SOIL CONSERVATION IN THE GISBORNE-EAST COAST DISTRICT

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To understand soil conservation problems in this district it will be necessary to note at the outset that our problems differ in many respects from those elsewhere in New Zealand, and particularly from those in the U.S.A. and Australia. The literature of soil conservation for the most part reports conditions in the U.S.A. and consequently to most people "soil conservation" conjures up pictures of gently rolling cropping land troubled by sheet and wind erosion and by minor gullying, all of which are brought under control mainly by measures which can be conveniently described as contour farming.

In this district land which is cropped is flat, while rolling country is not cultivated except to the extent necessary to establish pasture. The bulk of the area in the district is too steep to cultivate, the pastures having been established by oversowing on bush burns. It is on this steep country that erosion is occurring, and it is not sheet, wind, and gully erosion, in the sense experienced overseas; it consists rather of deep-seated instability of slopes and gullying on a much larger scale. Few of the principles underlying contour farming can be applied; in fact, the measures necessary are outside normal farming practices altogether, consisting as they do of tree planting for the stabilisation of slopes, afforestation for reduction of run-off, and various devices and methods for controlling erosion of stream channels.

This part of New Zealand having been, in the geological sense, recently uplifted, the processes of geomophology were rapid even before the arrival of Europeans. A rainfall ranging from 40 to 120 in. per annum and a fertile soil ensured a vigorous vegetation of forest and scrub, which acted as a brake on these processes, but the agents which accelerated them, namely a high rainfall and recurring earthquakes, were in the ascendancy by a small margin.

Clearing the bush for the purpose of establishing pasture began in earnest in the eighties and was virtually completed by 1930. The passage of the years has shown that in many parts of the district the character and condition of the underlying rock, and the surface slope, are such that grass is unequal to the task nature has assigned to vegetation. Eroding gullies and streams, slips and landslides, erosion debris lodging in river beds are the manifestations of the inadequacy of this alien vegetative cover.

Function of Vegetation

The reasons for this present lack of equilibrium can best be understood by comparing the effect of a forest cover with that of a grass cover on the behaviour of water falling as rain.

The widespread multi-tier canopy of foliage in a forest will intercept more rain than will grass. Of the amount of rain which falls on the forest floor the greater portion will be absorbed, whereas a grazed pasture, trampled by stock in numbers fixed by economic considerations, will not permit absorption of such a large proportion. The first consequence of the change from forest to grass is therefore increased run-off into streams. Inasmuch as this increased run-off causes degradation of stream beds it will contribute to the instability of slopes adjoining the degrading stream.

Considering again the water which actually enters the soil under the forest, it appears reasonable to assume that the disposition and depth of penetration of the roots of forest plants will always be such as to make the maximum use of rainfall for plant growth, thus maximising evapo-transpiration and minimising the quantity of water which will pass below the root zone. Under a grass cover, on the other hand, the root structure is on the much smaller scale consistent with the size of the plants it has to support. Therefore, although less water enters the soil under a grass cover, a greater net amount seems likely to be able to pass into the subsoil than could occur under a forest. This deep penetration of water is of great significance in that it will reduce the shear strength of the soil and increase pore water pressure, both factors decreasing resistance of slopes to sliding.

Forest had two other advantages over grass, the first being that, at least in small catchments, the channels were paved by a raft of roots offering considerably greater resistance to erosion than does a turf cover, and the second being the superior tensile strength of tree roots compared with grass roots. Tension and shrinkage cracks due to incipient slope failure and to drought are thereby minimised, with a consequent minimising of entry of water below the root zone.

Since each of the several factors just described contributes to reducing the factor of safety of slopes against sliding, it is not surprising that landslides and eroding gullies are now a feature of the local landscape.

Rock Types and Faults

Rocks in the district are all of sedimentary origin, the oldest being of Lower Cretaceous age. Their resistance to erosion and mass movement varies widely and approximately in the following descending order of stability: sandstones and limestones, argillites, massive mudstones, close-jointed mudstones, mudstone with bentonitic clay. An important factor in stability is the degree to which a formation has been crushed by tectonic movements since being laid down, consequently degree of crushing must be superimposed on the foregoing order. Thus, a crushed argillite will be more unstable than an undisturbed mudstone. It can be said that the erosion distribution pattern follows the fault pattern rather than the rock type pattern.

It should also be noted that the large number of fault zones which exist in this district is the reason why erosion and stability problems here are more serious than in other districts of New Zealand where the combination of rainfall, slope, and underlying rock is not greatly dissimilar.

Types of Earth Movements

Earth movements exhibit a very wide variety of characteristics, but for the sake of simplicity only a few easily distinguishable types will be described and some account given of control methods suited to each type. The graduation from type to type is in fact continuous and control methods likewise exhibit wide variety.

(a) **Earthflows:** The type of movement which occurs most frequently is referred to locally as an earthflow. Earthflows occur where the underlying mudstone rock has been disturbed by faulting. Topography is of moderate to low relief and bentonitic clay is frequently present. Movement is generally very slow, but persists all through the winter. In most cases a stream flows across the terminal face of the earthflow continually removing material by lateral erosion, encouraging, and at the same time permitting, further movement, The turf on the earthflow is broken up into large clods and hummocks while reversals of surface gradient form undrained basins which collect rainwater. These surface characteristics encourage penetration of water into the soil.

The sliding plane is marked by the presence of a thin layer of moister clay of the consistency of new made butter which acts as a lubricant. The clay below the sliding plane is naturally of very low permeability and is rendered even more so by the remoulding action on its upper surface. The clay above the sliding plane, on the other hand, has its natural impermeability reduced by movement. Conditions are therefore favourable for water to enter the soil and lodge at or above the sliding surface. Drought cracks also aid penetration of water, while swelling after wetting of the clay soil develops pressures which add to the component of gravity forces acting down the sliding plane.

Dimensions and other characteristics of two earthflows are given in Table 1.

TABLE I—*Earthflow* **Characteristics**

Ref.	Slope angle	Length ft.	Width ft.	Depth of sliding surface ft.	Distance moved per annum ft.	Shear strength below sliding surface (vane test) lb./sq. ft.	Gravity component at failure lb./sq. ft.
1	8”	1,100	60	8	30	1,100	90
2	5°	1,400	590	10.5	11.5	—	101

The surfacc of an earthflow, being disturbed by the repeated movement, provides very poor grazing. In winter such areas are impassable to horses and grazing stock can become bogged. Fences are not located across earthflows unless it is absolutely unavoidable, in which case various ingenious contrivances devised locally are employed to minimise maintenance which would otherwise be a day-to-day affair in a wet season.

The increasing difficulty of finding stable fence lines as mass movement extends steadily from streams to ridges is becoming recognised by local farmers as a major district problem, Not only is it often impossible to maintain the paddock patterns of 50 years ago-1 know of one 600-acre property near Ruatoria that is now one paddock-but the closer subdivision demanded by modern practice is simply unattainable until some degree of stability is first achieved.

Methods of arresting earthflow movement vary with the circumstances, but must include, wherever possible, prevention of stream erosion occurring at the terminal face. This will sometimes be sufficient in itself to stop movement, but generally other measures aimed at preventing access of water into the ground must be taken as well. Tree planting on the moving area is the usual method of moisture control, hybrid varieties of the poplar species being preferred, as they endure some degree of movement and strike well from cuttings. The cuttings are 10 to 11 ft long to ensure that the foliage is above the reach of cattle, spacing is from 15 ft to one chain or more, and the pattern is generally in lines or bands across the direction of movement. After a few years' growth the root system develops sufficiently to intercept percolating water and to prevent deep drought cracks. Access by water can also be prevented by establishing a good sole of grass after smoothing and cultivating, but this does not generally succeed until some degree of control has been achieved by other methods. This method also results in greater run-off, and channels have to be fit to take it.

(b) **Landslides:** These occur in crushed argillites and close-jointed mudstones and are sometimes initiated by stream erosion across the toe of a slope or more frequently by erosion by small streams flowing upon the lower part of the slope itself. Soaking rains occurring after this erosion has to some extent altered the over-all shape of the slope will reduce the shear strength of the soil to the point of failure. Failure occurs suddenly by movement along a steep surface of sliding which is curved concave upwards. The moving soil mass has considerable momentum, the debris generally moving beyond the former line of the toe for some distance before coming to rest. The escarpment left behind by the movement is quite bare and is subject in turn to further slides, particularly if the disturbed material at the foot of the escarpment is removed by new gullies which readily establish upon its surface. Repeated sliding in the same basin has produced some spectacular gulches, particularly in crushed argillites, the process involving deposition in the river systems of huge quantities of debris which cause serious aggradation of channels.

The effect on fences and the loss of grazing can readily be imagined, but the principal detriment is to property downstream affected by aggrading river channels.

Landslides can be prevented by preventing the gully and stream erosion which alters the geometry of the slopes, and by preventing the deep percolation of water into the country. Afforestation of the upper slopes achieves both these objectives simultaneously and will also cure well-established gullied slides provided there is a sufficiently large area of catchment above the gully on which trees can be planted to produce the desired reduction in surface run-off. Smaller landslides can be dealt with by methods similar to those used for controlling earthflows, namely prevention of toe erosion and planting of the surface for moisture control.

(c) Surface Slips: This term is applied locally to miniature landslides which involve little more than the topsoil. They occur on steeper slopes in many soil types, particularly those formed on unconsolidated sandstones in the Waipaoa, Ormond, and Te Arai series, which consist of sandy loams over a subsoil of silt or clay loams. Slips occur when very heavy rain saturates the soil down to the more impervious subsoil.

The scars left by surface slips after a heavy storm add up to a considerable area which is lost to grazing until grass can be re-established on the scars and the debris strewn below them.

Owing to the random distribution of these slips it is seldom practicable to employ tree planting methods used on other types of movement. Improved pasture could not fail to reduce their occurrence, although extraordinary rainstorms would still take their toll, even of the best possible pasture, wherever the slopes are steep and the subsoils impervious.

Eroding Gullies

Eroding gullies are an even more noticeable feature of an unstable landscape than are the earth movements which they initiate and maintain in motion. Most gullies existed in a state of equilibrium under the bush cover and did not become unstable until the bush was replaced by grass. A fairly large proportion have had their origin on the disturbed soil involved in recent landslides or earthflows.

A tendency to degrade is evidence of lack of equilibrium. Degrading is usually a tendency rather than an actuality, because soil will usually move into the channel just as rapidly as the stream can remove it, thus maintaining bed levels on an apparently stable profile.

Under a bush cover there was a balance between erosive power of water and resistance of the stream bed. Erosive power is a function of quantity of flow per unit width of bed and of the slope of the bed in profile. Under a grass cover quantity of flow has increased while both bed widths and resistance to erosion have decreased; consequently gullies are striving to flatten their profile slope by deposition downstream and by degrading upstream. This degrading tendency upsets the stability of the adjoining slopes. Instability takes a wide variety of forms grading all the way from low angle earthflows through steeper, shorter earthflows, to small-scale landslides, the nature of the movement depending on the shear strength of the soil and the slope angle.

To restore the equilibrium of a stream, measures to be taken must accomplish one or more of four objectives: (a) reduction of run-off; (b) increasing the resistance of the channel to erosion; (c) widening of the bed; (d) stabilising the side slopes.

(a) **Reduction of Run-off:** So long as the land remains in pastoral use run-off will continue to exceed that by which the existing topography was sculptured. This must never be overlooked when considering a gully problem. If the other methods given below cannot be employed in a particular case because their cost is prohibitive, then the original run-off status must be restored by afforestation of the catchment. Afforestation in that event need be applied only to that portion of the gully catchment upstream of the most critical section; that is, where the combination of width, slope, and quantity of flow departs most from corresponding conditions under the original forest cover. This point is generally situated near the place where the branches spread fanwise to drain the upper part of the catchment. Flow into eroding gullies can occasionally be reduced by diversion if a safe alternative channel can be found or created, or by construction of a flood detention dam if a suitable site can be found.

Improving the pasture on a catchment will reduce run-off to a limited extent and in so doing serve as an aid to other methods. Completely closing a grassed catchment to stock will result in rank growth which will reduce run-off considerably. Used as a temporary measure it gives respite while gully planting work is becoming established, but must be used with caution, since denial of grazing i's costly and the increased rate of infiltration could enhance the instability of slopes in some circumstances.

(b) **Increasing Resistance to Erosion:** The principal tool for increasing the resistance of channels to erosion is the exotic willow. It is indeed fortunate that this species is capable of preventing the erosion of stream beds, by its peculiar root system, much more effectively than could any native species. By its aid it will be possible to continue to use most of the land in this district for pastoral purposes while accepting the greater volume of stream flow which such land use implies. Establishment of willows does, however, pose many problems, because wherever gully erosion is very active, willow poles planted as required near the edge of the low flow channel are vulnerable to flood flow and to slips moving off the gully slopes. Devices which are used to support willows planted for this purpose include the lining of the beds of channels by fascines made of manuka or other brushy material and the construction of debris dams made of similar material. Wherever brush is used in this manner willow roots quickly permeate the silt which lodges in the brush and establish a protective covering for the stream bed before the brush disintegrates.

(c) **Widening the Bed:** This is accomplished by the construction of debris dams just referred to. The most frequently used type is constructed of brush, the amount of widening accomplished depending on the thickness of the mattress of brush used, which is generally about 2 feet, which results in a widening of about 8 to 10 ft. Dams composed of wire netting and willow poles give a greater degree of widening but must be very carefully constructed to avoid undercutting.

(d) **Stabilising the Side Slopes:** If the slopes adjoining the gully are very unstable, they have to be stabilised by planting; otherwise measures aimed at establishing willow growth alongside the channel and widening the bed as just described are subjected to the hazard of repeated slips off the slopes burying or dislodging the work. The slope immediately adjoining the stream is generally bare of vegetation and a good deal steeper than the grassed slope further back. This break in the grade is of considerable significance. Planting the slope below it is generally useless. The vigorously suckering silver poplar is planted a short distance above it while the hybrid poplars are planted further back still. The reason for this arrangement is that the silver poplars will in time colonise the steep frontal slope by suckering, or by movement from their original position, while the larger hybrids will regulate soil moisture on the slope beyond.

Distribution and Cost of Erosion

In general the severity of erosion increases inland from the coast and outwards from the main river valleys. Fortunately the rock underlying country along the main divide of the Raukumara Range is somewhat more resistant to erosion, but higher rainfall and steeper slopes in this same area, much of which is approaching the marginal in the usual sense of the term, does produce an erosion problem of a most intractable kind because of the economic factors involved. It is in such areas that greater reliance will have to be placed on large-scale afforestation.

Elsewhere the prospects are by no means hopeless from the point of view of successful continuation of grassland farming. Already the picture is taking shape of a predominantly grassed landscape with streams and slopes fitted by artifice and exotic tree species to endure the new conditions imposed by supplanting forest with grass. Small areas above problem gullies will be restored to a close planted forest cover, but the total area so occupied will be no more than should in any case be devoted to farm forestry.

Costs of erosion control on a per acre basis are estimated to vary from nil to approximately £8 per gross acre. A recent survey of 400,000 acres of the Waipaoa River catchment produced figures shown in Table 2, which will serve to indicate the distribution and severity of erosion in that part of the district.

TABLE *2-Costs of Erosion Control in 400,000 acres of Waipaoa River Catchment*

Class	Area (Acres)	Cost per Acre	Total Cost
Flats	14,000	Nil	—
1	88,000	10/-	£44,000
2	135,000	£1	£135,000
3	47,000	£2	£94,000
4	60,000	£4	£240,000
5	31,000	£6	f186,000
6	251000	£8	£200,000
		TOTAL:	£899,000

Organisation of Erosion Control

Erosion control work is being carried out by the farmers themselves employing their own labour force and receiving Government subsidy at the rate of £2 for £1. Guidance on method of working is given by the Catchment Board. Estimated expenditure for the current financial year is £28,000.

DISCUSSION

Q. Has any thought been given to the use of edible shrubs for erosion control?

A. I am not aware of any work being done, but it is important to remember that it is not possible to establish any sort of vegetation on bare soil subject to frequent surface movement.

Q. Has there been any planting of trees for grazing purposes?

A. (Mr Ayson, Wairoa): Plane trees have been used by a Mr Brooks in Te Kuiti, but this would be restricted to autumn grazing.

Q. It was stated by Mr Todd that there were 16,000 acres in headwaters of Waipaoa-very difficult country. Are there any other bad areas?

A. Yes, there are similar problems in the valleys of the Tapuaeroa, Mangaoporo, and Maraehara Rivers and rivers in the Matakaoa County.

Q. (P. D. Sears): Has any work been done with bamboo in erosion control planting?

A. Yes, but only where salt-laden winds are troublesome along coastal areas.

Comment (M. Holland, Ruatoria): Bamboo has been used in gullies, but these have died out through drought conditions after becoming well established.

Q. (D. A. Campbell): Mr Todd has been accused of being an extremely expensive item in the district. My comment is that he is providing a very cheap insurance for the land-no conservation, no land. What is the overall figure for conservation-(a) On the hills? (b) For flood control on the flats?

A. The average cost of conservation work on the hills is approximately £2 per acre. On the flats 23,000 acres have been protected for a cost of £800,000.

Comment (C. Hamblyn): My comment is that the area of hill country where expensive conservation work is required is very limited. The majority of the area can be corrected by comparatively cheap work with tree planting and improvement in pasture cover.

Q. (C. E. Iversen): You say that grass is not equal to the task, or effective in controlling run-off. Would you qualify whether you differentiate between good and poor grass?

A. The term “grass” is used as opposed to the term “forest”. Gisborne hill country generally has been developed under forest cover. Grass farming must continue, but on its own “grass” is insufficient as an erosion control plant.

Comment (C. Hamblyn): Trees are most necessary to control the gullies and give stability so that better grasses can be grown and kept.

A. H. Reeves: In Gisborne the aim is to seek a balance between grass production and stability.

P. D. Sears: I agree with Mr Todd that trees are necessary in steep country, but a selection of better type trees should be made.

A. H. Reeves: Grass is sufficient for erosion control in most areas, but in the Gisborne district it is necessary to stabilise first with trees before proceeding with topdressing, subdivision, etc.

Q. (Jackman): Have any observations been made on whether aerial top-dressing has increased or decreased soil erosion for, with pasture improvement, consequent better infiltration and increased worm activity, the water is able to reach the slip plane more quickly.

A. (C. Hamblyn): I have observed this to be so on certain areas where shallow slips have occurred on previously non-slipped areas.

Comment (J. W. Woodcock): Touching on the controversy going on for years between the merits of pasture and forestry for erosion control, the bulk of New Zealand can be controlled by improved grass cover and better farming methods but, in the case of the Waipaoa area, trees must be used.

D. A. Campbell: A recent survey showed that only 6 per cent of the country was in the very difficult class, so we come back to the point that an improved grass cover is satisfactory for erosion control in 90 per cent of the area. Trees provide a key role for a relatively small area. Grass provides the answer for the bulk of the area.

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