Muddied Waters

Estimating the national economic cost of soil erosion and sedimentation in New Zealand

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Abstract

Soil erosion research in New Zealand has focused on the on-site costs of soil loss in the form of production loss and storm damage. Subsidization and implementation of soil conservation measures have primarily been justified through maintenance or improvement of farm productivity levels. The shift in responsibility for soil conservation management and damage remedies from national to regional government has highlighted public good issues raised by soil erosion.

This paper develops an inventory and assessment of the relative magnitude of the impacts of soil erosion and sedimentation in New Zealand. It also provides an estimate of the total economic costs of these impacts based on the limited data available. The impacts of greatest economic significance are highlighted, as are impacts that may be significant but for which data is limited.

The implications for current and potential policy strategies are briefly discussed. The approach demonstrates the degree to which policy in this area is based on incomplete information. The nature and scale of the costs involved have implications for the relative efficiency of regional rather than national approaches to addressing this issue.

1 Introduction

Soil erosion research worldwide has tended to concentrate on the on-site costs of soil loss in the form of production loss and storm damage. A similar focus has also been adopted for soil erosion issues in New Zealand (Blackie, 1992). Subsidization and implementation of soil conservation measures have primarily been justified through maintenance or improvement of farm productivity levels. Estimates of the off-farm damages in recent decades have indicated that soil erosion reductions may benefit downstream users more than those on-farm (Crosson, 1984; Clark *et al.*, 1985; Ribaudo & Young, 1989; Fox *et al.*, 1995).

It is important, but particularly difficult, to provide estimates of off-site costs for targeted erosion control research and policy. There is often a lack of private economic incentives for land users to implement erosion control measures that surpass the level required to mitigate on-farm erosion damages (Ribaudo & Young, 1989). This leads to externality problems where addressing off-farm impacts becomes a public good issue. Such a form of market failure heightens the need to estimate the level of on and off-site damages, to prompt national policy makers to consider 'public' responsibilities for erosion damages.

The primary objective of this project is to estimate the national cost of soil erosion and sedimentation as a means of developing a comprehensive inventory and relative ranking of impacts.

In the process of fulfilling this objective several other outcomes are anticipated. First, to identify what *data currently exists* on the costs of soil erosion in New Zealand, and to ascertain where the *knowledge gaps* occur. Through the identification of the aggregated costs of soil erosion, and the relative contribution to these costs from individual effect categories, recommendations can be made for *future policy directions*. Highlighting categories of greatest economic cost is useful to indicate where research, advice or incentives may be targeted for greatest marginal damage reduction. Conversely, identifying knowledge gaps will show the 'holes' in current policy that need addressing. Additionally, a national estimate of costs will raise awareness of, and trigger increased discussion on soil erosion issues.

2 Method

2.1 Previous approaches

In 1985, Clark *et al.* conducted the first national investigation of the off-farm impacts of soil erosion in the United States. For their analysis, Clark *et al.* (1985) split off-farm impacts into in-stream and off-stream categories (Table 2.1.1). The $6.1 billion ($US1980) point estimate of annual off-site erosion costs calculated in the report has been criticized by several authors (Ribaudo, 1986; MacGregor *et al*., 1991; Crowder, 1987; and Smith, 1992). Criticism stemmed from the methodology and data sources used and the relative lack of precision. To some degree the criticism was unwarranted because Clark *et al.* had explicitly discussed the validity and precision of their estimates in some detail. In particular, they placed considerable emphasis on a value range within which costs fell rather than the point estimate seized by their critics. Their primary objective, as is ours, was to identify the order of magnitude of the problem and the relative importance of the various contributing factors.

The US study helped guide the identification of impacts for this project, and while the specific figures themselves may not be useful in a New Zealand context, the facts that recreational damages, for example, were found to be the largest category and biological impacts were considered too difficult to measure, provides an indication of possible issues of importance in this study. Clark *et al.* also provide ideas of potential data sources for erosion-related costs.

Table 2.1.1:
Clark, Haverkamp and Chapman (1985) – Off-farm impacts of erosion in the US

Impacts	Description
In-stream	
Biological	Effects on aquatic flora and fauna
Recreational	Effects on fishing, boating, swimming, number of accidents
Water-storage facilities	Lost storage capacity, contaminants
Navigation	Dredging, accidents, delays, engine damage
Other in-stream uses	Commercial fishing, preservation values, hydro turbine abrasion, decreased capacity
Off-stream	
Flood damage	Increased flood height/volume, reduced productivity, lost lives
Water conveyance facilities	Sediment removal, maintenance costs, weed control
Water treatment facilities	In addition to filtration
Other off-stream uses	Costs to industrial/municipal use, irrigation

In contrast to Clark *et al.*, this study is designed to estimate both on-site and off-site erosion damage costs. Clark *et al.* focused only on the latter, and while several papers used their data to investigate other aspects of off-site soil erosion, there appears to have been no further attempts to undertake such-large-scale damage estimations.

Significant differences obviously exist between the United States and New Zealand. Our active geology, small population and strong agricultural base ensure that any framework for this country would be different in focus from the one developed for the United States. Clough and Hicks (1992) emphasise this in producing a comprehensive categorization of New Zealand soil degradation effects (Table 2.1.2). While their division of the forms of degradation into on-site and off-site impacts follows that adopted in previous work, impacts are listed in a higher degree of detail. However, the diffuse and often imprecise form in which soil erosion costs can be obtained make it difficult to estimate costs at such a fine level of detail.

One important contribution of Clough and Hicks' framework is to identify the marginal impact soil erosion has on the level of costs attributable to flooding. The sediment carried in flood waters can contribute to increased flood risk, increased water filtration costs and reduced aquatic production.

Table 2.1.2: Clough and Hicks (1992) – Effects of soil degradation in New Zealand

Forms of degradation	Description
On-site	
Reduced vegetative production	Pasture loss, lower crop yields
Lowered animal performance	Reduced feed conversion, decreased health
Damage to fixed structures	Fences, tracks, bridges, dams
Disruption to site operations	Changed stock rotation, increased transport
Off-site production effects	
Reductions in adjoining site outputs	Spread of pests
Processing losses	Value added on lower output
	Lost scale economies
Off-site community/environmental effects	
Increased sediment loading	Increased flood risk
	Increased lateral erosion risk
	Increased water filtration costs
	Reduced aquatic production
	Reduced aesthetic amenity
Visual detraction of slip scars	
Increased dust nuisance	Wind-eroded soil
Off-site transitory effects	
Infrastructure disruption	National utilities and transport

2.2 The approach of this project

The lessons learnt from reviews of past approaches in this field lead our framework to be designed to identify the main impacts of soil erosion, but to keep the level of detail consistent with the potential data sources available (Table 2.2.1).

In terms of data collection, the initial research approach, involving a literature review of relevant soil erosion research in New Zealand, proved largely unhelpful for providing the type of data required for many of the damage categories. Past storm events have spurred some reports into damage costs; however, it was difficult to extrapolate such spatially and temporally point-sourced information to a national scale. Such localized information that identified the scope and scale of erosion damage, when evaluated in conjunction with the approaches used in previous erosion cost estimates, did, however, help the production of our framework.

Table 2.2.1: Framework for economic costs of soil erosion to New Zealand

Effects	Explanation
Soil erosion effects	
Agricultural production loss	Reduction in pasture and crop productivity from soil loss
Farm infrastructure damage	Cost of repairs to tracks, bridges and fences
Residential properties	Loss to residential structures from landslides
Road/rail infrastructure damage	Landslide erosion damage to national road and rail network
Utility network damage	R & M of telephone and electricity network
Recreational facility damage	Repair of walking tracks, huts, public facilities
Loss of visual amenity	Aesthetic impact of slip scars
Other	Farming confidence
Sediment effects	
Increased flood severity	
- Insured loss	Flood costs covered by public or private insurance
- Production loss	Loss of production due to sedimentation on flood plain
Reduced water quality	
- Consumption	Costs of filtering sediment from urban drinking water
- Processing	Filtering costs, loss of machinery efficiency, increased wear
- Recreation	Loss of fishing days, swimming, boating
Biological degradation	Loss of aquatic habitat
Dredging	Sediment removal from : ports, irrigation canals, hydro dams/canals, storage dams
Other	Dust nuisance

When the lack of published data on national scale soil-erosion costs became apparent, the research focus moved to identification of organisations that might hold data on each of the designated impacts. Examples are the Earthquake Commission of New Zealand, which is responsible for covering landslip damage to residential properties, and Transit NZ, which is responsible for repair of the national roads network affected by erosion.

3 Results

The overall framework and results currently obtained is presented in Table 3.1. The following section outlines the processes involved in obtaining the cost estimates.

3.1 Direct effects

3.1.1 Agricultural production loss

Our assessment of on-site effects of soil erosion in agriculture is based on the limited number of damage estimates for major storm events published in reviews (Clough & Hicks, 1992; Harmsworth & Page, 1991) and in storm-specific damage reports (Basher *et al.* 1997 and 1999; Hicks, 1988; Hicks *et al.*, 1993; Korte, unpublished). Most of the data contained in the former are concerned with characterizing the erosion damage while that in the latter, generally prepared to support applications to central Government for assistance of some kind, focuses on the economic costs of damage.

In most cases farmers, agricultural consultants, scientists or valuers have made estimates of the costs of damage soon after the event. In only one case was a follow up analysis done (Hicks *et al.*, 1993). Farmers were interviewed again 10 months after the event to check the consistency of their earlier predictions of the costs incurred. While the revised data varied little from the initial estimates (within 2%), detailed analysis of the farm accounts from six properties failed to show as marked an influence on financial performance as was suggested by the surveys. Although the authors offered a range of reasons for this, it raises questions about the accuracy of farmer-based –erosion damage estimates, particularly when they are made soon after the event and while the immediate effects of the event are foremost in people's minds. Nevertheless, point-based estimates of erosion damage are often the only available data.

On-site costs of soil erosion have been estimated for two generic forms of erosion – mass movement (land slipping, gully erosion, earth flow, debris avalanches) and surface erosion (rilling, sheet wash, wind erosion). Costs of mass movement erosion have been split into damage costs and costs of lost productivity but have been estimated across all agricultural land uses. No data have been found on the economic costs of mass movement erosion in production forestry. Lost productivity costs alone have been calculated for surface erosion, because damage to structures from surface erosion is uncommon. Separate estimates have been made, however, for productivity losses in pastoral farming and in arable cropping. In the latter case, the regular cultivation of the soil surface leads to significantly increased rates of surface erosion.

a) Mass movement erosion

Damage costs

An estimation technique proposed by Forbes (1980) has been used to transform cost data from individual storms of varying return periods (magnitudes) into an annual estimate of the expected level of erosion cost. Damage from storms is characterized by the area of scar damage generated. Using Forbes' (1980) approach an annual expected area of eroded land can be estimated as a percentage of land susceptible to mass movement erosion. This estimate, combined with a generalisation of Korte's (unpublished) regression between scar area and infrastructural damage, and Clough & Hicks' (1993) estimate of agricultural land susceptible to mass movement, has been used to calculate an expected annual national damage cost of mass movement erosion.

Costs of lost productivity

De Rose *et al.* (1995) have published an expected pasture production recovery curve for areas lost to slipping in Taranaki. A transformation of the expected pasture production curve into financial productivity using average gross margin and stocking rate data for pastoral farming (Oliver & Burtt, 1995) has been used to estimate the present value of the lost productivity caused by mass movement erosion. To estimate the annual value of lost productivity this present value is applied to the expected area of newly eroded land.

2) Surface erosion

Costs of lost productivity in pastoral agriculture

An estimate of lost productivity in pastoral agriculture due to surface erosion has been generated by applying an average annual loss in productivity due to soil loss derived from data in Clough and Hicks (1992) to their estimate of total agricultural land susceptible to surface erosion less approximately 600 000 ha currently in arable production (Molloy, 1988).

Costs of lost productivity in arable cropping

While there are a reasonable number of estimates of annual soil loss from arable land due to surface erosion processes, there is little quantitative research on the impacts of such loss on productivity. In practice, fertiliser and management inputs mask much of the loss. Clough and Hicks (1992) quote an array of studies that Hicks later used to estimate losses in productivity on cropped land (Hicks 1995). All these studies, however, quote changes in productivity due to a change in management practice. While the increase in production quoted in the studies is partly due to reduced soil erosion, none of the studies break the improvement into its contributory causes. For this reason we are unwilling to provide an estimate of the costs of lost productivity in arable cropping. However the costs are likely to be significant. With an average gross margin across all arable crops in the order of $750/ha, a 0.5% loss in productivity per annum has an estimated economic cost of $22 million per annum.

3.1.2 Residential property damage

The Earthquake Commission of New Zealand is responsible for covering insurance claims on damage caused by landslides, on and around residential buildings. While the Commission has been responsible for such damage costs for several decades, a change in accounting and recording systems from 1997 meant that only one full financial year of data, 1998/99, was readily available, in addition to parts of the 1997/98 and 1999/2000 years. Officials at both EQC and Transit NZ commented that 1998/99 had produced exceptionally high erosion-related costs. An annualized monthly average cost has therefore been used to give the best possible estimate from the data available.

3.1.3 Road and rail infrastructure damage

Previous reports, such as Ericksen (1986), have indicated that damage to road and rail infrastructure from erosion is significant. Transit NZ and Tranzrail were contacted for a current annual national average of these costs. Transit NZ is responsible for the road network in New Zealand, and Tranzrail owns the rail network.

While Transit NZ has no specific category for the impacts of soil erosion, their expenditure on ‘emergency works’ is primarily due to erosion-related damage. There are also some relevant costs incurred under the ‘preventative maintenance’ budget. The combined spending on these two areas in 1998/99 was $36 million dollars. However it only amounted to $14 million and $12 million in the 1996/97 and 1997/98 fiscal years respectively. Additional years of data have currently been requested, but an estimate was made for this paper, taking into account the exceptionally high 1998/99 year, and assuming that 100 percent of emergency works are erosion related.

Tranzrail, which used to be the state-owned Railways Department, is privately owned and operated. As with Transit NZ, Tranzrail does not specifically record costs of erosion, but does account for ‘weather-related incidents’. An estimate of these costs was obtained for one of the three accounting regions over the last four financial years. Upon advice from Tranzrail management, the average figure obtained was simply multiplied by three to obtain a national annual average.

3.1.4 Utility network damage

Storm damage reports have indicated that, due to soil erosion, significant damage can occur to electricity and telephone networks, primarily in the form of pole disturbance. Before the recent restructuring of the electricity industry, individual power boards were responsible for energy retail and reticulation. Privatisation and restructuring of the electricity industry in New Zealand has lead to commercially owned companies being responsible for line maintenance. Approximately 35 companies are individually responsible for electricity line maintenance throughout New Zealand. Two rural companies were asked to estimate the amount they spent on line maintenance due to erosion. A figure of five to six poles per year per region was postulated, at an average cost of $2,500 per pole. Assuming constant damage costs across all rural line companies, an interim national cost estimate of utility network damage is $300,000 per annum.

Given the level of costs incurred by line companies above, it is expected that Telecom NZ, which operates most of the telephone line network in New Zealand, would have similar scale costs. However, at the time of writing the company was still working to provide an estimate.

3.1.5 Recreational facility damage

The Department of Conservation (DoC) manages a national conservation estate of nearly one-third of New Zealand’s land area. Public facilities on the estate include over 970 huts, 11 000 kilometres of tracks and 1070 road and track bridges. The Department spends $42 million annually on ‘Provision of recreation opportunities: access, facilities and services’, which includes maintenance on tracks and structures. DoC officials are currently attempting to determine the relevant erosion costs, and in the absence of firmer figures an estimate of these costs was obtained for this paper. We have conservatively estimated that one percent of expenditure on access, facilities and services would be due to erosion-related matters, giving an annual cost of damage of $420,000.

The Department has recently completed an inventory of visitor facilities, and developed a new ‘Visitor Asset Management’ database. Although this is not currently operational, the intention is that the computer-based system will allow detailed interrogation of the database by keyword within two years permitting more accurate analysis of the causes of failure or damage to facilities.

3.1.6 Loss of visual amenity

Clough and Hicks (1992) identified the visual impact of erosion scars on land users and tourists as a potential effect of soil erosion. Anecdotal evidence from major storm events suggests that the visual and psychological effect on farmers of widespread slipping is significant and debilitating. The initial visual estimates of damage are frequently far higher than the actual damage because of the spread of debris from shallow landslides. In recent years, commentators have also raised the possibility of the obvious visual impact of mass movement erosion triggering environmentally based trade sanctions against New Zealand’s primary produce. This aspect has therefore been included in the assessment framework; however, no quantitative information was found to indicate the present or potential costs involved.

3.1.7 Other

There are other possible impacts related to soil erosion that are not addressed in the above categories, such as the potential loss in farmer confidence due to farming of erosion-prone land. As with the loss of visual amenity, however, no values could currently be placed on this factor.

3.2 Indirect effects

3.2.1 Increased flood severity

The direct supply of sediment to watercourses during storm events and the aggradation of watercourses by sediment from previous events increase the flood height and severity of damage caused by flooding.

Insured loss

Flood losses for 1980 published by Ericksen (1986) in an analysis of the trends in flood damage from 1969 to 1980 have been extrapolated to provide a preliminary basis for estimating the increased cost of damage from flooding caused by erosion. Twenty percent of flood-damage costs have been used as an estimate of the marginal contribution of soil erosion and sedimentation, based on estimates quoted in Clark *et al.* (1985). More recent data are currently being sought from the Earthquake Commission and private insurers.

Production loss

The loss of production due to sedimentation of flood plains may have a significant impact on individual farmers/growers in flood-prone areas. The effect of major floods on productive flood plains can be dramatic, e.g., losses to viticulture and cash cropping farms on the Waipaoa flood plain in 1988. The regular losses at a smaller scale on recent river terraces, however, may be more significant. These well-drained, flat, fertile areas are often the most productive areas on hill country sheep, beef, and dairying properties, and are often used for calving or lambing. The loss of these areas can be more significant than their absolute area, given their role in the annual feed budget and stock movement cycle. A value is yet to be identified for this impact.

3.2.2 Reduced water quality

Consumption

The impact of sediment on urban water supplies is primarily the cost of filtration to remove it. Our preliminary estimate of these costs is based on the amount of filtering required at the Palmerston North water treatment plant. The local authority responsible for this plant does not separate the cost imposed by sediment from soil erosion, and personnel at the plant indicated that this would be the case for most such water treatment facilities in New Zealand.

A water supply engineer estimated that 10% of the total treatment costs can be attributed to sediment filtration. Assuming constant per capita costs for supplying water in New Zealand cities (population centres over 30 000), and that rural water is not supplied through centralised systems, a national estimate can be made. Christchurch city has been excluded because its source of water is solely from bores, which generally do not require sediment filtration. Using this approach, our estimate of the national costs of filtering potable water supplies is $2.8 million.

Processing

The filtration and damage costs incurred from sediment in water used in the processing industry are also potentially significant. At the time of writing no estimates had been ascertained.

Recreation

Sediment in waterways has an impact on recreational opportunities, such as water contact sports and fishing. Anecdotal evidence suggests significant costs of lost fishing days to professional fishing guides from turbid streams and rivers. Lost recreational fishing days to the general public may be even more significant. We are aware of another paper at this conference on the latter subject, and a number of willingness-to-pay studies for recreational fishing. These are not matched, however, by data on the loss of days for fishing or other recreational pursuits as a result of turbidity, and so we are not able to estimate the cost of these losses at this point.

3.2.3 Biological degradation

The impact of sediment on aquatic flora and fauna is primarily a non-market cost, although there are some commercial implications for shellfish production and inshore marine fishing. Although this category may be expected to contribute a significant cost to the overall erosion damage estimate, little work has been conducted to attribute economic values to biological degradation from sediment.

3.2.4 Dredging

Ports/marinas

Figures received from a large New Zealand port indicated that in total commercial ports in New Zealand dredge about 500 000 m^3 of sediment annually in their maintenance operations. A port hydrologist suggested that the costs for dredging varied from about $5/$m^3$ to $40/$m^3$, but that an average cost per cubic metre for all the port dredging is $15/$m^3$. These figures suggest a national estimate of port dredging costs in the order of $7.5 million.

Irrigation canals

Sedimentation of irrigation canals causes costs in the form of dredging and irrigation machinery wear. The annual national dredging cost estimate was based on costs from a major irrigation scheme management company, and converted to a value per hectare of land irrigated. While further refinement of the figure is expected, we are reasonably confident in the current order of magnitude.

Hydro lakes

Through contact with several of the electricity generation companies, it was confirmed that sediment does generate additional costs in New Zealand hydro-electricity schemes. These are due both to loss of dam capacity and wear on turbines. At this stage, however, none of the companies have been able to place an economic value on the impact. A cost estimate was still sought at the time this paper was written and is expected to be included in the final report.

3.2.5 Other

There are additional indirect costs that are smaller in scale relative to those discussed above, or are significant in specific regions. An example is the costs imposed from wind erosion in the form of dust nuisance on downwind properties. This is only an issue in Canterbury, Wairarapa and Hawke’s Bay, and while some commentators have indicated costs from individual events of up to $200,000, the impacts are generally too diffuse to estimate.

3.3 Regional council soil erosion spending

Direct expenditure on soil conservation programmes has been estimated from the 15 Regional Council and Unitary Council annual reports for the year ending June 1999. As far as is possible, expenditure on statutory planning has been excluded. A proportion of expenditure on maintaining and enhancing flood and catchment works is included (30%), as are proportions of monitoring and environmental education initiatives from some Regional Councils where they include soil conservation initiatives. This estimate is almost certainly an underestimate as it excludes all expenditure that is completely independent of Regional Councils. This may not, however, be significantly large, given that many Councils have easily accessible subsidy programmes in place. Total public and private expenditure in these programmes is included in the estimate.

Table 3.1: Economic costs of soil erosion and sedimentation in New Zealand (interim)

Effects	Cost ($millions) $NZ1998
	INTERIM
Direct	
Agricultural production loss	31.4[3]
Farm infrastructure damage	6.2[2]
Residential properties	4.3[3]
Road/rail infrastructure damage	18.2[2]
Utility network damage	0.3[3]
Recreational facility damage	0.4[2]
Loss of visual amenity	-[4]
Other	-[4]
Indirect	
Increased flood severity	
Insured loss	
Production loss	14.0[3]
Reduced water quality	-[4]
Consumption	
Processing	2.8[3]
Recreation	-[4]
Biological degradation	-[4]
Dredging	-[4]
Ports/marinas	
Irrigation canals	7.5[3]
Hydro lakes	0.4[2]
Other	-[4]
	-[4]
Total	**85.6**[3]
Regional authority spending on soil erosion control/research	26[1]
Grand total	**111.6**[3]

[1] Final estimate, reasonable confidence in size and precision [3] Incomplete
[2] Final estimate, required significant generalising assumptions [4] No estimate to date, significant impact

Note: A significant non-quantifiable effect is the loss of cultural values associated with degradation of the landscape, reduction in water quality, and loss of traditional food sources.

4 Discussion

The project has developed sufficiently for some points of discussion to become apparent. A major objective of the project was to identify the types of costs generated by soil erosion in New Zealand and the availability of data to quantify these. As demonstrated in the preceding section, good quality data has been difficult to collect. We suggest a number of reasons for this:

4.1 Lack of institutional incentives for maintaining this information

The organisations that bear much of the economic damage due to soil erosion do not generally appear to be aware of the specific magnitude of these costs. None explicitly identify erosion costs in their accounting or management systems, nor is a single person clearly responsible for reviewing the impacts. There could be a variety of reasons for this.

For some, the problem might not be significant enough to warrant time and effort in isolating soil erosion as a cause of damage. This is probably the case with many of the electricity line companies where fewer than five power poles are affected per year. For others, where the costs might be more significant, e.g., the Department of Conservation, that there is little preventative action possible may act as a disincentive to determining the precise cause of any particular damage. The conservation estate is concentrated in mountainous, erosion-prone terrain, and the Department has a policy of not interfering with natural processes. Aside from keeping huts and tracks away from obvious erosion areas there are few preventative works the Department can carry out to minimise their annual soil erosion costs.

4.2 Costs of data collection

As well as problems of data availability, it is clear that the existing data are less accessible than in the past. This is largely the result of the regionalisation of responsibility for environmental management, and the sale and fragmentation of national state monopolies.

4.2.1 Decentralisation of responsibility for environmental management

Less than two decades ago, the National Water and Soil Conservation Authority (NWASCA) administered a national budget for soil conservation, drainage and flood prevention. This was then distributed to a number of regional catchment authorities. Since the late 1980s, the funding of environmental management issues has been devolved to local government, specifically 15 regional or unitary councils. This leads to an obvious increase in effort required to aggregate information on national soil conservation spending. The more significant difficulty is in rationalizing the quite diverse range of approaches to management and funding that are used. Some regional councils budget and manage by issue or environmental effect, others by statutory function, and others a hybrid approach. It is therefore quite difficult to isolate expenditure on a particular environmental issue across all Councils.

4.2.2 Privatisation of major utilities

The privatisation of major utilities has similarly added to the number of commercial organisations managing the effects of soil erosion. It is not yet clear whether the scale of these smaller units will improve or reduce the quality of management and financial data collected. The privatisation and fragmentation of the former New Zealand Forest Service has arguably seen a marked decline in the amount of management information collected and utilized by some of the companies now managing the resource. Anecdotal evidence suggests that this is primarily an issue of scale with the largest companies maintaining management systems at least as comprehensive as the former parent.

4.2.3 Commercial sensitivity

An additional factor constraining the level of financial information available from newly formed competitive state-owned enterprises, or their private equivalents, is the concern for commercial sensitivity. An example of this is found in a series of flood events within a catchment system resulting in a hydroelectric power-generating company receiving heavy criticism for allowing properties to be inundated. Residents argued that a major contributing factor was reduction in storage capacity of a reservoir due to sedimentation and that the company had taken insufficient remedial action to maintain the reservoir capacity. Not surprisingly, in the midst of a public fracas, the company concerned was reluctant to provide detailed information about the costs associated with sedimentation.

4.3 Quantification difficulties

A third major issue in collecting data for this study has been the difficulty of quantifying some effects that, in economic terms, are likely to be significant costs of soil erosion.

4.3.1 Diffuse nature of effects

Many damaging effects that occur as a result of soil erosion are small and diffuse in nature and are extremely difficult to aggregate. Their significance may be collectively large at a national scale, yet small at the individual level. Small-scale sedimentation effects on flood plain production discussed earlier, is a case in point. While there are hundreds of hectares of land affected by overtopping and sedimentation each year, each farming unit has only a proportion of their total land area affected. Few regions have a monitoring system in place at a resolution that picks up events of this type.

4.3.2 Lack of economic assessment of physical research

There is a considerable history of geomorphological research into the frequency and severity of erosion events in New Zealand. Much of the focus, however, has been on quantifying the impact of particular storm events. In more recent years long-term erosion rates have been studied but at a spatial scale ~~that~~ much larger than the average size of land management units. With the exception of work by DeRose *et al* (1995) and the work that preceded it, there has been little attempt to quantify the long-term economic effects of erosion at a scale that is appropriate to the business enterprises – farms, forests, orchards – that are affected by it.

Data collected for this study suggest that the annual expected cost of lost production and erosion damage to the average pastoral farm is relatively small. Consequently, observed strategies like compensatory applications of fertiliser rather than widespread conservation planting may be economically rational. Assessment of storm-damage data suggest that damage costs on individual properties from intense rainfall events can be very high. There is little research, however, addressing the probability of such damage and appropriate risk management strategies for farm managers.

Regional Councils are taking a range of approaches to addressing soil conservation. The major investment is in maintaining large-scale catchment and flood prevention programmes with a mix of levy and public funding. Some Councils invest significantly in grant schemes, others in education and facilitation. Without the necessary economic research, it remains difficult to determine the effectiveness or efficiency of these programmes.

5 Conclusions

This study is a first attempt to quantify the economic impacts of soil erosion in New Zealand. In developing a method for this study, the unique nature of this country had to be taken into account. New Zealand is geographically, environmentally, topographically and economically distinct from the United States, where the only other major effort of this type was attempted. Several characteristics of the New Zealand experience are brought to light in such an exercise.

One such characteristic is the difficulty in delineating divisions between natural and man-made erosion or between agricultural and urban effects of erosion. Thus no attempt was made in this study to make such distinctions. Similarly, our relatively steep, short rivers and low population density see erosion damage most strongly affecting infrastructure and agricultural production loss rather than sedimentation effects (recreation, water storage, navigation) as in the United States.

Another characteristic of the New Zealand study is the relative paucity of data from which to build the estimates. Our decentralised system of erosion control and the privatisation of major utilities have contributed to a fracturing of the data available for assessment. In addition, the diffuse nature of these effects allows little incentive for individual companies or environmental management organisations to collect specific data on soil erosion damage.

As outlined in this paper, the collection of data was quite difficult, and the accuracy of many of the figures is questionable. Accordingly, even the final value estimate that will arise from the completed work will have to be viewed with significant caution. It is our intention that the result never be considered more than an order of magnitude estimate. That is, even if the interim $112 million result we show here was the final value, we would stress that we can say nothing more specific than that the *real* value is likely to be closer to $112 million than it is to $1120 million. If there is any room for certainty in the estimates, it is that the actual value will almost certainly be larger than our estimate, as we have always striven to err on the conservative side when estimating.

However, if we assume that the interim value is approaching the final value of our research, the question then arises as to what significance this may have for soil erosion policy in New Zealand. The first observation we make is that current expenditure on the prevention of additional erosion is approximately $26 million, a significant proportion of the value of our remaining damages.[1] While we cannot comment on the efficiency of the existing expenditure, the relative magnitude of the figures does not suggest that immediate large reductions in damage could be achieved by increasing expenditure on soil conservation. This is particularly true when one considers that the geology of this country has a natural propensity toward major events of soil movement.

But neither does that mean that no gains are possible. Rather, we suggest that consideration of individual conservation policies or projects would be a better way to approach efficient new investments in soil conservation.

[1] This observation should be acceptable whether the final value remains near $86 million or settles out at several times that number.

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