Proceedings of the New Zealand Grassland Association 45: 66-76 (1984)

SOIL SLIP EROSION AS A CONSTRAINT TO HILL COUNTRY PASTURE PRODUCTION

N.A.TRUSTRUM, V.J.THOMAS and M.G.LAMBERT
Soil Conservation Centre, MWD, Palmerston North
Applied Mathematics Division and Grasslands Division, DSIR, Palmerston North.

Abstract

The results and implications of applying remote sensing techniques together with pasture measurements to quantify the influence of soil slip erosion oh hill country pasture productivity in the Wairarapa are reviewed.

Sequential aerial photographs were used to identify, date, and measure the area of slip scars of different age. The reduction in potential productivity of hillslopes due to erosion was then determined by measuring the pasture growth rates of the different aged slips (and uneroded ground) and integrating these with the proportions of the hillslopes of each age class.

Three years of pasture measurements in the Wairarapa hill country showed that although slips revegetated rapidly over the first 20 years to within 7080% of the uneroded productivity, further recovery was slow. Our evidence suggests that these man-modified forest soils, once eroded, may never regain the same potential for agricultural production under a pasture regime. Reduction in pasture production associated with erosion was most severe in summer and mid-winter when farmers have the highest risk of major feed deficits.

Since native forest removal, the reduction due to erosion in potential pastoral productivity, integrated over whole hillslopes, has reached 18% on these hillslopes. An estimation of the extent to which improved farming technology has probably masked this reduction in potential productivity is discussed.

On hillslopes where severe erosion occurs continually, farmers will be faced with increasing difficulty in maintaining animal production levels unless soil conservation and farm management strategies are designed to further mask the impacts of erosion and thereby prolong the viability of pastoral agriculture on such hill country.

Keywords: soil slip erosion; pasture production; hillslope; potential pasture production; hill country pasture; erosion rate; farm management technology; physiographic areas; fertiliser level.

INTRODUCTION

Quantification of the effects of erosion on pasture productivity is required if agricultural policy makers are to predict the relative long term economic and environmental effects of alternative hill country land management strategies (Perrens & Trustrum, in press). Poor management decisions may result in an irreversible loss of the soil resource, or conversely its under-utilisation, and therefore, a loss of income to the farmer and supply to the consumer.

There has been much attention focussed on the hill country over recent years as there is considered to be a large unexploited potential there for agricultural production (Brougham & Grant 1976, NRAC Hill Country Working Party Report 1977, Taylor 1982 and Joblin 1983). If further expansion of agricultural production is going to occur in the hill country, a clear understanding of both environmental and socio-economic constraints to pasture production is required.

Animal production is largely influenced by rate of pasture production (Clark & Lambert 1982). In many hill country areas the variability of pasture production between years and seasonally within any year, can be the greatest factor limiting stocking rates as farmers usually stock for the ‘harder’ years to minimise risk.

Many environmental factors such as climate, aspect and soil characteristics influence the variability of pasture production of hillslopes. Erosion is considered to be an important factor influencing the formation and variability of hillslope soils, thereby affecting pasture productivity through reduced nutrient and water supplying power and poorer soil structure.

Although soil conservation works have been applied in New Zealand since the 1940s there has been very little work done to quantify the impact of soil slip erosion on soil productivity and, therefore, there is a paucity of information on the effectiveness of different soil conservation techniques. Published work mainly refers to sediment yields from mountain and forest lands rather than to loss of soil as an agricultural resource on hill country (Mather 1982).

Despite the continuing denudation of hillslopes by erosion, improved farm management techniques often mask the impacts that such erosion is having. It is increasingly difficult to justify the application of soil conservation techniques while farmers can maintain pasture production levels through improved farm management technology which may include high inputs of fertiliser.

In this paper we review the results and implications of work done in the "seasonally dry" Wairarapa hill country to measure the rate of pasture recovery on soil slip scars and determine the reduction in potential productivity of hillslopes due to erosion. The probable extent to which improved farm management technology has masked the reduction in potential productivity of hillslopes is also discussed.

EROSION HISTORY OF HILLSLOPES

The terrain in the study area is steeply dissected by incised streams and is underlain by unconsolidated, tectonically deformed Tertiary sediments, characteristic of 55% of the North Island's pastoral hill country (NWASCO 1975-79). Over the years, intensive rainstorms and/or prolonged winter wetness have caused severe soil slipping over extensive areas: consequently hillslopes exhibit a complex pattern of different-aged erosion scars. These tend to coalesce on the headward side slopes and gully heads adjacent to ephemeral watercourses (Fig. 1). Sequential aerial photographs, taken since 1944 have enabled old regrassed scars, visible on the 1979 multispectral aerial photographs (Fig. 2A), to be dated and hillslopes divided into physiographic areas with different erosion histories (Trustrum & Stephens 1981, Trustrum et *al.*, 1983). The ages of the erosion scars which appeared on the aerial photographs were determined more exactly by relating them to known erosion events. In this way soil slip scars of six different age groups, and a debris accumulation zone, were mapped for each hillslope (Trustrum *et al.*, 1983).

EROSION RATE OF HILLSLOPES

Measurements of the long-term increase in area of eroded ground were taken on 41 hillslopes of varying aspect in the study area. The boundaries of the different aged scars, the accumulation zones and the perimeters of the hillslopes, were digitised so that the areas (and percentage of overlap) of the six age groups of slip scars, and the accumulation zones, could be calculated (Trustrum et *al.*, 1983).

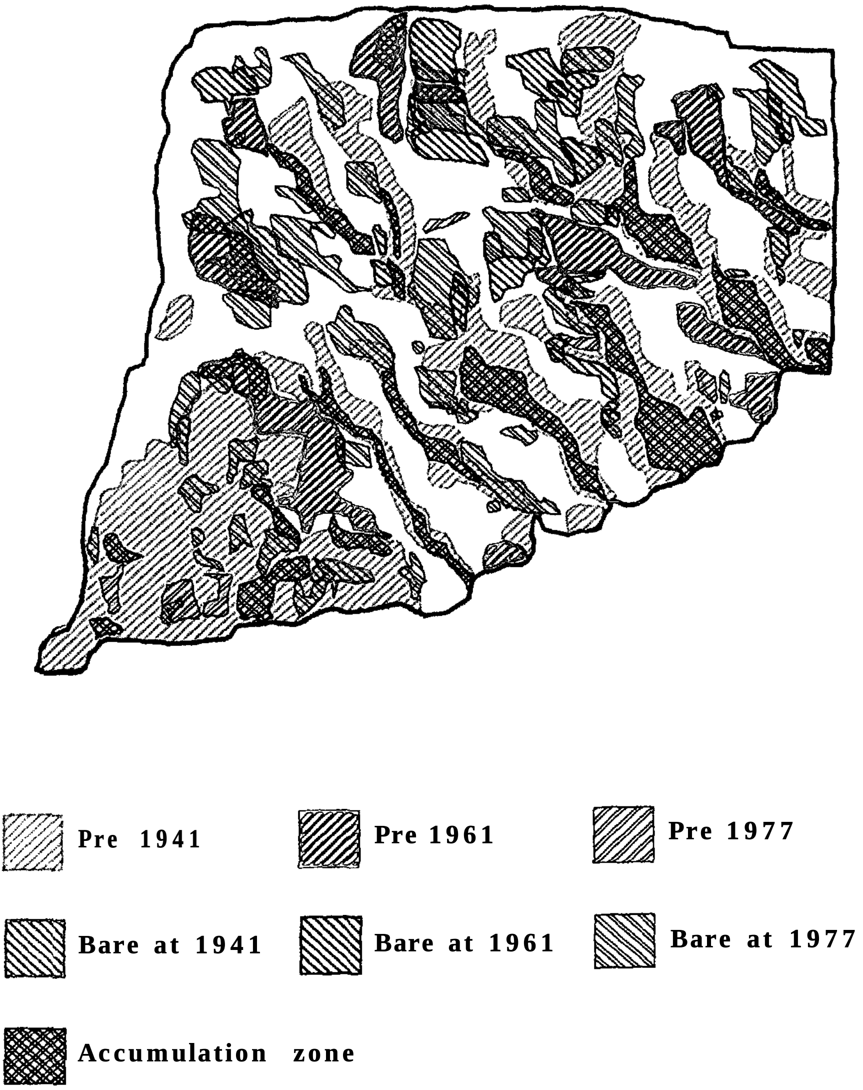
Results show that soil slipping initially does not recur on the same site, but shifts to adjacent uneroded ground with each successive erosion event, the different aged scars being more or less contiguous (Fig. 2B). On old regrassed scars, slipping does tend to recur; presumably as new soil profiles are formed on the

Figure 2: Spatial and temporal distribution of soil slip erosion scars on hillslope shown in Fig. I, in the Wairarapa hill country.

A. False colour composite print of multispectral aerial photographs taken in January 1979 showing 1977 scars (white colours), old regrassed scars (dark green) and uneroded ground (red colours). (Photo: Remote Sensing Group, Soil Conservation Centre, Aokautere, Palmerston North.

B. Computer plot of the Wairarapa slip erosion sequence at site in Fig. 2A.

Wairarapa soil slip erosion



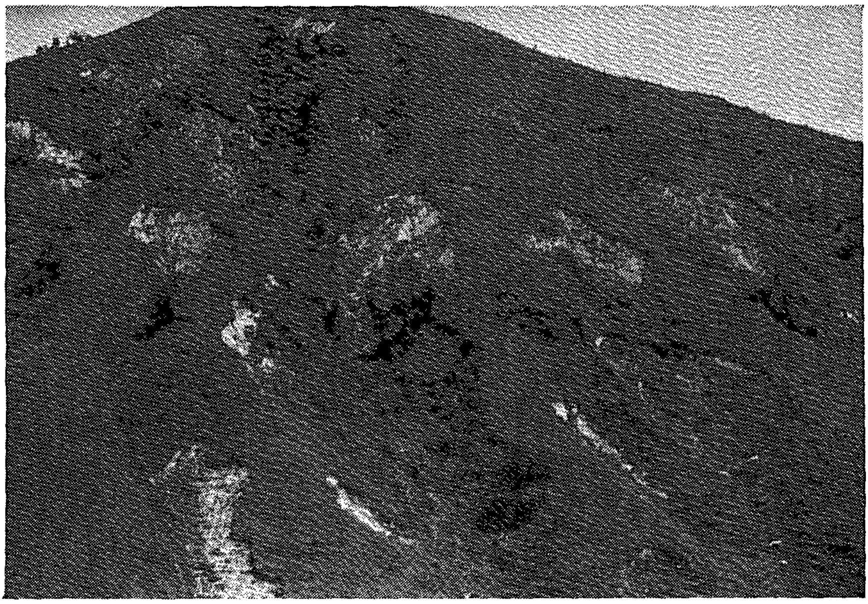


Figure I: Complex of different aged soil slip scars on a southerly facing hi//slope in the study area. 1977 scars are partially revegetated: photo taken in November 7979.

old scars they once again become susceptible to erosion. The relationship between the date of erosion event and corresponding increase in percentage of hillslope eroded, is illustrated in Figure 3. Trustrum et *a/.,* 1983 describes the assumptions used to interpolate the magnitude of erosion events which occurred prior to 1941. From this figure the rate at which the area of uneroded ground (no soil slip erosion since native forest removed) is being reduced, the 'erosion rate' was calculated. Up to 1938, 45% of the total area of the 41 hill slopes had been eroded and from 1938 to 1977 a further 11% was eroded giving a cumulative eroded area of 56% (44% of the hillslopes are as yet uneroded). The measured 'erosion rate' between 1938 and 1977 is 2.8% per decade. Of course, this 'erosion rate' will tend to decrease as the proportion of uneroded hillslope diminishes: on average, 45% of the 1977 erosion occurred on uneroded ground and 55% on previously eroded sites.

The rate of erosion measured over the last 45 years together with the frequency of erosion events recorded since c. 1870 (Trustrum *et a/., 1983)* suggest that the removal of native forest has had a significant effect on the landscape, inducing the present erosion phase and thereby affecting land productivity.

RATE OF PASTURE PRODUCTION ON SOIL SLIP EROSION SCARS

In 1979 a trial was initiated in the study area to measure the rate of pasture production on different aged soil slip scars and on uneroded ground, and so determine the trends of production loss, caused by erosion, and the long-term rate of Pasture recovery (Lambert *et a/.,* 1984). Results (Fig. 4) show that the pasture growth on recent 1977 scars is about 80% down (on average), compared

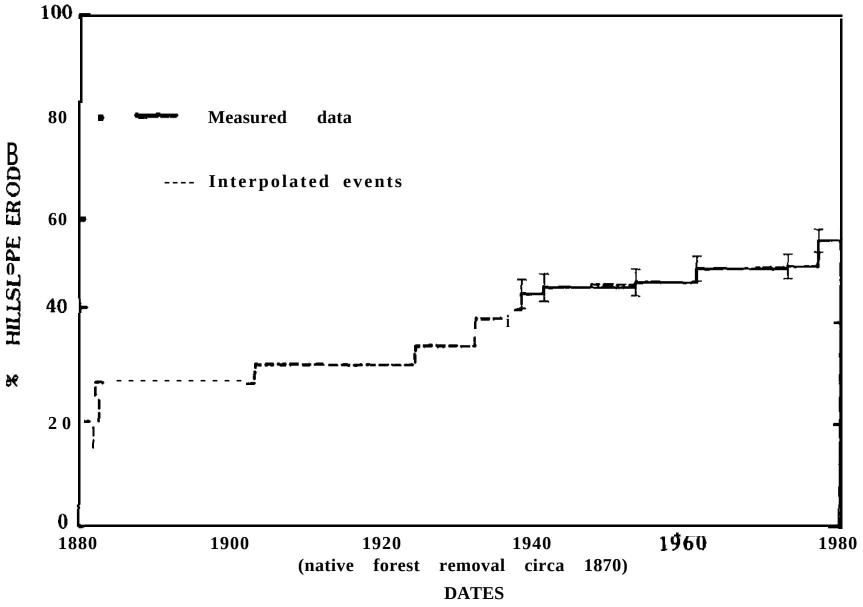


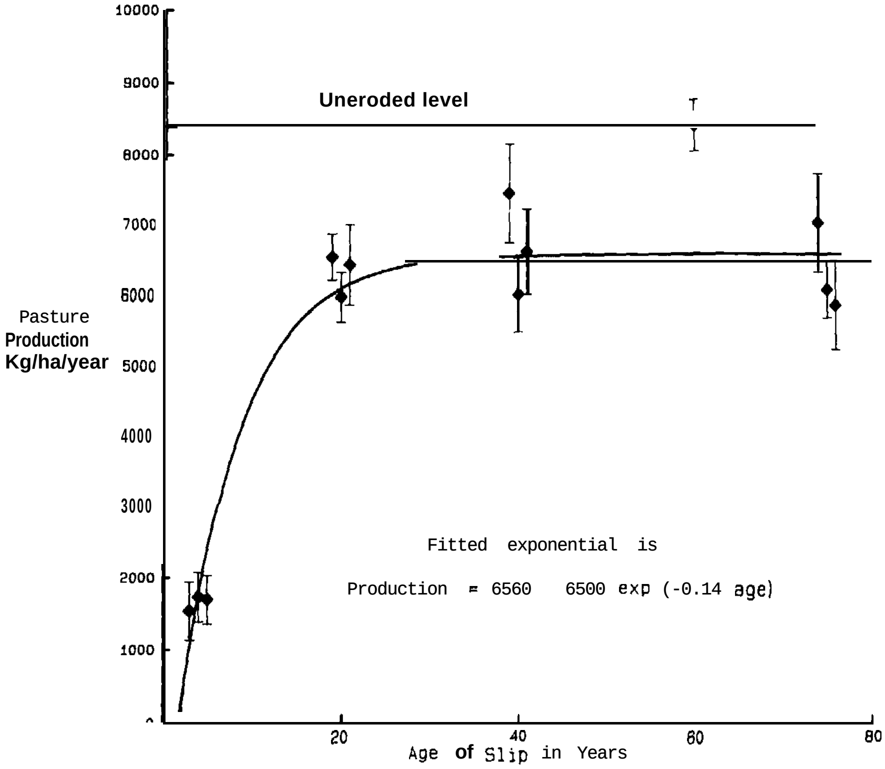
Figure 3: Relationship between the long term increase in percentage of hillslope eroded and erosion events. Mean of 41 hillslopes. Vertical bars represent the standard error of the mean.

to uneroded ground, and even after 50 years the pasture growth on old regrassed scars is on average 21% down.

Scars recover rapidly over the first 20 years to within 70-80% of uneroded productivity level (Fig. 4). However, there does not seem to be any indication of further recovery. Measurements of the nitrogen and carbon contents of top-soil on slip scars show a similar trend, appearing unlikely to attain levels of un-eroded sites. (Lambert *et al.*, 1984).

The uneroded ground is a man-modified forest soil. Our evidence suggests that once this is eroded it may never regain the same potential for agricultural production under a pasture regime. While the pastures on the slip scars probably respond well to the frequent application of mineral fertiliser, the formation of the organic content of these soils may take a long time, during which the soils will have impaired nutrient supplying power, poorer soil structure and reduced capacity to store plant-available soil water.

Depression of pasture production on erosion scars was most severe in summer time and in mid-winter (Fig. 5). In January, pasture growth on old regrassed scars (20-75 years old) shows a marked depression, attaining only 63% of un-eroded site productivity, with 1977 scars reaching only 18%. This is probably due to the reduced capacity of shallow soils on eroded sites to store plant-available water. A similar pattern of depression occurs in July. This depression of growth rates on slips in winter may be due to the lower growth rates on the legume-dominated pastures (Lambert *et al.*, 1984). These depressions in pasture production on erosion scars coincide with times of the year when pasture growth rates are at their lowest. Clearly, the impact of erosion on pasture production is



Pasture recovery curve

Figure 4: Rate of pasture recovery on slip scars of different age relative to productivity of unerodedground. Each point is the mean of 56 measurements taken over one year. Vertical bars represent the standard error of the mean.

greatest when farmers have the highest risk of major feed deficits.

REDUCTION IN POTENTIAL PRODUCTIVITY OF HILLSLOPES

The measured reductions in pasture production of different aged erosion scars were integrated with the proportionate areas of eroded ground of each scar age group to give a quantitative measure of the reduction in potential productivity (production expected from uneroded hillslope) of hillslopes due to erosion (Trustrum *et al., 1983).* These include both the reduction over the past four decades, and the inferred reduction since native forest removal (c. 1870). A computer program was developed to integrate the effects of sporadic erosion events with a continuous pasture recovery curve to provide a graph of continuing loss of potential pasture production (Fig. 6). Since native forest removal this reduction has reached 18% for these hillslopes. Care must be taken in using Figure 6 alone as a basis for predicting trends in future potential productivity. A mathematical model being developed to simulate the impacts of future erosion events will also

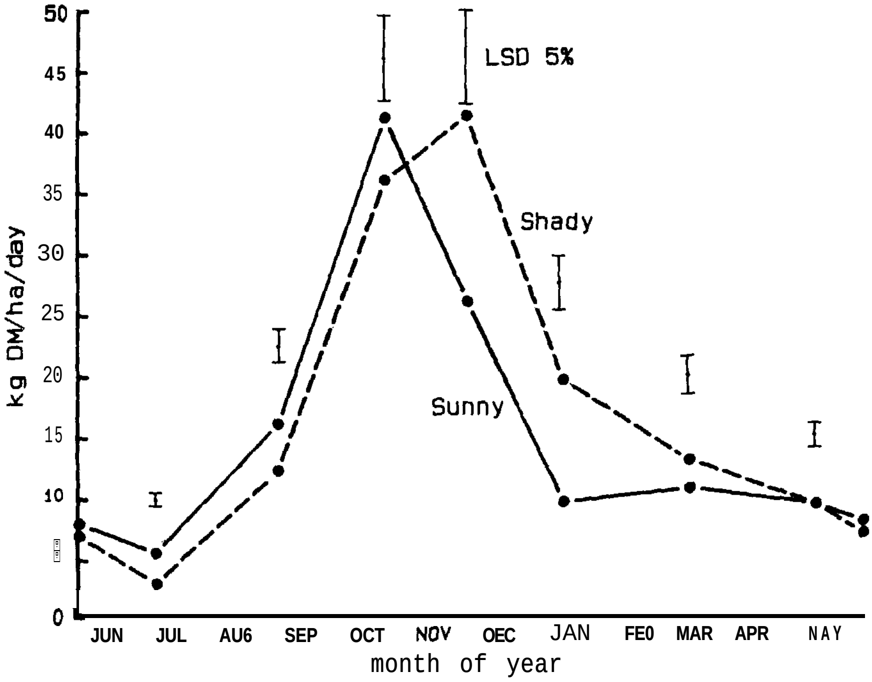


Figure 5: Pasture productivity on sites of different slip age relative to that on uneroded sites during the year. Means of 3 years of data. Vertical bar represents the LSD for harvest values.

consider the effects of many soil conservation and land management techniques on the rate of pasture recovery of scars and, therefore, allow the probable magnitudes of long-term reductions in potential productivity to be determined. Assuming a constant level of applied land management technology, the measured pasture recovery rate (Fig. 4) suggests that as the area of uneroded hillslope approaches 0%, the potential productivity of hillslopes will fall below the 80% level.

A compensatory effect of erosion may exist in terms of increased pasture production during the summer time on accumulation zones where there is more plant-available water compared to eroded ground. However, pastures developed on these zones are frequently buried by erosion debris from successive erosion events: the resulting losses in productivity probably offset the gains in other years, when feed quantities are likely to be less critical. (The validity of this assumption is currently being checked by measurement).

Hillslope units studied in this paper occur within landforms which represent 60% of the total areas of two 'hill country' farms (Stephens ef *al., 1983)* and, therefore, these results are not directly applicable to the "whole farm" situation.

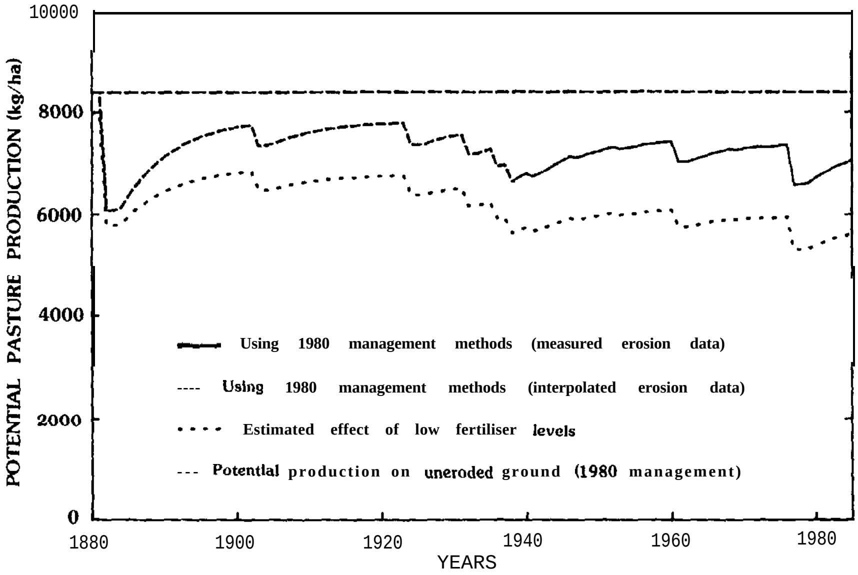


Figure 6: Effect of soil erosion on potential pasture production. The estimated effect of low fertiliser levels on the reduction in potential production of hillslopes is also *shown. Mean of 4 1 hillslopes.*

EXTENT TO WHICH IMPROVED FARM MANAGEMENT MASKS THE REDUCTION IN POTENTIAL PRODUCTIVITY OF PASTORAL HILL SLOPES

Although the reduction in potential productivity of these hillslopes does not seem too serious, having reached 18% to date, the extent to which this reduction is masked by improved farm management technology, (such as aerial application of fertiliser and legume seed, subdivision by fencing) has not yet been measured. Unless the increases in potential pasture productivity due to improved management are determined, the 'real' effect of erosion on hill country pasture productivity cannot be accurately quantified. Hillslopes in the study area have received regular applications of superphosphate fertiliser (100 kg/ha/yr) since the 1950s. Evidence outlined below suggests that the reduction in potential productivity is likely to be greater on hillslopes on farms in this region where fertiliser levels are lower than those of the study area. The validity of this hypothesis is being tested in the field.

An estimation of the probable effects of lower fertility levels was made by modifying the measured pasture recovery curve (Fig. 4) by referring to the interim results of a fertiliser trial in the Wellington region (Hart & Healy (1980) and J.P.Widdowson & J.N. Watts, *pers comm.).* Their results, from five years of measurement, showed that higher rates of fertiliser application mask differences in pasture productivity between unmined (no topsoil removed) and soils mined to a depth of 20 cm. At the medium rate of fertiliser application the mined soils attained pasture growth rates of only 38% of that on the unmined controls, whereas at the high rate of fertiliser application mined soils reached 56% of that on unmined controls. (Soil Type of their trial site was Judgeford silt loam; with depths of topsoil generally similar to those recorded for uneroded hillslopes in the Wairarapa study area, (K.Vincent, Soil Bureau DSIR, *pers comm.).*

The curve modified according to the trends of their results has an asymptote at 63% of the measured pasture recovery curve shown in Fig. 4. Differences in pasture productivity between the medium and high fertiliser rates on unmined soil were very small (ratio = 0.95) and the uneroded productivity level (Fig. 4) was modified accordingly. However, it was recognised that differences resulting from low to medium fertiliser rates would probably have been greater, but no further adjustment of the uneroded level could be made as this was not measured. If the modified curve is then integrated with the proportionate areas of eroded ground of each scar age group, the reduction in potential productivity increases to the level shown by the lowest curve in Figure 6 (i.e., potential productivity decreases by about 30% overall). Although this level has not yet been validated by experiment, it does give an indication of the likely effects of erosion on hill country pasture productivity in the Wairarapa under a lowtechnological management system, such as low fertiliser application.

On hillslopes where severe erosion occurs continually, farmers will be faced with increasing difficulty in maintaining production levels unless soil conservation and farm management strategies are designed to further mask the impacts of erosion and thereby prolong the viability of pastoral agriculture on such hill country.

ACKNOWLEDGEMENTS

We thank J.P.Widdowson and H.M.Watts, Soil Bureau DSIR, for use of unpublished data.

REFERENCES

Brougham, R.W.; Grant, D.A. *1976: Proc. West Virginia University, Morgantown, WV, USA.* October 3-9, pp. 18-23.

Clark, D.A.; Lambert, M.G. 1982: *Proc. N.Z. Soc. Anim. Prod. 42: 173-175.*

Hart, P.B.S.; Healy, W.B. *1980.* N.Z. *Soil Bureau, Lower Hutt.* 41p.

Joblin, A.D.H. 1983. *Proc.* N.Z. *Grassld Ass. 44: 108-l 19.*

Lambert, M.G.; Trustrum, N.A.; Costall, D.A. *1984: N.Z. J. agric. Res. 27 (1):* in press.

Mather, AS, *1982. The Geographical J. 148 (2): 207-218.*

NRAC (National Research Advisory Council) 1977: Hill country research. Report of the hill country research working party. National Research Advisory Council, Wellington.

NWASCO (National Water and Soil Conservation Organisation) 1975-1979: New Zealand Land Resource Inventory Worksheets. Water and Soil Division, Ministry of Works and Development, Wellington.

Perrens, S.J.; Trustrum, N.A. (in press). Assessment and evaluation for soil conservation policy. To be published by the East-West Environment and Policy Institute, East-West Centre, Honolulu, Hawaii.

Stephens, P.R.; Trustrum, N.A.; Hicks, D.L. 1983: *Water and Soil Miscellaneous Publication* No. 52. (Ed. P.R. Stephens). Ministry of Works and Development, Wellington: pp 129-154.

Taylor, N.W. *1982. Proc.* N.Z. *Soc. Frm Mgt. Nat, Conf. Masterton,* N.Z., *November 16-18.* pp. 61-76.