Predicting where soil will erode

Soil erosion by water is a massive problem of agricultural land world-wide. In Australia, it affects more than 200 000 sq. km of cropping country.

The method can predict where soil will erode.

The problem is usually tackled, if at all, by patching up the worst-eroded sites. Prevention would obviously be much more desirable, but cost generally rules out measures that treat the entire landscape.

Dr Ian Moore and Dr Gordon Burch, of the CSIRO Division of Water and Land Resources, now believe they can offer a tool that will make the job of erosion prevention and mitigation much more efficient. They have developed a mathematical model that can be used to pin-point regions predisposed to erosion. All that one needs are a contour map, a knowledge of soil types, and records of rainfall intensity.

The scientists have confirmed, on a number of sites, that their model mirrors what actually happens and are now refining it (taking account of factors like vegetation cover) in a program of field work at Wagga Wagga, N.S.W., funded by the National Soil Conservation Program.

The Australian Water Research Advisory Council is also providing money for a study, being carried out in collaboration with the Soil Conservation Service of New South Wales, the Sydney Water Board, and Melbourne University, of erosion susceptibility in the Warragamba catchment, near Goulburn, N.S.W.

Since the method is universally applicable, the researchers are keen to see the technique used widely overseas as well as in Australia.

An empirical equation has been developed in the United States, known as the Universal Soil Loss Equation, based on decades of study of many uniformly sloped test plots, tilled and cropped. Unfortunately, this equation is unreliable when it is applied to long and/or steep slopes and to converging or diverging land surfaces.

The difficulty arises from the way water flows over the surface of real hills and gullies. Instead of a uniform two-dimensional flow, we have water spreading out or diverging as it moves downslope from ridge sections of an actual three-dimensional surface, and converging in valley sections. This convergence or divergence of flow, caused by the shape of the land surface, greatly influences the amount of erosion or deposition that will occur.

The beauty of the new model is that it allows for this effect of topography. It applies to the erosion problem a hydrological model developed by Dr Emmett O'Loughlin of the Division for studies of water run-off in catchments. The scheme calculates, for any point in the landscape, the total flow over it resulting from all contributions from higher ground, assuming a constant run-off rate. In gullies, naturally, this flow will be accentuated; over crests it will diminish.

The ability of water flowing over the land surface to transport sediment depends on the strength of the flow (mathematically called unit stream power) and on the size of the soil particles over which the stream flows. Fine silt is easier to shift than coarse gravel; in fact, theory predicts that sediment transport will increase tenfold if the median particle size falls from 0·3 mm to 0·1 mm.

If flowing water carrying sediment slows down (unit stream power decreases), sediment will be deposited; if it speeds up (due to an increase in the slope of the land) further erosion will occur, increasing the sediment load. There's a critical balance between the sediment load and the dissipation of energy in the system.

The phenomenon whereby uniform sheet flow transforms itself to a flow pattern dominated by rivulets is called rilling. The water flowing in a rill generally has a greater sediment-transport capacity than water flowing as a uniform sheet.

The method makes clear the importance of rills in causing erosion. Where flow converges, or land slope increases, rills often develop and concentrate overland flow, which increases flow depth and speed. The ensuing increase in the unit stream power leads to erosion. In a similar way, identifying where flow diverges (or land slope decreases) and rilling ends allows areas of sediment deposition to be predicted.

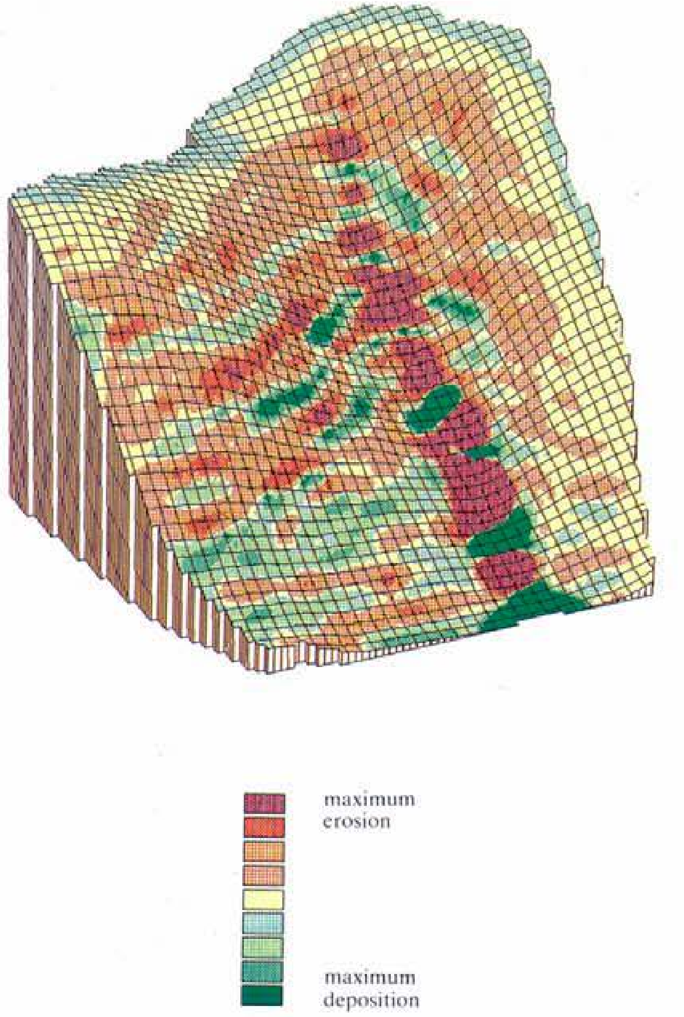
The scientists have examined data derived from a number of soils and slopes and obtained very good correspondence between the data and theoretical predictions.

At Wagga Wagga, the Soil Conservation Service of New South Wales has been monitoring the run-off and sediment yield of two 7-ha catchments. One has been treated with contour furrows, while the other remains untreated. The annual sediment yield from the latter averages 2200 kg per ha, and that from the former 32 kg per ha.

Applying the prediction method to the untreated catchment produced the diagram shown. The scientists assumed a run-off of 10 mm per hour — representative of soil-damaging heavy storms expected several times a year in the area. The purple and orange sites are those where high erosion rates can be expected and, indeed, they correspond with areas where severe gully and sheet erosion has been observed.

Note that areas of deposition (green) and erosion occur in close proximity to each other. Erosion occurs where the local land slope increases or the flow concentrates, and deposition occurs where the slope decreases or the flow diverges. While people may be able to look at a landscape and say off-hand that erosion is likely in a depression area where the flow converges (that is, a gully forms), they would seldom be able to point to where erosion

Relative erosion and deposition rates



A computer plot of the Wagga Wagga catchment. The most severe erosion can be expected in the purple areas and maximum sediment deposition in the dark green areas.

and deposition are likely to occur elsewhere in the landscape.

The modelling method has also been applied to the contour-furrowed catchment. Pleasingly, the result gives a sediment-transport figure that is in accord with the measured one.

Potential users of the prediction scheme need to assemble a number of pieces of information. First, they require a digitised version of a topographical map with a contour spacing of 1–5 m, depending on the size of the area covered. A second requirement is knowledge of the size of the soil's constituent particles, and of some simple soil hydraulic properties. Finally, figures for the intensity and frequency of rainstorms complete the set of variables.

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