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# Annual and decadal variation of sediment yield in Australia, and some global comparisons

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**Abstract** An analysis of 275 estimated sediment yields from Australia shows that regional differences of yield correlate with different variables for different sizes of drainage basin. Despite this scale-dependence, high yields in large streams appear to be the result of high delivery rates from uplands, controlled substantially by rainfall and runoff energy, and the nature of drainage networks. Land use plays a subsidiary role, modulating upland yields. These regional patterns of sediment yield do not in general support conclusions reached by analyses of global data; specifically, altitude is not a useful discriminator of yield, and the slopes of the regression equations relating yield and basin area do not fit global patterns. The implication of the analysis in this paper that is worthy of further investigation is that most sediment reaching most large rivers comes from channels in small upland basins.

## INTRODUCTION

Predictions of event sediment fluxes through the components of a sediment budget for large basins is an ideal against which to measure the success of all existing models of basin wide sediment transport. With such an ability, or a close approximation, many practical questions could be answered: for example, the effect of land management on downstream sediment loads is, in important respects, unknown for areas larger than experimental plots.

In the absence of estimates of the fluxes through even the most significant components of the sediment budget, in this paper resort is made to the identification of the sources of variation in mean annual sediment yields estimated for a wide range of basin sizes in different parts of Australia. The approach reflects some of the spatial complexity of the source-yield linkages that would otherwise be made explicit in a sediment budget, and supplies a synoptic view of scale-dependent yields across the continent.

## REGIONAL SEDIMENT YIELD

Previous compilations of Australian sediment yield data (Olive & Rieger, 1986; Olive & Walker, 1982) have been added to from a variety of sources: searches by the author of the unpublished records of government agencies and mining companies; surveys of reservoirs and farm dams; and, in a few cases, the use of tracer-based estimates of sub-basin sediment yields. The 275 estimated mean annual yields cannot be fully documented in this brief paper, but can be obtained from the author. Most yields are of suspended load but some (like those estimated from sediments in reservoirs) include bed load. The inclusion of bed load in some estimates of sediment yield introduces an uncertainty that is believed to be small relative to other uncertainties.

The first order global control of sediment yield, for basins $>100$ km$^2$ in area, appears to be relief (Pinet & Souriau, 1988; Milliman & Syvitski, 1992) and so tectonic history. By contrast, within Australia the small differences of relief between the major geomorphic provinces are unlikely to be the only key determinants of yield. Therefore, the data have been grouped according to geomorphic province and climate. Obviously the availability of data in particular regions sets another limit on these groups. The groups are as follows: (Fig. 1):

1. *Southern Uplands* – includes the Gippsland and central uplands of Victoria, the Snowy Mountains, the southern and central Tablelands of New South Wales (NSW). This is a region of slight winter maximum rainfall in the south, extending to a slight summer maximum in the north with values of the USLE erosivity factor ($R$) of 750-2000 MJ mm (ha h year)$^{-1}$. A landscape of rolling hills, some high plateaux and the deepest incisions in the continent. Land use is mainly grazing, with large areas of native forest.
2. *Southern Uplands – pre-European settlement yields* – estimates of the yield of sediment from drainage basins on the southern tablelands of NSW and the ACT, for the immediate pre-settlement period, based on stratigraphic methods.

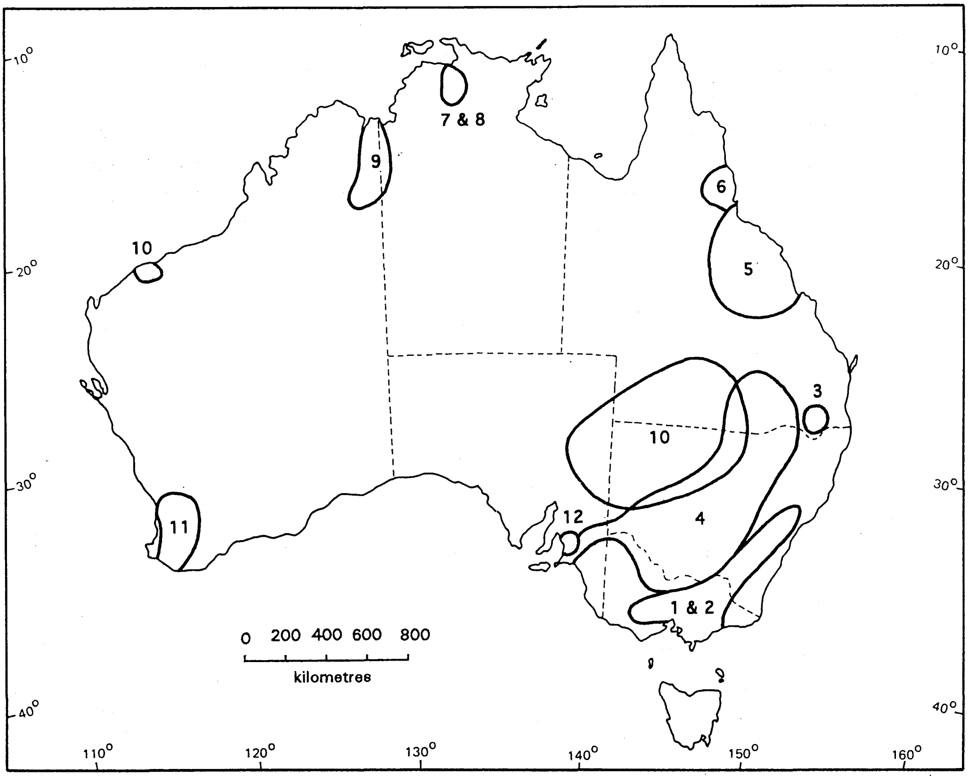

**Fig. 1** Map of Australia showing the regions for which sediment yield data are available. The numbered regions are described in the text.

3. *Darling Downs* – a relatively small area in southeast Queensland, of rolling and mesa topography, in an area of (sometimes) intense summer rain. The land is intensively cropped, and grazed. *R* values range from 2000 to 3000.
4. *Lowlands of the Murray-Darling Basin* – all of the data from this region come from large rivers of low gradient, in a landscape extending from the rolling "slopes" of the eastern uplands (1 and 2 above), to the nearly flat riverine plains and Mallee. This is an area of semiarid to arid climate, with a winter rainfall maximum in the far south and a summer rainfall maximum in the north. *R* values range between 500 and 1500.
5. *Sub-humid central and northern Queensland* – a region of dry season drought and summer rainfall which is often intense; *R* varies from 2000 to 9000. Here in the semiarid tropics grazing is the main land use in a rolling landscape.
6. *Humid northern Queensland* – here in the humid tropics, intense summer rains are common, with *R* between 5000 and 16 000 in a landscape of moderately high relief. Undisturbed rainforest lies beside sugarcane cropland and grazing.

7/8. *Northern Territory* – an area of long dry seasons and short wet seasons, with intense summer rains and *R* between 3500 and 4000. The landscape is generally of low relief, with some relatively high escarpments and plateaux. The Magela Creek is largely undisturbed (7), while the South Alligator basin has been intensively grazed by domestic cattle and feral buffalo (8).

9. *Ord River* – this area experiences the most strongly seasonal climate of all the regions. A long warm to hot dry season is punctuated by a short warm to hot summer wet season during which rainfall intensities can be very high. The landscape is often planar to rolling, set in between blocks of rugged hills of moderate relief. Land use is grazing by domestic cattle. *R* varies between 2000 and 3000.
10. *Arid Australia* – reservoirs in the southeastern part of the arid zone, and a few plot experiments within the arid part of the Murray-Darling Basin, are supplemented by data from one site in arid Western Australia (Harding River). The range of climatic types is wide, but all sites are grazed by either sheep or cattle. The basins and sites are physiographically diverse, from rocky uplands with narrow alluvial plains to near-flat plainlands. *R* varies between 500 and 1500.
11. *Southwest Western Australia* – an area straddling the boundary between the forests of the humid coastal fringe and the croplands further inland. A landscape of low rolling hills, with a winter rainfall maximum of generally low rainfall intensity. *R* varies between 500 and 750.
12. *Adelaide Hills* – an area of Mediterranean climate with a winter rainfall maximum, and *R* between 500 and 750. The landscape is undulating, with some areas of steep slopes – land uses range from intense horticulture to grazing.

For each of these regions, sediment yield data show a relationship with basin area of varying statistical strength; that is, large basins yield most sediment. The least squares power function equations for each region are assembled in Table 1, relating mean annual sediment yield (t $\text{year}^{-1}$) and basin area ($\text{km}^2$). Only regions 4 and 11 have unsatisfactory values of $r^2$, but only region 1 contains sufficient data to be confident that a few observations are not contributing undue leverage on the regression equation. For example, regions 7 and 8 are levered by one observation of hillslope erosion on a plot, while region 5 is levered by two observations of large basin yield. Nonetheless, there is a coherence to most of the data sets, so that high specific yields on hillslope plots are

**Table 1** Regression equations relating mean annual sediment yield ($y$, t year$^{-1}$) and basin area ($x$, km$^2$).

| | | | $r^2$ | $n$ | Classification* according to Milliman & Syvitski |
|---|---|---|---|---|---|
| 1. | Southern Uplands | $y = 33x^{0.94}$ | 0.89 | 131 | 3 |
| 2. | Southern Uplands – pre-settlement | $y = 1.6x^{0.79}$ | 0.85 | 11 | 3 |
| 3. | Darling Downs | $y = 480x^{0.86}$ | 0.87 | 11 | 2 |
| 4. | Lowlands of the Murray-Darling Basin | $y = 17x^{0.89}$ | 0.61 | 14 | 1 |
| 5. | Sub-humid central and northern Queensland | $y = 248x^{0.97}$ | 0.79 | 29 | 2 |
| 6. | Humid northern Queensland | $y = 488x^{0.48}$ | 0.78 | 11 | 3 |
| 7. | Monsoonal Northern Territory – undisturbed | $y = 5.5x^{0.86}$ | 0.95 | 7 | 1 |
| 8. | Monsoonal Northern Territory – mod undisturbed | $y = 17x^{0.90}$ | 0.97 | 7 | 1 |
| 9. | Ord River | $y = 96x^{1.12}$ | 0.82 | 16 | 2 |
| 10. | Arid Australia | $y = 470x^{0.85}$ | 0.89 | 15 | 1 |
| 11. | Southwest Western Australia | $y = 25x^{0.38}$ | 0.5 | 5 | 1 |
| 12. | Adelaide Hills | $y = 13x^{0.89}$ | 0.93 | 18 | 1 |

*Classification according to Milliman & Syvitski (1992): 1, lowlands; 2, highlands; 3, mountains.

**Table 2** Rank order of specific sediment yields for regions containing reliable data.

| Region no. | Area (km$^2$) | Specific sed. yield (t km$^2$ year$^{-1}$) | Rank order | $EI_{30}$ | Area (km$^2$)* | Specific sed. yield (t km$^2$ year$^{-1}$) | Rank order | $EI_{30}$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.01 | 12 ± 21 | 1 | 1240 ± 150 | 15 500† | 36* | 2 | |
| 3 | 0.01 ± 0.001 | 1270 ± 100 | 4 | 2070 ± 300 | 500† | 184* | 4 | |
| 10 | 0.01 ± 0.002 | 156 ± 87 | 3 | 1000 ± 280 | 1068† | 89* | 3 | |
| 12 | 0.00008 | 78 ± 68 | 2 | ~600 | 351† | 12 ± 10* | 1 | |
| 1 | 0.01 | 12 ± 21 | 1 | 1240 ± 150 | 1.21 ± 0.4 | 161 ± 68* | 1 | 1240 ± 150 |
| 5 | 0.0001 | 235 | 2 | 2750 | 0.09 ± 0.03 | 1830* | 2 | 2750 |
| 9 | | | | | 0.06 ± 0.02 | 155 ± 153* | 1 | 2500 |

* Channelled basins; all others are unchannelled.
† These are the largest basins in the data sets from each region.

accompanied by high specific sediment yields from large basins (Table 2, Fig. 2). The exceptions to this are regions 6 and 11. In the case of region 6, the plot data (~0.0001 km$^2$) are from cultivated land while the large basins are forested. There are

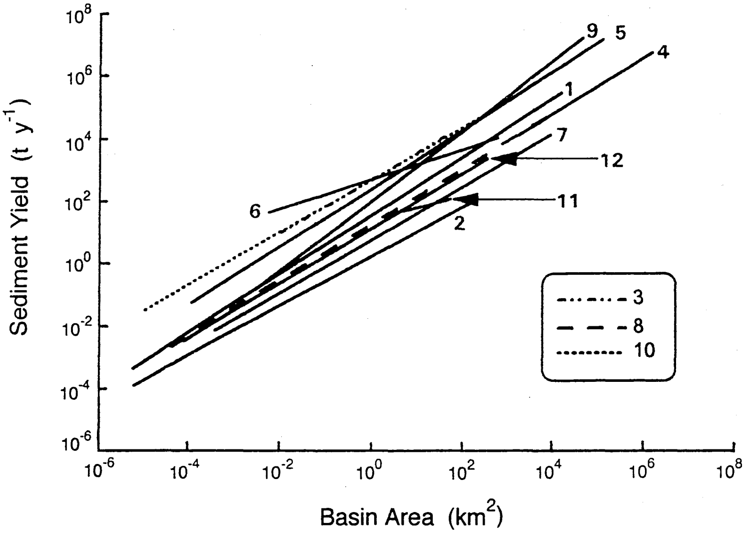

**Fig. 2** Regression curves, for each Australian region, relating mean annual sediment yield and basin area. Note that the curves for regions 3 and 10 coincide over part of their range.

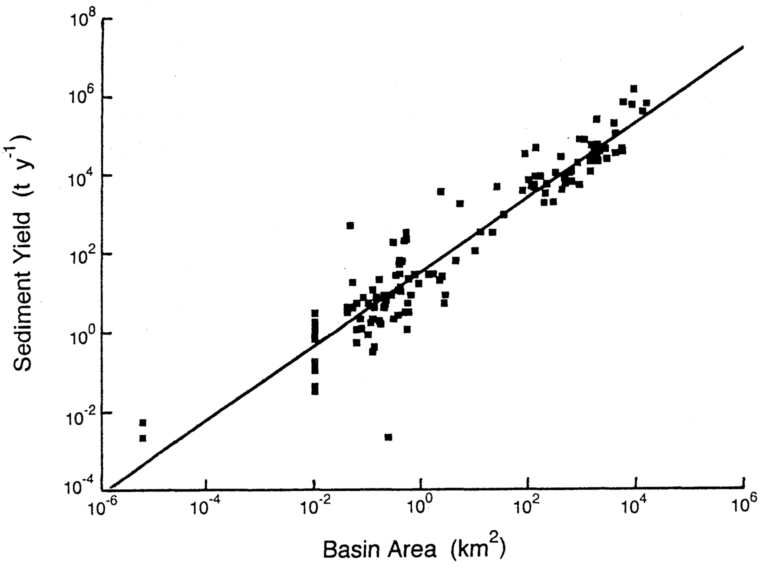

**Fig. 3** Mean annual sediment yield *vs.* basin area for region 1, the southeast Uplands.

too few data for region 11 to be sure that the curve in Fig. 2 is not an artefact of the sample size. For example, individual regression equations for parts of the range of values of basin area in Fig. 3 show different exponents, ranging from 0.77 to 0.93 (Table 3); indicating that the slope of a curve for a limited range of basin area values could be unreliable.

From the above discussion, the most reliable equations are for regions 1, 2, 3, 9, 10, 12. With the exception of the Ord River basin (region 9), all of these regression equations have values of $b < 1.0$. That is, as basin area increases the basin specific yield (t km$^{-2}$ year$^{-1}$) decreases. In the Ord River, specific sediment yield increases with basin area ($b = 1.12$).

## GLOBAL COMPARISON

Two comparisons are explored here: the relationship between mean annual sediment yield and basin area in the various regions of Australia and in the global compilation of Milliman & Syvitski (1992); and between the slopes of the regression equations that describe the relationship between yield and area, both in the Australian region and in the rest of the world.

Milliman & Syvitski (1992) grouped their global data on the assumption that the maximum elevation of a basin is a surrogate for its tectonic character, and that yield is largely a function of basin area and elevation. They identified five topographic/tectonic groups, from coastal plains to high mountains. Each of the Australian regions (defined in the previous section) has been classified according to the scheme of Milliman and Syvitski. If the Australian regions matched the global groups, then regions 1 (southeast Uplands) and 4 (Lowlands of the Murray-Darling Basin) should have the highest yields because they contain the highest land in their basins. This is not the case, with regions 3 and 8 being consistently higher for yields from areas $\geqslant 100$ km$^2$ despite their classification as highland and lowland, respectively, in the global groups.

The possible reasons for this disagreement are: the global groups include a wider range of topographic settings than is represented in any one of the regions of Australia; Australian basins behave differently from other parts of the world. Visual inspection of the Milliman & Syvitski (1992) scatter diagrams suggest that the former explanation is likely: the global data show a large spread around the regression lines. In addition, the data for global coastal plains coincide with that for regions 1 and 4 in Australia, global lowlands and region 10 (arid Australia) are indistinguishable and global highlands data coincide with that from region 9 (Ord River). The last two regions and groups fit within the same topographic settings (if region 9 is redefined as a highland, rather than as mountainous in Milliman & Syvitski (1992); a redefinition consistent with topographic data), and so the assumption of a first-order topographic/tectonic control of sediment yield seems to be justified. But regions 1 and 4 do not fit the global pattern, a result it is believed of low rainfall intensities and stream gradients.

At the regional scale, therefore, factors other than topography play a role in sediment yield. This conclusion suggests that it may be hazardous to apply the global relationships to the estimate of sediment yield in regions where there are no data.

The second comparison is of regression slopes for equations relating sediment yield and basin area in different regions of Australia and different parts of the world. The pattern indexed by $b < 1.0$ is traditionally explained as the result of two factors: most sediment is produced in headwater areas where slopes are steepest, drainage density highest, and storage small; in larger basins, storage increases and sediment production rates decrease with gentler slopes and lower drainage densities. Dedkov & Mozzherin (1984, 1989) argue that $b \doteq 1.0$ occurs in undisturbed plainlands and in forested mountains. They also note that $b < 1.0$ occurs in undisturbed basins in unforested mountains, and is common in agricultural basins. The case where $b > 1.0$ has been previously described by Church & Slaymaker (1989), a pattern they attribute to the dominance of secondary reworking of deposits in valley floors rather than primary denudation of the land.

These explanations are not completely appropriate for the Australia data; for example, $b \doteqdot 1.0$ in the southeast Uplands where considerable clearing has occurred, and $b > 1.0$ in the Ord basin where the most erodible soils occur in the downstream areas. But there is an additional complication; the values of $b$ and $r^2$ are dependent on basin area. For the most complete set of data, the southeast Uplands, values of $r^2$ and $b$ are set out in Table 3 for various ranges of basin size. The value of $b$, and the proportion of the total variance accounted for by basin area, decrease as basin area decreases, and as the total range of values of area decreases. These results show that the value of $b$ for different basin types should only be compared for comparable ranges of basin area and, more importantly, the arguments of Dedkov & Mozzherin (1984, 1989), and Church & Slaymaker (1989), do not have universal applications.

The explanation of the separation of the regression lines in Fig. 2 appears to lie in the causes of sediment supply, namely rainfall and runoff energy for the same landuse and topography. For the most reliable sets of data where $b < 1.0$ (regions 1, 3, 10, 12), specific sediment yield from both hillslope plots and basins of $10^2$-$10^3$ km$^2$ are in the same rank order, noting that numbers 1 and 2 for the large basins are probably indistinguishable (Table 2). That is, high hillslope erosion rates are accompanied by high basin yields. It might be concluded that high specific yields from large basins are therefore sourced from hillslopes which are eroding quickly. But Table 2 shows that, for regions where appropriate data exist (regions 1 and 5), high hillslope yields are accompanied by high rates from channels in small basins; a theme to be explored further below.

**Table 3** Scale-dependence of $r^2$ and $b$ for region 1 (southeast Uplands).

| Basin area (km$^2$) | $r^2$ | $b$ | $a$ | $n$ |
|---|---|---|---|---|
| <10 000 | 0.88 | 0.93 | 35 | 131 |
| <1000 | 0.82 | 0.92 | 34 | 108 |
| <100 | 0.67 | 0.92 | 33 | 88 |
| <10 | 0.53 | 0.81 | 24 | 80 |
| <1 | 0.48 | 0.79 | 23 | 70 |
| <0.1 | 0.55 | 0.77 | 23 | 29 |

## SUB-REGIONAL SEDIMENT YIELD

Variations of estimated sediment yields for a constant value of basin area produce the scatter around the regression lines of Fig. 2, and are illustrated most completely for region 1 (Fig. 3). This variance is produced by: errors in estimating the yields; data collection over different time periods during which climate has varied (years to decades) and/or changes have occurred to the eroded area (e.g. drainage density has changed over decades); and variations in erodibility and land use (years to decades). In this paper, space permits only a brief exploration of these causes of the variance.

Many of the regional data show that the variance about the regression line of yield *vs*. basin area is not independent of basin area: small areas have higher variances. Analysis of the data for region 1 (southeast Uplands) shows that the highest coefficient of variation (CV) of mean annual sediment yield occurs in basins $\leq 10^{-1}$ km$^2$ (Table 4). These areas are almost all unchannelled hillslopes in the data used in this paper. Areas $\geq 10^{-1}$ km$^2$ almost always contain channels, usually gullies, and the CV decreases with basin area. These results show that there is large basin to basin variation in small areas, which lessens as area increases. It might also be inferred from these results that different explanations of the variance will be required for different sizes of basin. This approach will be adopted in what follows.

**Table 4** Scale-dependent variance of mean annual sediment yield for region 1 (southeast Uplands).

| Basin area (km$^2$) | *n* | Mean *y* (t year$^{-1}$) | Sample $\sigma$ (t year$^{-1}$) | Coefficient of variation (%) |
|---|---|---|---|---|
| $10^5$-$10^4$ | 2 | $4.55 \times 10^5$ | $1.46 \times 10^5$ | 32 |
| $10^4$-$10^3$ | 21 | $1.64 \times 10^5$ | $3.07 \times 10^5$ | 187 |
| $10^3$-$10^2$ | 21 | $1.22 \times 10^4$ | $1.62 \times 10^4$ | 133 |
| $10^2$-$10^1$ | 7 | $6.64 \times 10^3$ | $1.07 \times 10^4$ | 162 |
| $10^1$-$10^0$ | 10 | $5.3 \times 10^2$ | $1.12 \times 10^3$ | 211 |
| $10^0$-$10^{-1}$ | 41 | $3.28 \times 10^1$ | $6.83 \times 10^1$ | 208 |
| $10^{-1}$-0 | 23 | $1.82 \times 10^1$ | $8.70 \times 10^1$ | 478 |

## UNCHANNELLED HILLSLOPES

In region 1 these landforms are $\leq 0.63$ km$^2$ in area, and can be much larger in flatter landscapes. The yield of sediment from such landforms has been the subject of a large amount of research, and is most practically estimated using the USLE. Much of the variation of hillslope yields between regions in Table 1 can be accounted for by the *R* factor of the USLE. Freebairn (1984) showed a strong correlation between *R* and annual erosion rates for similar soils and cropping systems along a south-north transect through the upland part of the wheat cropping areas of eastern Australia. But the large CV in region 1 (Table 4) is primarily the result of different land uses applied to the erosion plots at Wagga Wagga and Cowra (Edwards, 1987). For example, at Cowra volunteer pasture plots of 0.01 km$^2$ yield $0.17 \pm 0.06$ t year$^{-1}$ and 2 year wheat rotations yield $1.68 \pm 0.35$ t year$^{-1}$.

## GULLIED SMALL BASINS

In region 1, the mean annual specific yield of ungullied basins (0.04 to 0.63 km$^2$ in area) under native pasture is $19 \pm 5$ t km$^{-2}$ year$^{-1}$. For gullied basins (0.08-9.8 km$^2$) under native pasture, the specific yield is $161 \pm 68$ t km$^{-2}$ year$^{-1}$; gullies produce $9 \pm 5$ times more sediment than ungullied land in this region. Within the ungullied basins, there is a statistically weak relationship between mean annual yield and % of cultivation, while, at the extremes, forests yield 4 ± 2 t $km^2$ $year^{-1}$ and cropped land 57 ± 15 t $km^2$ $year^{-1}$. Within the gullied basins, mean annual yield is a linear function of gully density (km $km^{-2}$), a function that accounts for 77% of the variance in yield. Addition of land use to the regression analysis makes no significant difference to the explanation of variance, supporting the idea that most sediment comes from the gullies.

In region 5, data from the Kangaroo Hills basins (0.03-0.31 $km^2$) show that sheet erosion yields 260 t $km^2$ $year^{-1}$, minor gully and sheet erosion 420 t $km^2$ $year^{-1}$, and severely gullied basins yield on average 1830 t $km^2$ $year^{-1}$ (Prove, 1992). A linear function between yield and gully density accounts for 53% of the variance in yield. In region 9, (only) three estimates of basin yield show a power functional relationship with gully density, where 99% of the variance is accounted for.

While drainage density is an important determinant of sediment yield (as previously shown by Hadley & Schumm, 1961), the differences between yields in different regions is also partially a result of erosivity. Table 2 shows that $EI_{30}$ is highest in region 5 where the specific yield is also highest for gullied basins. The two low values of specific yield and $EI_{30}$ are indistinguishable given the variations. The rank order of these data is consistent with the rank order of the yields from unchannelled hillslopes in the same region, so there appears to be a correlation between rainfall erosivity and runoff rate. As discussed earlier, high yields from medium to large basins appear to be the result of high yields from small gullied upland basins, a conclusion which rests upon more than simply the data presented in Table 2. It is important to note that the data from the small basins comes from headwater uplands rather than from the gentler slopes of downstream parts of the basin.

## MEDIUM AREA BASINS

Only data from basins between 3.1 and 321 $km^2$ in region 12 are suitable for analysis of the sources of variance of the mean annual sediment yield. Clark (1988) has compiled data for the areas of various land uses (urban, horticulture, orchards, bushland, pasture) averaged over the period for which sediment data were collected (Clark & Crawley, 1987). Differing from the equation in Table 1, the power function relating yield to basin area for the slightly smaller range of basin areas analysed in this section accounts for 59% of the variance in yield. None of the correlations between mean annual yield and individual land uses gave better results. However, mean annual specific yield correlates most strongly with the area of horticulture and orchards ($r^2$ = 0.73). This result indicates that, once basin area is taken into account by using specific yield as the dependent variable, the effect of the most intensive land uses can be detected. The same result emerges from multiple linear regressions where $r^2$ changes from 0.05 to 0.93 when basin area is included with all of the land use variables. So the mean annual yield is a function of the area of land yielding sediment (and water), but the rate of delivery from a unit area is strongly influenced by the presence of intensive land use. This result is consistent with the results of Clark (1988). Basin area and drainage density may also be correlated, and so it may be eventually shown that in this area land use simply modifies topographic (i.e. drainage network) controls on sediment yield.

## LARGE BASINS

Table 4 shows that the CV for large basins in region 1 is low, a result consistent with the relationship between yield and basin area for the Lowlands of the Murray-Darling Basin (Region 4). Although lacking data to test the hypothesis, it is likely that land use is far less important, as an explanation of sediment yield in large basins, than the area from which sediment can be derived. The summation of the effects of very small basins, each of which shows some differences from its neighbours, produces an "averaging" that is reflected at large scale by low values of the CV. It is therefore likely that either land use or drainage density are useful explanatory variables, and that basin area alone has predictive power for mean annual sediment yield. Of course area will be related to different values of yield in different regions, reiterating the link between large scale yield and the causes of sediment release from the uplands.

## CONCLUSIONS

A new compilation of sediment yield data from Australia, ranging from erosion plots on hillslope segments ($10^{-5}$ km$^2$) to the largest exorheic basin, the Murray-Darling Basin ($1.6 \times 10^6$ km$^2$), has been partially analysed in this paper. The estimated yields in many cases average decades of runoff events because data come from reservoir surveys, and from long records of sediment sampling in rivers and from erosion plots.

These data have been arranged into coherent groups which can be clearly separated by regression equations relating yield and basin area. While basin area accounts for most of the variation of yield within a region, it appears that processes operating in small upland basins account for most of the sediment that reaches large rivers. High yields from large basins are accompanied by high yields from upland hillslopes and small channelled basins. This conclusion has two testable implications: that sediment transport in Australian rivers is supply limited (cf. Olive & Rieger, 1986; Srikanthan & Wasson, 1993); and that lowland slopes and streambanks are minor sources of sediment for large rivers.

The Australian data do not support the generalizations made by Milliman & Syvitski (1992) and Dedkov & Mozzherin (1984, 1989), and add to the argument of Church & Slaymaker (1989). Altitude is not a sufficient explanatory variable for regional sediment yield in Australia, and the slopes of the regression equations relating yield and basin area in different regions do not conform to the global patterns identified by Dedkov & Mozzherin. The presence of erodible soils in the downstream part of a basin produces the same effect as the secondary reworking of glacial deposits by producing an increase of specific sediment yield with basin area.

At the sub-regional scale, different "explanations" of sediment yield appear to apply to different basin sizes. Unchannelled hillslopes have the highest spatial variance of sediment yield. For the same land use and soils, erosivity accounts for different sediment yields in various regions. In small gullied basins, a large but variable fraction of the variance of sediment yield is accounted for by drainage density. That is, channels are the most important source of sediment, but the yield from these channels is dependent in part on the runoff rate which is assumed to be correlated with rainfall erosivity. Land use appears to play only a minor role as an explanatory variable. In medium size basins, intensive land uses are an important source of sediment, although sufficient data do not exist to confirm the relationship derived for the Adelaide Hills. Finally, the averaging effect of land use, erosivity and drainage density appear to make basin area the best predictor of sediment yield in large basins, although the yield of headwater basins $>10$ km$^2$ may be the best predictor of yield from these large basins.

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