SOIL CONSERVATION PRACTICE – IN SEARCH OF EFFECTIVE SOLUTIONS

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Abstract
Observations of soil conservation practices in Australia and overseas suggest that inappropriate solutions are commonly applied, often achieving only a partial solution to the identified “problem” and/or unforeseen detrimental impacts. Often the objectives of the conservation practice are poorly defined and the rectification strategies poorly targeted and/or executed. The strong visual elements of some soil conservation practices lend themselves to compliance monitoring and may partly explain their appeal to users and/or regulators. This review critically evaluates the effectiveness of some soil conservation practices currently used in the agricultural, mining and urban construction industries. A problem-solving framework to better address soil conservation issues is presented.

Examples of partial solutions in the agricultural sector include the use of graded banks. Similarly, waste rock dumps on minesites commonly incorporate berms on steep slopes to slow, retain, or control runoff flows. However, in the longer term berms generally promote gully formation instead of controlling erosion. In the building industry, silt fences, sediment dams and other barriers to sediment movement are widely used and commonly required by local regulation. However, these structures typically have little effect on the movement of suspended sediments and nutrients which have the greatest impact on water quality.

Additional Keywords: soil conservation, problem solving

Introduction
In broad terms, soil erosion occurring at rates higher than acceptable is a problem. Soil conservation is the act of solving that problem. Yet while that sounds simple, in practice it is not. Nor should we expect it to be.

Problem solving has well-defined components. The first is problem definition, using the questions:

- What/when/where **is** the problem; and just as importantly
- What/when/where **is not** the problem.

In some cases, testing may be needed to verify the exact cause of the problem, though with soil erosion that is usually unnecessary.

The second component, preferably applied after a problem has been defined, is to devise ways of preventing or avoiding the problem. In soil conservation, this is usually a matter of identifying:

(a) What properties of the site/situation have greatest impact on the erosion process of concern (and will therefore be most effective); and
(b) Which properties of the site can be altered or controlled.

There is the added consideration that technological change can greatly change what is possible, so that (b) above is not a constant. Unfortunately, it is common for a solution to be adopted before the problem is properly identified.

The history of soil conservation in Australia provides ample opportunities to assess our success at problem solving, and to demonstrate that problem definition is not as simple as it would seem.

Soil Conservation in Cropping Lands – the eastern Darling Downs of Queensland, Australia
Background
The Darling Downs is an area of approximately 1.84M ha. Cropping began in the area in the 1840’s, with a period of rapid agricultural expansion between the two World Wars (Skinner *et al.* 1977). With growing mechanisation during that period, erosion was reported to become intense, so that “gully filling after every heavy rain was a routine procedure”, and “many cultivations were divided into strips and ‘islands’ by gullies” (Skinner *et al*. 1977).

Early soil conservation efforts focussed on construction of mechanical barriers to flow, with design and surveying of graded banks and waterways being carried out by State Government officers. As these soil conservation methods provided no immediate benefit to farmers, construction and maintenance of such structures was seen as both an investment in the future productivity of the land and as a common good. For a range of reasons, adoption of such measures was neither as rapid nor as complete as was considered desirable. In 1973, Areas of Erosion Hazard were declared, with provision for subsidy to be paid to farmers for erosion works within those areas, and potential to enforce the construction of specified works.

Aided by a major increase in staff and resources, this achieved a considerable increase in the area of land on which soil conservation structures were constructed.

However, by the early 1980's, it was plain from both observation and research data that the main soil conservation approach being applied was not successful in controlling erosion. Research data indicated erosion rates of 30-60 t/ha/y between graded banks (Freebairn and Wockner 1986), and heavy rilling was clearly visible between graded banks (Figure 1). The main options considered were to either (a) recommend a halving of the spacing between graded banks, or to (b) encourage the greater adoption of stubble retention and reduced tillage. These options were not necessarily mutually exclusive, and both were being encouraged to greater or lesser degrees at that time.

Figure 1. Widespread rilling between graded banks

Eventually, it was decided that efforts to increase stubble retention would be greatly increased. This erosion control option had become possible due to the increased availability of suitable herbicides, and the development of suitable tillage and planting equipment.

Subsequently, reductions in tillage, increased cropping frequency, and retention of crop residues have become common practice in the region. The main incentive has been better use of soil moisture, reductions in labour and costs, greater flexibility in cropping, and better returns. These incentives are widely regarded as being more effective than government coercion (Cramb 2004).

Analysis

The soil conservation efforts in Queensland are considered typical of "conventional" soil conservation programmes carried out in the United States (Cramb 2004) and in other parts of Australia. It may be unduly harsh to view such programmes as “remarkable failures”, as do Pretty and Shah (1994), but it is clear that local approaches to soil conservation have evolved greatly from the 1970’s.

If we view the history of soil conservation on the Darling Downs as a problem solving exercise, we would ask “what were the problems being solved?”

In broad terms, the answer is “an unacceptably high rate of erosion”. However, there was also the specific problem of “high rates of gully erosion, which rapidly rendered land unsuitable for farming”. This was a more immediate concern, as it took land out of production relatively quickly.

For this latter problem, graded banks and water ways were an effective solution. As well, they were the only solution that was technically possible for some 30 years, until development of suitable tillage equipment made stubble retention possible, and availability of herbicides led to drastic reductions in tillage. However, it is interesting that, with time, regulatory authorities began to view graded banks and waterways as the solution for the more pervasive problem of high rates of erosion, so that the “old” solution began to impede potential advances in erosion control. Effectively, inadequate problem definition was an impediment to progress.

It is interesting, too, that efforts were so strongly directed at reducing slope length, when research data and model relationships (such as that in the Universal Soil Loss Equation) point strongly to slope length being the component of an eroding system to which erosion is least sensitive. Problem definition – regarding excessive erosion as a deviation from some baseline “acceptable” condition - would have probably focussed attention on the loss of vegetative cover and excessive tillage that were features of mechanised agriculture in the early 20th century.

In the situation that prevailed in the late 1970’s, with the declarations of erosion hazard enabling both compulsion of landholders to meet specified requirements with respect to soil conservation, and with subsidies available for such works, reliance on highly-visible and easily-documented structures was undoubtedly a more manageable way to handle the bureaucratic aspects of soil conservation in Queensland. One of the attractions of any highly-visible soil conservation practice is that it makes it extremely easy for a regulatory officer to tick a box.

Rehabilitation and stabilisation of mine site waste rock dumps.

Background

For open-cut mines, large volumes of overburden are generally removed to gain access to an ore body. The overburden is commonly placed in waste rock dumps, and one of the requirements for mine site rehabilitation is that the waste rock dumps should be made stable and self-sustaining. As there are often restrictions (legal and economic) on waste rock dump area, it is not uncommon for waste rock dumps to be constructed to heights of 40 m. Regulations and guidelines vary from one Australian state to another, but it is common in Western Australia and the Northern Territory for outer batter slopes to be constructed in lifts up to 10 m high, with gradients of 20 degrees (36%), and to be separated by 5 m wide inward-sloping berms. Waste rock dump heights of 40 m are common, and dumps are largely designed to be water-retaining (water being ponded in berms and on dump tops). In Queensland, graded banks and waterways are commonly used to reduce slope lengths during revegetation, but may be removed once vegetation is well established.

Mines across Australia cover an enormous range of rock and overburden types, and an enormous range in climate. With that in mind, the industry’s attempts to use relatively similar methods for waste rock dump construction and stabilisation irrespective of location suggest immediately that success is not likely to be high.

Some surprising misconceptions apply.

The approach used indicates that interrill and rill erosion of the outer batter slopes is perceived to be the primary concern, with reduction in slope length being adopted as the main method for reducing erosion. However, inspections of waste rock dumps invariably identify gully erosion as the primary erosion mechanism. Gullies are typically triggered by either overtopping or tunnelling of berms, and are driven by the flow concentrations that the berms create, so the major “control” practice is effectively the major cause of erosion. It is surprising that engineered structures requiring regular maintenance should be adopted for situations where the ideal situation would require no long-term maintenance at all.

There is also strong focus on establishment of vegetation to achieve site stability.

Analysis

Although problem definition is poor, understanding of available options for erosion control has been of greater concern.

The importance of gullying as a problem may have been recognised, but the potential contributions of tunnel erosion to gully formation were not.

The major erosion control practice adopted (berms to reduce slope length) has been spectacularly unsuccessful in situations where there is potential for tunnelling to develop. Ponding of water in berms has been a major factor in the initiation of tunnels (Figure 2). In the longer term, berms have failed and gullied even when tunnelling did not occur, simply because such structures require regular maintenance, and such maintenance does not occur on rehabilitated minesites. A more long-term view is gradually becoming adopted, with some sites now considering waste dump stability for periods up to 200 years. As well, all "flow control" structures are designed to some "return period", so there is an element of certainty in their failure. (Sooner or later, the design storm will be exceeded.)

Figure 2. Tunnel development due to ponding of water in a berm on a mine waste rock dump.

As in agriculture, control of slope length is a relatively ineffective tool for control of erosion. However, unlike agriculture, minesites have the potential to alter slope gradient and material erodibility, and cannot plead the defence that slope length is the only thing that can be altered by management or design.

The importance of surface cover in some environments is grossly overestimated. For sites where 60-100% contact cover can be achieved, revegetation is a reasonable priority. But, in large areas of the continent, where annual rain is in the order of 250-400 mm, it is extremely unlikely that vegetation cover will be adequate to stabilise steep slopes, especially if concentrated flows are being developed. Data presented by Kirkby (1969) for the United States show increases in erosion to a maximum as annual rain decreases to approximately 250 mm/y, suggesting that as rain decreases, vegetation growth becomes increasingly insufficient to control erosion, and that erosion control by vegetation is minimal as rain approaches 250 mm/y. Hence reliance on vegetation as a means of site stabilisation is somewhat misplaced for a high proportion of sites in arid parts of Australia.

As well, there appears to be remarkably little understanding of the difference between contact and canopy cover, and ecological considerations still tend to result in deliberate suppression of grass and planting of high densities of trees and shrubs, even on steep slopes where a grass component in vegetation would give greater and more rapid erosion control. For some sites, the potential to add rock to the surface layer means that a (relatively) permanent level of surface cover can be created.

Recent developments in minesite rehabilitation
In response to growing realisation of the need to purposely design waste dumps if a stable outcome is to be achieved, recent work has focussed on:

- Characterisation of spoils excavated on minesites;
- Selective placement of materials of low erodibility on batter slopes;
- Addition of rock to batter slopes where available and necessary;
- Avoidance of placement of dispersive (tunnel-prone) materials on batter slopes or berms;
- Elimination of berms and rock drains wherever possible; and
- Adoption of concave batter slopes.

These changes have been based on a clearer identification of waste dump problems, and have aimed to base erosion control on the most effective factors that can be controlled on a given site. The developments have been largely driven by minesites committed to construction of waste rock dumps and tailings dams that will exceed current expectations, and that will be stable in the long term.

Erosion control on building sites
Background
Authority to enforce erosion control on building sites is usually held by the City or Shire Council that issues an approval for the construction activity. In Queensland, most councils base their requirements on Guidelines for Soil Erosion and Sediment Control prepared by the Institution of Engineers, Queensland. In New South Wales, there are similar guidelines.

To date, erosion control in these situations is strongly dominated by highly-visible structures such as silt fences and check dams, together with various catch and diversion drains. Other recommendations in the guidelines, such as management or placement of surface cover, and timing of activities to avoid periods of peak erosion hazard seem to be ignored. In general, oversight of building sites is limited, and fines in many areas are so small that compliance is not strongly encouraged.

Analysis
On-site damage to a construction site is clearly not a concern. However, off-site impacts from sediment and associated nutrients are of considerable concern. This should be particularly so in coastal areas of sandy soil, as there is potential for initial flushes of sediment to be highly enriched in organic matter and nutrients (Costantini and Loch 2002).

The problem – off-site movements of sediment - seems to be clearly identified, though not fully understood.
Sediment moving from a disturbed area will tend to deposit rapidly if coarse, and to move long distances in aquatic systems if fine. Nutrients tend to be most strongly associated with the finer fractions of sediment.

Large deposits of bedload sediment can be a problem, both in reducing capacity of small creeks and in causing nuisance to adjoining roads and properties. But, fine, nutrient-rich sediment is undoubtedly the component of erosion with greatest potential for environmental harm.

Nonetheless, erosion control methods widely adopted for building sites focus heavily on sediment trapping. As neither silt fences nor small check dams are likely to trap a significant proportion of the fine sediment that is detached, it seems that the major component of the erosion problem in this situation is being ignored.

Again, the preference for highly-visible soil conservation practices is quite striking.

Conclusions

In a number of areas where soil conservation is perceived to be important and has received considerable effort, it appears that considerable effort and expenditure is wasted, due to:

- Inadequate problem definition; and
- Reliance on inappropriate and/or ineffective practices.

Uniformly, there has been a strong preference for highly-visible structures, which may be consistent with all three situations having – at one time or another – elements of regulatory control and assessment of compliance for which highly-visible actions would be convenient.

In many situations, a problem solving approach would lead to somewhat different soil conservation methods being adopted, and should achieve a higher level of success.

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