. However not all aeolian derived materials are readily erodible with the clayey surfaced lunettes and swales close to playas (Assoc. LSC) not eroded at all. This suggests that the nature of the soil is more important in determining erodibility than parent material origin. This proposition is supported by the incidence of erosion in the undissected lateritic terrain (Assoc. UDL) where 41% of the soils were eroded, despite aeolian deposition possibly being of limited extent. Consequently, sites were classified in terms of the clay content of the surface (Ap) horizon (Table 3), with erosion confined to soils with <5% clay. Moreover the incidence of wind erosion generally decreased with small increases in clay content. A classification based on surface clay content, or texture, may therefore provide a better estimate of wind erodibility than one based on geomorphology. Such a classification however will require more intensive field observations and therefore be more costly, than one based on geomorphology and air photo interpretation.

The idea that past geomorphic history (aeolian activity) may explain future events (i.e. wind erosion) is only partly tenable in farmed areas, such as reported here. Cultivation has introduced a degree of soil surface destabilisation without a prior analogue.

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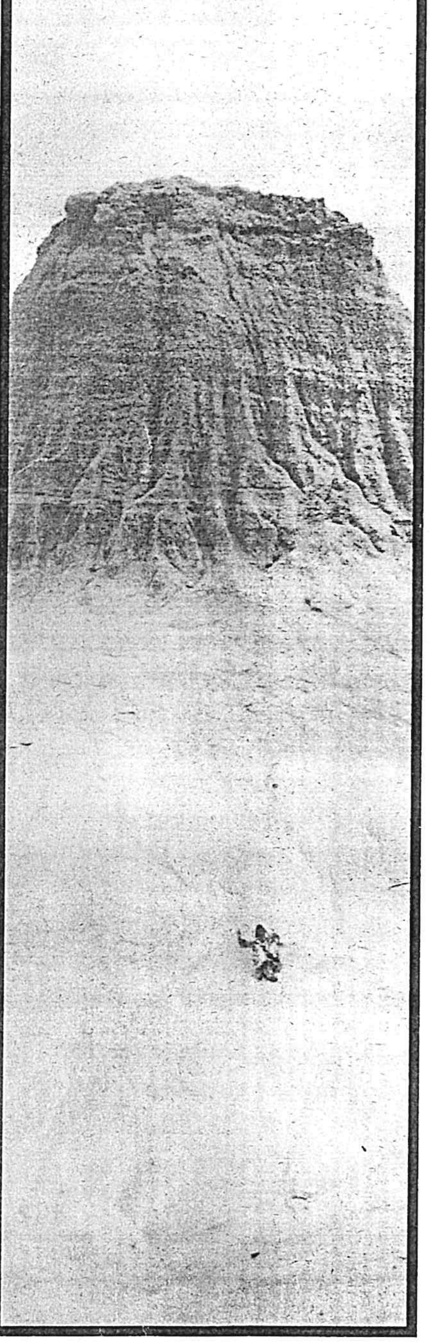
The role of geomorphology in land resource assessment



We were pleased with the response to this issue's theme of 'The role of geomorphology in land resource assessment'. Numerous descriptive models are cited that have the capacity to greatly improve the quality of land resource assessment. One of the major challenges facing survey staff is to gain the skills and acquire the resources for better quality geomorphic work. Greg Chapman's Constable Plod has to become Sherlock Holmes but at the same time acquire quantitative skills. We would welcome commentary on how this could be achieved. To those readers who have sent in articles which have not been included in the newsletter to date, fear not, your time will come! In the meantime please keep the articles coming.

The planning for the ACLEP technical field workshop in North Queensland is well in hand thanks to the efforts of Catherine Williams in particular. Some 58 people will attend the workshop and the meeting promises to be very rewarding for all involved. A report from the workshop will be included in the next newsletter. A workshop summary will be produced for distribution to all land resource agencies and those who were interested but unable to attend.

The next issue has a theme of "From Box Brownie to Multi-spectral Analysis" - the use of photography and imagery in land resource assessment. Some would argue that the benefits promised by the remote sensing community have not been realised. What are the impediments to successful use of remotely sensed imagery and have you or your group had a contrary experience? The deadline for contributions for the next issue is 20 November 1993. If you have a special interest in seeing an ACLEP newsletter issue with a particular theme, please let us know - we are always looking for fresh ideas.

GEOMORPHOLOGY IN LAND RESOURCE ASSESSMENT - PARADIGM REGAINED? - Robin Thwaites

So what can we do with geomorphology in land resource assessment? Is there a need for it? Or is it a foisting upon us by out-of-work geomorphologists?

Well, perhaps we had better look at how we do things now. Aren't we managing well enough as we are — steady-as-she-goes and all that?

Maybe not. We have been made aware that there is more than an undercurrent within the fraternity to suggest that all is not well with