New Zealand Journal of Agricultural Research

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tnza20

Effect of soil slip erosion on seasonally dry Wairarapa hill pastures

M. G. Lambert a, N. A. Trustrum b & D. A. Costall a

a Grasslands Division, DSIR, Private Bag, Palmerston North, New Zealand
b Soil Conservation Centre, Aokautere Ministry of Works and Development, Private Bag, Palmerston North, New Zealand


To cite this article: M. G. Lambert, N. A. Trustrum & D. A. Costall (1984): Effect of soil slip erosion on seasonally dry Wairarapa hill pastures, New Zealand Journal of Agricultural Research, 27:1, 57-64

To link to this article: http://dx.doi.org/10.1080/00288233.1984.10425732

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.tandfonline.com/page/terms-and-conditions

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.
Effect of soil slip erosion on seasonally dry Wairarapa hill pastures

M. G. LAMBERT1
N. A. TRUSTRUM2
D. A. COSTALL1
1Grasslands Division, DSIR
Private Bag, Palmerston North, New Zealand
2Soil Conservation Centre, Aokautere
Ministry of Works and Development
Private Bag, Palmerston North, New Zealand

Abstract
Production, botanical composition, and some soil fertility parameters of pastures on seasonally dry Wairarapa hill country subject to soil slip erosion were measured over 3 years, beginning in 1979. Measurement sites were on sunny and shady aspects of 'uneroded' areas of hillslopes, and slip scars of 4 ages (mean dates of slipping: 1977, 1961, 1941, and 1906). Average annual pasture production on uneroded areas was 8391 kg DM/ha. Pasture yields on the 1961, 1941, and 1906 sites, and the 1977 sites were about 77 and 20% of this level respectively. Uneroded sites were generally less steep than eroded sites, and this complicated interpretation of data. Correction for this slope discrepancy would increase the 77 and 20% values slightly. The results of this study suggested that pasture production on hill soils formed under pastoral agriculture was unlikely to return to the production levels supported by soils formed under the original forest vegetation. Botanical composition of pastures was influenced by the time elapsed since erosion. Grass dominance increased, and legume dominance decreased, with increasing length of time since slipping. Uneroded sites were the most grass dominant. N and C contents of soil increased with time since slipping, but were much lower for soils on all slip scars than soils on uneroded sites.

Keywords: hillslope; soil slip; hill country; erosion; pasture production; pasture composition; land productivity

INTRODUCTION
Erosion has an important influence on the formation of hillslopes (Trustrum et al. 1983). Justification for soil conservation work includes: the deleterious effects of erosion on water quality (McColl & Hughes 1981); damage caused by flooding of lowland; decrease in aesthetic appeal; and long-term losses in land productivity as a result of soil loss. The impact of flooding and soil erosion on the New Zealand landscape, and the necessity of applying soil conservation techniques to maintain land productivity have been discussed comprehensively by McCaskill (1973). Although soil conservation practices have been applied on pastoral hill country since the 1940s, there is little information about the impact of soil slip erosion on land productivity. Soil loss could decrease land productivity, both directly, by pasture removal, and indirectly, because young soils on erosion scars probably have lower levels of available P and N (Walker & Adams, 1958) than uneroded soils, thus restricting organic matter formation and pasture production.

Production of animal products from North Island hill country is directly influenced by rate of herbage production (Clark & Lambert 1982) and is at least indirectly influenced by pasture botanical composition (Lambert et al. 1982). These pasture characteristics, and seasonality of herbage production, are in turn influenced by cultural practices (e.g., fertiliser application, manipulation of stocking rate, grazing management) and environmental factors (e.g., climate and soil characteristics). In this paper, erosion is considered to be an important factor influencing the formation of hillslope soils and thereby affecting land productivity.

In August 1979, a trial was initiated in the Wairarapa hill country to measure pasture growth and botanical composition on different-aged soil slip erosion scars and on uneroded ground, to determine the trends in production loss caused by erosion, and the long-term rate of pasture recovery.

MATERIALS AND METHODS

Trial site
The trial was located on Te Whanga and Kumukumu stations, which are adjacent properties 15 km east of Masterton in the Wairarapa. The terrain is steeply dissected by incised streams, and is underlain by unconsolidated, tectonically-deformed Tertiary sediments. Extensive areas of soil slipping are a feature of the landscape, and hillslopes have a complex pattern of different-aged soil slip erosion scars which tend to coalesce on side slopes adjacent to ephemeral water.
courses (Fig. 1). Soils on the older scars and uneroded areas were tentatively classified as Kourarau steepland soils, related to moderately leached yellow-grey to yellow-brown earth intergrades derived from fossiliferous siltstone; hillslope soils would have an Ustic soil moisture regime (R. H. Wilde pers. comm.). Hillslopes studied in this paper are mapped as Land Use Capability Classes VI and VII, with a moderate to severe erosion limitation to pastoral use (Noble 1979). The average annual rainfall is 975 and 1075 mm on Kumukumu and Te Whanga stations respectively, and the climate is seasonally dry, with frequently occurring summer droughts. According to local opinion, there was no severe drought during this trial. Native vegetation type was podocarp-hardwood forest, which was felled and burned, and the land sown to pasture, between 1860 and 1890 (H. Beetham pers. comm.). Superphosphate fertiliser (about 100 kg/ha per year) had been applied on the trial areas since the 1950’s.

Measurement sites
Forty measurement sites were selected on erosion scars of 4 different ages and on uneroded areas. Sites were selected and dated using an aerial photographic technique (Trustrum & Stephens 1981; Trustrum et al. 1983). Evidence for the 1977, 1961, and 1941 slip dates was firm, but precise dating of erosion events between 1890 and 1941 was difficult, and our best estimate of mean date of pre-1941 slip occurrence was 1906. We assumed that no soil slip erosion had occurred at the uneroded sites after forest had been removed. The average depth of soil overlying bedrock was 0.45 and 1 m for eroded and uneroded sites respectively. However, there was more variation in soil depth to bedrock for eroded sites (K. Vincent pers. comm.).

Measurement sites were split equally between sunny and shady aspects, and included 2 slope classes (which had average slopes of 33 and 27°, respectively) with 2 replicates of each treatment combination. Slope effects, which were not consistent across years, have not been considered in detail. Each site was about 30 m² in area, located on the backward shear-plane surface of the slip scars. The micro-relief of recent (1977) slip scars is characterised by a network of small rills which occur at right angles to the slope contour (Fig. 2). On older regrassed slip scars small terracettes
traverse the slope. Within each site 6 pegs were used to define points of similar micro-relief (Fig. 2).

**Measurements**

Pasture production was estimated using one 0.5 m² grazing exclosure cage per site. Pasture was trimmed with hand-shears to 5–10 mm before cage placement. Cages were removed 30–76 days later, depending on pasture growth rate, and accumulated herbage was harvested to 5–10 mm. This procedure was repeated sequentially at 6 previously defined points per site; slope of sites ranged from 19 to 42°. Seven harvests were made each year for 3 years from August 1979. Pasture dry matter (DM) production and botanical composition were determined at each harvest. In 1981, soils were sampled to a depth of 100 mm, taking six 25 mm diam. cores from each site, and analysing the samples for total N, organic C, organic P, inorganic P, and Olsen P status. Total N was determined following Kjeldahl digestion; organic C by the Walkley and Black procedure, and total P by the method of Saunders & Williams (1955). Siltstone samples, collected from the face of a recent slip within the trial area, were also analysed for total N and organic C content.

**RESULTS**

**Total pasture production**

Average annual pasture production was greatest on uneroded sites (Fig. 3). Pasture production on the 3 oldest slips was similar, and was about 77% of that of uneroded sites (Fig. 3). Pasture production on 1977 slip scars was only about 20% of that of uneroded sites (Fig. 3). Depression in pasture productivity associated with erosion was most severe in summertime and in mid winter (Fig. 4). Pasture productivity was higher on sunny than on shady aspects from May to October (Fig. 5), the reverse situation occurring at other times. However, there was no significant difference (P>0.05) in average annual pasture production between north and south aspects, except for 1977 slip scars where yield on the sunny aspect was twice that of the shady aspect.

**Botanical composition**

Ryegrass (*Lolium perenne* L.) and subterranean clover (*Trifolium subterraneum* L.) content of pastures was not affected by erosion (Table 1). Content of other grasses increased with slip age, whereas that of white (*T. repens* L.) and suckling (*T. dubium* Sibth.) clovers
Fig. 3  Annual pasture production on sites of different slip age relative to that on uneroded sites. Each point is the mean of 56 measurements taken over 1 year. Bars represent the standard error of the mean.

Fig. 4  Pasture productivity on sites of different slip age relative to that on uneroded sites during the year. Means of 3 years data. Bars represent LSDs.
decreased. Other legumes and other species content of pastures was lowest on 1977 slip scars and uneroded sites, and was highest on slip scars of intermediate age.

Aspect affected botanical composition; other grasses and white clover being more important on shady aspects, and subterranean clover and other legumes dominating on sunny aspects (Table 1). Slip age x aspect interactions occurred for content of all species categories except ryegrass and other grasses. White clover content of pastures on 1977 slip scars was less on sunny (7%) than on shady (16%) faces; but was little different on other slip ages. Aspect x age interactions for other legumes were caused by greater aspect effects on intermediate age slips; for other species content interactive means showed no clear or easily interpretable trends.
Fig. 6 Quantities of N and C in top 100 mm of soil on slip scars and uneroded sites. Bars represent LSDs.
Table 2—Effect of slip age on soil nutrient status parameters (to 100 mm soil depth).

<table>
<thead>
<tr>
<th>Slip age</th>
<th>N (%)</th>
<th>C (%)</th>
<th>Total P (ppm)</th>
<th>P as organic P (%)</th>
<th>Olsen P (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uneroded</td>
<td>0.369a</td>
<td>5.10a</td>
<td>459bc</td>
<td>86a</td>
<td>5.1a</td>
</tr>
<tr>
<td>Pre-1941</td>
<td>0.198b</td>
<td>2.35c</td>
<td>556a</td>
<td>68c</td>
<td>4.4a</td>
</tr>
<tr>
<td>1941</td>
<td>0.209b</td>
<td>2.98b</td>
<td>445bc</td>
<td>65b</td>
<td>5.9a</td>
</tr>
<tr>
<td>1961</td>
<td>0.149c</td>
<td>1.96c</td>
<td>370c</td>
<td>51c</td>
<td>4.4a</td>
</tr>
<tr>
<td>1977</td>
<td>0.061d</td>
<td>0.76d</td>
<td>208d</td>
<td>27d</td>
<td>2.8b</td>
</tr>
<tr>
<td>Siltstone</td>
<td>0.050</td>
<td>0.36</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

'Values within columns having the same letter alongside them are not significantly different at the 5% level.

Nutrient status of soils

Total N and C content (%) and N and C quantities (t/ha) in the top 100 mm of soil increased with age of slip (Table 2; Fig. 6). N did not appear to increase in the first 4 years of soil formation following slipping, whereas C did. Total P content of soils and the proportion of total P as organic P were lowest on 1977 slip scars. Olsen P status, which was very low on all sites, was also lowest on 1977 slip scars. There was no significant difference in soil nutrient status (averaged across slip ages) between north and south aspects.

DISCUSSION

Pasture productivity was strongly influenced by occurrence of soil slip erosion. Over the 20 years after slipping, increase in productivity to 70–80% of the level on uneroded sites was rapid, but there was no indication of any further recovery (Fig. 3). Average slope of uneroded sites (26°) was less than that of eroded sites (31°), which could be expected to lead to higher measured pasture production on uneroded sites (Gillingham 1974). Data analysis using the slope groupings previously mentioned indicated significant slope effects in 1979–80 (P<0.05) and 1980–81 (P<0.01), but not in 1981–82 (P<0.25). Average change in annual pasture production, over all sites other than 1977 scars, was –165 kg DM/ha per year per degree slope increase. Application of this value as a slope-correction factor increases the 77% relative production (with respect to uneroded sites) of intermediate-age slips to 86%; the 20% of 1977 scars is increased to 22%. The validity of this slope correction procedure is uncertain, so the pasture production values presented here have not been modified. However, interpretation of these data should be made with this slope effect in mind, although the effect is relatively minor.

Pasture productivity on erosion scars was depressed in summer (Fig. 4) probably because of lowered soil moisture-holding capacity on shallower soils, lower organic content, and poorer soil structure. The depression on slips in mid winter may have been associated with the lower growth rates of the more legume-dominant pastures at that time of the year.

The legume content of pastures decreased with increasing slip age (Table 1), presumably because of increasing N status (Table 2), and competition from associated species, with time. Increased legume content, and hence higher feeding value of herbage (Ulyatt 1978), may partially offset the effect of decreased pasture productivity on grazing animal performance.

Aspect effects on pasture production in this seasonally dry hill country were similar in nature but much greater than those in moister North Island hill country (Lambert et al. 1983). Sunny aspect productivity was about 100% greater than that of shady aspects in winter (compared to about 40% in moister environments), and about 30% less in summer. Differences in botanical composition of pastures on sunny and shady aspects were also greater than those in moister hill country (Lambert unpublished data).

Aspect x slip age interactions for botanical composition data may be explained in terms of environmental differences between different aspects of 1977 scars being greater than those between different aspects on older slips and uneroded sites. The 1977 erosion scars were aerially oversown (5.6 kg/ha Huia, 0.6 kg/ha Mt Barker, 16 kg/ha Ruanui) and topdressed (62 kg/ha Ammosphos) in May-June 1978. This oversowing may explain the relatively good performance of subterranean clover on shady faces, and white clover on sunny faces and ryegrass on both, of 1977 scars, in comparison with performance in pastures on other slip sites and uneroded sites.

C accumulation appeared to proceed more rapidly than N accumulation despite the high legume content of pastures on young slips. N retention may have been poorer in the relatively non-carboniferous soils of recent slip scars. C:N ratio of siltstone was 7.2, whereas that of soils on weathered slip scars and uneroded sites was 11.9–14.3. Increase in proportion of P in the organic form is to be expected, as organic material build-up proceeds during soil formation. Olsen P status of soils indicated gross P deficiency at...
all sites through low P supply by soils. Although Olsen P status was lower on 1977 scars than on other sites, P stress may have been more acute because of low vigour of associated grasses as a result of low N supply. The N and C content of topsoil on slip scars is unlikely to attain the levels of uneroded site topsoils.

Care must be taken in extrapolating the data presented here to the whole farm situation and to other regions:

(1) An erosion and catchment condition survey (Stephens et al. 1983) of this Wairarapa hill country showed that the hillslope units studied in this paper occur within landforms which represent 56% and 60% of the total areas of Te Whanga (1430 ha) and Kumukumu stations (725 ha) respectively.

(2) Data from this study may not be applicable to other areas where rock type, erosion type, climate, and speed of pasture recovery following erosion may be different.

(3) Interpretation of some data is difficult. Pre-1941 sites could not be accurately dated, and data from these sites do not appear to fit trends implicit in data from other sites. If results from pre-1941 sites are ignored, N and C recovery appears to have continued beyond 20 years. However, pasture production still does not look likely to return to levels of uneroded sites.

The uneroded site soils could be regarded as vestiges of the original forest ecosystem, and the soils on erosion scars could be regarded as being representative of soils formed under pastoral agriculture. Although mineral soils may develop rapidly on soft tertiary sediments, the organic phase of these soils takes much longer to develop (Ross et al. 1982) resulting in impaired nutrient-supplying power, structure, and moisture-holding capacity.

Loss of soil from hillslopes by erosion results in the replacement of the original forest soils with soils formed under pasture. Implications of this replacement include lower potential levels of pasture productivity, and hence reduced levels of animal production. Trustrum et al. (1983) have determined that the overall loss in potential pasture productivity of these hillslopes because of erosion, to date, is 18%. The frequent use of mineral fertilisers may reduce this loss. Nevertheless, on hillslopes where erosion continually occurs, farmers will be faced with increasing difficulty in achieving production goals.

ACKNOWLEDGMENTS
We thank M. D. Guy and D. R. S. Pringle, Grasslands Division, for collaboration in this trial; P. R. Stephens, Soil Conservation Centre, Aokautere, for his initiation of the trial; A. G. Foote, Soil Conservation Centre, Aokautere, for assistance in the field; R. H. Wilde, Soil Bureau, for soil classification; K. W. Vincent, Soil Bureau, for soil bulk density values; Herbage and Soil Laboratories, Grasslands Division, for analyses; V. J. Thomas, Applied Mathematics Division, DSIR, for exponential curves; owners and managers of Te Whanga and Kumukumu stations for access to the trial area.

REFERENCES


