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Geomorphology 68 (2005) 314–333

GEOMORPHOLOGY

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Catchment-wide soil loss from pre-agricultural times to the present: transport- and supply-limitation of erosion

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Received 16 November 2003; received in revised form 30 September 2004; accepted 16 October 2004
Available online 2 March 2005

Abstract

A high-resolution record of catchment-wide soil loss for the period c. 1806–1990 has been obtained from Little Llangothlin Lagoon on the New England Tablelands of northeast New South Wales, Australia. The mean annual rate of mineral erosion since the time of European contact in the late 1830s was 269 t km^{-2}. The mean rate of mineral denudation immediately prior to this was 25 t $km^{-2}a^{-1}$. In the 25 years after the arrival of the first sheep in the catchment, erosion rates increased by a factor of over 50 to 1360 t $km^{-2}a^{-1}$. After c. 1861, however, there was an apparently sharp transition to a new, low and very constant rate of denudation, 52 t $km^{-2}a^{-1}$. Eighty-five percent of post-contact erosion thus occurred in the first quarter of a century of European land use.

The low and constant erosion rates of the last century or more cannot be attributed to stable environmental conditions, to a decrease in land use intensity or to the introduction of soil conservation measures. Instead, it is possible that early colonial erosion almost entirely depleted the catchment of erodible material with the result that erosion moved from a transport-controlled regime to one that was limited by the rate at which catchment material was made available for transport by weathering. Alternatively, the high, early colonial rates of erosion may have been associated with the extension and deepening of the drainage net during the initial phase of European contact. The subsequent establishment of a new drainage net equilibrium may have reduced soil loss to a low and stable level.

Much of the evidence available to test these competing hypotheses is equivocal. Nevertheless, the gullying model must be rejected, first because there is no evidence of past or present dissection of the catchment surface, second because gullying would seem incapable of providing the highly constant rate of sedimentation that has prevailed in the basin over the past century or more and third because the gullying model cannot explain the step change from high to low rates of sedimentation in the basin. Further support for the supply-limitation hypothesis comes from the concordance between likely rates of soil formation in the catchment and rates of sedimentation in the lagoon.

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0169-555X/$ - see front matter
doi:10.1016/j.geomorph.2004.10.008

These conclusions have implications for our cognisance of the role of supply-limitation in geomorphological processes, for soil conservation practice and for our understanding of the long-term impacts of agriculture on soil erosional systems.

Keywords: Australia; Soil erosion; Agriculture; Supply-limitation of erosion; Pre-European; Post-contact

1. Introduction

An understanding of the causes of soil erosion and a knowledge of those land use practices that allow the maintenance and survival of particular soils are essential for the sustainability of agricultural systems worldwide. Most attempts to obtain the information necessary to tackle these issues have involved the investigation of soil loss over limited areas, such as small test plots, and over short time spans. This work has four main drawbacks. First, it is difficult to judge the long-term effects of land use practices (and changes in land use practices) on soil loss. Second, it is hard to evaluate the impacts of secular environmental variation, to establish the antecedents of modern problems, to calculate trends and rates of change, and to establish the lag times between catchment modification and catchment response. Third, short-term measurements tend to miss the impact of rare, high-magnitude events such as major floods and droughts or, if they are fortunate enough to monitor such events, are not able to place their impact in the context of the long timescale. This means that it is difficult to obtain information on long-term responses and recoveries. Fourth, by making studies at the local or microscale, it is not always easy to extrapolate soil losses across entire catchments, particularly as such studies are often made of sites that are experiencing rapid rates of erosion or that are otherwise special for some reason. As a result of all this, it is difficult to establish relationships between erosion and productivity, to test erosion models and to suggest what restrictions to land use are necessary to minimise soil losses.

An approach that potentially overcomes one of these problems is to measure stream sediment loads and thus to determine catchment-wide rates of fluvial erosion in the upstream basin. Unfortunately, only a proportion of the material eroded in a drainage basin will find its way to the basin outlet, and the estimation of the size of that proportion is beset with difficulties (Walling, 1983). In addition, the amount of sediment transported out of a basin may reflect past erosion and sediment delivery processes rather than current activities; in other words, there may be a lag between erosional cause and sediment-yield effect.

An alternative approach involves investigating soil loss from catchments that drain into enclosed basins. These basins act as sediment traps in which the products of denudation throughout the entire catchment may accumulate over long time spans. Examination of the resultant sediments enables the investigation of the behaviour of systems over timescales longer than that allowed by direct observation. The deposits may reveal the amount of material lost from the surrounding catchment over time, may provide a comparison between agricultural and pre-agricultural rates of denudation, may show the effects of natural events of given magnitude on overall rates of denudation and may reveal the impact of changes in land use on rates of soil loss.

Although this approach has been used relatively widely in the last decade, several practical problems have limited its usefulness. First, it is essential that the results of sediment-based environmental reconstruction are placed in a high-resolution dating framework. The most appropriate technique given the timescales involved is ^{210}Pb analysis. But, because the dating range of this technique is limited to 150–200 years, in most situations this fails to cover the full span of agricultural impact on the environment. Yet the initial impacts of agriculture may have had a critical effect on the landscape and may have dictated the nature of subsequent soil loss and land degradation. Second, the restricted dating range of ^{210}Pb methods means that information on pre-agricultural conditions is often unobtainable. It may thus be impossible to establish a pre-agricultural control against which to judge the impacts of agricultural activity.