MANGATU: A PRODUCTION FOREST WITH MAJOR PROTECTION VALUE

P. F. OLSEN *

SYNOPSIS

The geology, geomorphology and recent history of deforestation are briefly reviewed and the coincidence of recent increase in flood deposition rates and deforestation is noted.

The activity of the N.Z. Forest Service in reforestation of part of the Waipaoa head waters is documented and a description given of the debris control techniques employed in the more critical eroding areas.

The experience of the ten years following planting in Homestead Creek is more particularly described, as are the results apparently attributable to reforestation.

A theoretical basis for these results is postulated and the conclusions in terms of future forest practice derived. In addition, some measure of the return from protection and production forest investment is attempted in terms of downstream values and future industrial potential.

The activities of the Waipaoa River have been of morbid interest to Gisborne residents since at least 1932. The flood of that year made plain the effects of the devastation occurring in the hill country of the East Coast and subsequently considerable local effort has been expended in arousing governmental interest in the problems of local erosion and flooding. In 1949, proposals to control flooding in the Waipaoa River were formulated and in 1950 approved by Cabinet. These proposals were expanded to incorporate afforestation of 16,000 acres of the headwaters of the Waipaoa and Mangatu Rivers (Todd, 1964) and formed the basis for commencement of planting by the N.Z. Forest Service in 1960 at Mangatu Forest. More recently public interest has centred around the conclusions of the report of the Technical Committee of Enquiry into Problems of the Poverty Bay-East Coast District (1967) commonly referred to as the "Taylor Report" wherein, of four recommended alternative schemes of control, Government has opted for the recommendation that 346,00 acres, defined by a blue line on the map in Appendix 4, be reforested and/or maintained in trees. This scheme is described in broad terms in the *Wasco Bulletin* No. 9 (1970).

(1) The geology of the area is the major factor affecting the erosion rate and type. Hamilton and Kelman (1952) refer to the rocks in the Mangatu Forest area as crushed argillites associated with severe crush zones of bentonitic mudstones. More particularly, the area of older planting at Mangatu in the lower Homestead Creek has been described by N.Z. Geological Survey as characterized by blue-grey muddy siltstone and pale grey mudstone which latter becomes increasingly

*Principal Forester, N.Z. Forest Service, Rotorua.

bentonitic downward. Below this and to the west and north are blue calcareous silty mudstones and fine-grained highly calcareous muddy siltstones with montmorillonite as the most common constituent. This material is a typical swelling bentonite. In passing from this rock to the type below there is often a reduction in bentonitic constituents. These lower rocks which characterize the northern section of the catchment are again muddy and calcareous with fine grain and enclose rhyolitic tuffs showing rusty weathering. Overlying these in the north-west are traces of Taupo pumice shower material. Two of the rock terms most commonly used in discussing Mangatu type erosion forms are "argillite" and "bentonite". An argillite is essentially a clay rock (Tyrell, 1948) which is composed of the finest materials of rock decay and in this case compacted into a mudstone. Bentonite is a clay believed to result from the decomposition of volcanic ash and is made up of two forms of aluminium silicate, montmorillonite and beidellite (Read, 1946). It generally does not become plastic on wetting as do most clays but swells considerably.

All of these rocks in the area have been severely crushed and faulted by recent tectonic activity resulting in uplift and consequent stream and slope readjustments (Hamilton and Kelman, 1952). The crushing extends to considerable depths and the profile is usually deeply penetrated by water. Exposed surfaces have pH ranging from 9.2 to 9.5 in the grey subsoil to 2.4 in the deep, black, sulphur-smelling subsoil.

(2) Erosion has proceeded in the area at an accelerated rate following recent uplift. Thus the area has been characterized by slips, slumps and earth flows prior to removal of the native forest. Pullar (1970) has commented on the catastrophic rate of infilling of the trough of the Waipaoa probably in the period 1650 to 1700. This was followed by a period of slow depositions. For the period 1853 to 1876, no flooding was noted and the period prior to 1906 is characterized by a slow deposition rate. In 1906, widespread accumulation occurred which is noted as the result of accelerated erosion following European settlement. This latter phenomenon has been recorded by a number of authors, notably Poole (1960), Pullar and Metser (1956) and Hamilton and Kelman (1952), the latter dating felling in the catchment as being from 1890 to 1910. Henderson and Ongley (1920) describe the process of felling the podocarp/hardwood associations which occurred in the lower hill country and note that by 1920 Gisborne depended for timber supplies on the Motu. They particularly drew attention of Government to the rapid aggradation which had been evident for at least 15 years in the Waipaoa at Whatatutu and particularly noted the severity of erosion in the Mangatu Valley and the Waipaoa Valley above Waipaoa Homestead.

The various forms that erosion assumes on the deeply shattered mudstones of the area depend on a number of variables, only some of which are properly understood. Browsed pastures on areas of low relief where slopes do not exceed 25° are usually marked by earthflows with surprisingly rapid flow rates. Todd (1965) and Campbell (1966) give descriptions of flows at Ihungia and Waerenga-o-kuri, respectively, which are quite comparable with Mangatu flows. They have a flat semi-ellipse cross-section generally 8 to 10 ft deep sliding on a lower surface of similar soil type but of lower moisture content. They may be as much as 500 ft wide and often exceed 1,000 ft in length. Campbell records the movement of the Waerenga-o-kuri flow as 23 ft in the period 1963 to September 1965, much of which could be correlated with weekly rainfall. The surface of these flows is hummocky with numerous deep cracks; the upper end of the flow is marked by arcuate slump scars of up to 10 ft depth often exposing an extremely wet porridge-like mudstone/water slurry beneath the grassy turf surface. Much of the surface in the upper sector of the flow is boggy with sedge and *Ranunculus* amongst the pasture grasses. The bottom sector is activated by stream cutting of the toe of the flow which allows movement to continue. After a period of heavy rain, the lower portion of a flow may "drop out" in an extensive slide of mudstone slurry, and gully erosion then commences to eat rapidly into the lower sector of the flow. This gully erosion characterizes the steeper topography or steeper changes of gradient and once this commences any bare slope over 8 to 10° is prone to erode or slump when the mudstone is saturated with water (Hamilton and Kelman, 1952). Thus, in the Homestead Creek area of lower relief, the major problem has been earthflows, with incipient gully formation occurring near the toe, while in the Te Wheraroa Stream the problem is largely steep, active gullies accompanied by headward slumping. Hamilton and Kelman (1952) estimated that in 1952 there were twelve miles of gullies in this stream, the catchment of which is characterized by slopes often in excess of the maximum slope which could be maintained in a grass crop, that is, 28 to 29°.

(3) Floods in the Waipaoa have been the major problem with which catchment engineers have had to grapple. The problem has two aspects, water volume or flow rate and sediment load. Because of the very fine-grain clay material of the eroding rocks of the headwaters, the river always appears dirty. It is the forester's job to attempt to reduce this sediment load rather than flood severity. It is probable that the latter will be achieved and thus complement the work of the flood control works in the lower Waipaoa Valley. However, peak flow sediment loads constitute the major factor which may limit the life of the downstream engineering investment. Todd (1964) describes the scheme as having a design capacity of about 168,000 cusecs for the lower 28 miles of the river. The previous flood history and the flood peak of 140,000 cusecs recorded at the Kanakanaia Bridge for the 1948 flood (which probably equalled the 1876 flood) indicate that with the above capacity the lower valley is expected to be protected from the worst flood considered likely to recur once each 150 years. The scheme is as yet incomplete, as the Matawhero cut, expected to deepen by flood sluice action, requires now to be dredged. Cost to date is estimated by the Poverty Bay Catchment Board

TABLE 1

	Species Planted							
Year	*P. radiata*	*Ps. menziesii*	*P. nigra*	*Cup. lusitanica*	*E. botryoides*	*Poplars*	*Other*	*Total*
1949-59	7	8	5			13	22	55
1960	63					32		95
1961	338		188		3		1	530
1962	510	176	302	2		42		1,032
1963	567	296	326			78		1,267
1964	507	557	239	9	5	140		1,457
1965	510	289	507			33	1	1,340
1966	477	400	82	43		126		1,128
1967	933	749						1,682
1968	1,070	716		100	103			1,989
1969	1,553	79			84	2	173	1,891
	6,535	3,270	1,649	154	195	466	298	12,466

(Annual Report 31/3/66) to be $1,541,272, while the Matawhero cut will cost a further $429,190 for dredging (Annual Report 31/3/68).

(4) Planting at Mangatu is given in Table 1.

Among species utilized are *Pinus nigra, Pseudotsuga menziesii, Cupressus lusitanica, Eucalyptus botryoides* and *E. delegatensis*, together with poplar and willow planted in association with erosion control engineering work. Corsican pine and Douglas fir have been of limited success. On topography which would enable Douglas fir to be thinned economically, much of the area is often marred by earth flows. These wet sites do not allow the species to establish itself and even four years after planting significant mortality associated with inadequate root aeration has taken place. Also on weedy sites the species has been slow to occupy the site with consequent high releasing costs. On higher sites more exposed to wind, it appears that the species does not do well. These difficulties, plus the suspicion that the currently used provenance may be prone to *Phaeocryptopus gaumanii*, have resulted in a suspension of the use of Douglas fir at Mangatu. Corsican pine, initially favoured for difficult areas exposed to severe gales, is now in general disfavour. High releasing costs have been incurred owing to slow initial growth and the species is prone to *Dothistroma pini* now endemic in the forest. These reasons, plus the development of full canopy closure at the same slow pace as Douglas fir, has resulted in discontinuance of the species, particularly as most areas require as rapid a crown development as possible. The lower altitude areas of easy topography and high fertility which can be treated as being of low priority from the erosion control viewpoint have been used for smaller areas of apparently higher quality species such as *Cupressus lusitanica, Eucalyptus botryoides* and latterly *E. delegatensis*. The cypress has a growth rate initially better than Douglas fir with, however, a high incidence of malformation, partly due to opossum damage. This provenance is now not favoured and planting is discontinued pending results of trials of Kenya provenance. *Eucalyptus botryoides* has done well on a good site with height growth in excess of *Pinus radiata*. It appears unaffected by insects, plants out with relative ease as one-year open-rooted stock, and should provide a cabinet grade hardwood in a fairly short time. *Eucalyptus delegatensis* also does well with an even faster start than *E. botryoides* and may be marketable for light-coloured cabinet grade use.

However, all the evidence to date points to the fact that, for maximum control of the site and for the most rapid results in erosion control, *P. radiata* is the species of first choice.

(5) In areas of severe erosion where either the species planted is slow growing or conditions of erosion suggest some likelihood of success, structures have been used to speed up the process of debris retention and stabilization. In Compt. 5 in Homestead Creek, a series of experimental structures were tested in 1962 and 1963. In the sector of the gully where rate of fall was low, polythene sheet reinforced with mesh net-

ting was used to line V-shaped ditches down which the water was channelled. Polythene on its own was inadequate. On each side of the channel the plastic sheet was pinned down with golden willow or silver poplar rods. Where the stream gradient steepened, the sheeting could not sustain itself against the increased flow velocity and wooden dam structures were employed. These were in the form of a box with the lower end knocked out to form the spillway to the upper end of the next structure. Waste 1 in. timber was employed in the construction of these. The major aim was to provide an artificial bottom to the stream to prevent further down-cutting or flanking by the stream and also to avoid overwhelming by slumping from the side by over-steepened mud slopes. In Compt. 5 on an average slope just under 12°, the effort appears to have been successful. However, it has been costly, maintenance was still required up to 1968 and the success appears to be coincident with delayed adequate crown development in the Corsican pine planted in the catchment of the eroding area.

Work of this sort shifted to Compt. 60 in 1963 and 1964 where box-type log structures were employed using thinnings of *P. contorta* and *P. radiata* planted by the Poverty Bay Catchment Board in the period 1949-59. This work required heavy maintenance also, and was hampered by lack of adequate equipment to transport materials quickly to the work site. Maintenance work in 1967 and 1969 still has not completely solved the problem of water seepage, whereas the growth of planted radiata pine plus sedges and toi toi appears to be giving increasing control. In 1966-67, Compts. 14, 24 and 29 were the site of attempts to diversify the form of structure employed in gullies too steep for use of the polythene lining techniques. Wing dams using a board spillway covered with polythene and rising wing sides of polythene sheet reinforced with boards or wire were employed. These structures were anchored back into the surrounding mud by wire supports tied back to waratah standards. The debris built up to the level of the bottom of the spillway of the upstream structure and thus down-cutting could, in theory, be prevented. However, although costs tended to be lower per unit structure, the wing dams were prone to overwhelming by side slumping and also by flanking by the stream. Where the catchment had started to dry out with surrounding planted radiata pine as in Compt. 14, this risk was contained by application of bitumen on one or two weak areas and the gully was stabilized with little difficulty. By early 1968 it was evident that there was sufficient knowledge available to enable a gang to be put on to the work full time and emphasis was then placed on developing techniques of lower maintenance content. This latter was necessary as, after every major downpour, inspection and patching were required and, as more structures were put in, maintenance grew to the stage of reducing the capability to cope with new country. Work was transferred to Compt. 102 in 1967 and continued through 1968 and 1969. Here the use of wooden step dams, polythene lining, wing dams, lay-flat tubing, alkathene piping, paper pipe, and lately hard plastic 4 in. pipe have all been tried. There are about 200 structures in Compt. 102.

Expenditure has been as follows: For 1967, \$8,000; 1968, \$8,572; and 1969, \$7,392. Of this cost, approximately 70% has been labour, 20% plant and 10% materials. The surrounding area planted in Douglas fir in 1967 is still very wet with mortality in the upper part of the earth flow continuing to be significant in March 1970 when trees were 4 ft high. In the February-March rains, approximately 80% of the structures were overwhelmed and repairs are currently being undertaken. Work of a similar nature in Compt. 117 at a cost of approximately \$3,300 where piping, bitumen coating and seeding of resistant grass and weed species were tested, was similarly overwhelmed in the February downpour.

In summary, work on structures has taken place in six major eroding gullies costing approximately \$50,000 on an area of approximately 120 acres. Where we have been successful, the tree species have already established themselves and drying out has been well advanced. Where we have failed, the tree species has not yet occupied the site and little drying out has been obtained. It thus seems obvious that it is an unnecessary risk to attempt engineering in the eroding areas at least until the surrounding tree crop has attained crown closure. It may then not be necessary.

(6) Roading had previously caused difficulty of access and increased costs of establishment and silviculture. Up to 1967, river travel with 4×4 drive vehicles was the rule and only tracks of relatively low quality were taken into the planting site on dry ridges. As work has moved on to a rock type more stable than that of the initial planting area, more emphasis has been placed on good quality roads. For a 30 ft to 32 ft formation, allowing 24 ft of carriage way, 1969-70 costs per chain have been as follows:

Construction and formation	\$45
Culverts and grading	\$10
Metal (from the Waipaoa)	\$20
Total	\$75

The material used for metalling from the riverbed is taken from deposits with as low a proportion of soft mudstone as can be selected. A high crown to the road must be maintained to reduce water infiltration with consequent development of rutting and it appears that it is necessary to screen out the mudstone in a crusher operation to give a running surface of harder wearing quality for logging operations. This will be, I consider, preferable to attempting to cart metal from a good quality source at some distance. Roading at Mangatu requires considerable care with water-table formation, culvert design and dispersal of collected water below the road. Also the problem of batter slumping in areas permeated by deep seepage water is still not solved and will no doubt give difficulty until trees have achieved the necessary drying out. The success attendant on the roading of the earth flow in Homestead

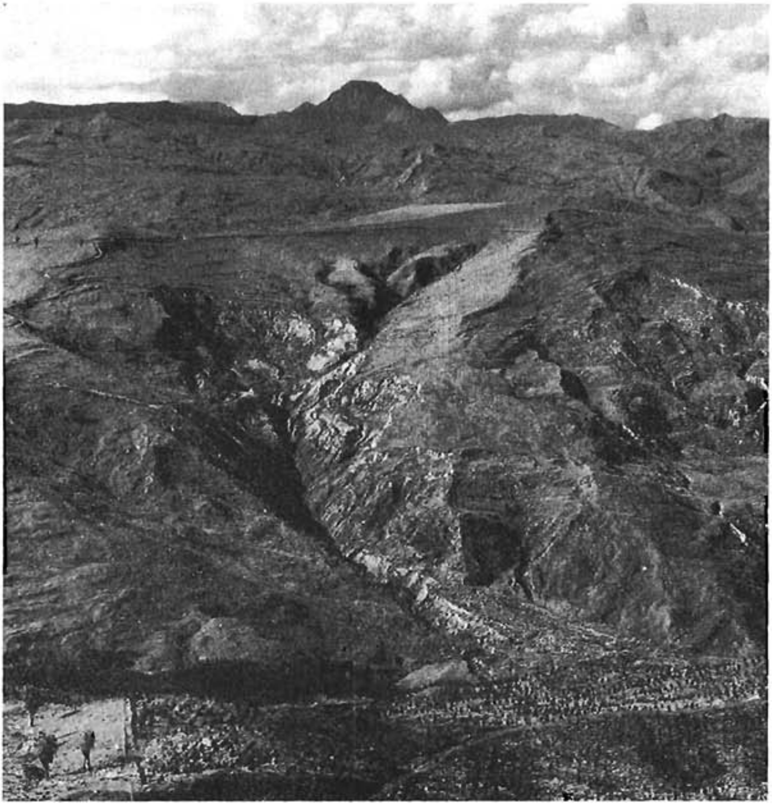

FIG. 1: *Homestead Creek, 1964, shortly after planting. (N.Z Forest Service photo by J. H. Johns, A.R.P.S.)*

Creek noted below indicates that, if conditions are too difficult prior to planting, we can expect to get logging access once the site is under control and thus all areas are potentially accessible to logging.

(7) The results of work done to date can mostly be given only in general terms. The chances of achieving stability in this area and maintaining this can possibly be estimated from analysis of the erosion behaviour of similar rock types under native forest for the period 1910-1970. Wallis (1970) has investigated the headwaters of the Waikura River where an association of tawa, scattered podocarps and hardwoods at present largely unmodified by animals occupies approximately 2,000 acres of Mangatu type rocks. The fact that there is no evidence of accelerated erosion is less significant when it is shown that there is an absence of the intense crush zones found at Mangatu, topography is steeper and more dissected, and thus apparently not so affected by recent tectonic activity.

FIG. 2: *Homestead Creek, 1970, showing successful stabilization. (N.Z. Forest Service photo by J. H. Johns, A.R.P.S.)*

In the country to the west of Mangatu in the Mangaotane, in similar rock type and in a tawa podocarp hardwood association slightly modified by animals, severe channel disturbance and erosion damage generally as described by James (1969) is characteristic. This is a continual process and all channel margins are characterized by young vegetation of various ages. There is some evidence of old slumping of limited significance which has not added to the debris problem in the main stream.

These data are of some significance. However, the behaviour of the oldest planting on actively eroding areas provides more convincing data. See Fig. 1.

The first catchment where the development of the tree crop now appears to be effective in controlling both runoff and debris/sediment flow is in Homestead Creek. This catchment, which was characterized in the lower sector by severe earth flow and gully erosion in 1960 and had a rapidly aggrading stream-bed, now appears stable although only a relatively low proportion, 47%, is in tree crop with relatively well-developed crown closure. In February and March 1970, the catchment was tested by two different levels of heavy rainfall. Between 8 and 12 February 1970, 7.6 in. of rain fell, 4.05 in. falling in 24 hours on 10 Febuary. On 21 March, 3.2 in. fell in 2.5 hours with falls on preceding days as follows:

15/3/70	....	....	....	0.24 in.
16/3/70	....	....	....	0.31 in.
18/3/70	....	....	....	0.09 in.
19/3/70	....	....	....	2.11 in.
20/3/70	....	....	....	0.35 in.

Apart from some minor down-cutting in the lower stream, no damage resulted and debris transported was of little significance. Although peak flows in both cases were of high turbidity, the stream rapidly reverted to a low turbidity flow with only minor cloudiness from the fine clay fraction. With the removal of suspended load, the stream is now degrading fairly rapidly in the soft flood terrace deposits.

This area was the sector where a considerable amount of experimental work was done. The major work was planting of as much of the catchment as conditions would allow. On the wet sector of the major earthflows on both sides of the lower catchment, conifer species would not take. Poplars of various types were planted in these wet zones and, where soil conditions were extremely unfavourable, even these would not take. Following from three to seven years after planting, some of these flows and gully areas were replanted in radiata pine. By this stage dry sectors could usually be expected to support radiata, yet certain of the blue-grey clays were still too difficult for radiata pine, owing presumably to adverse pH. Thus the canopy of the 1960 and 1961 plantings have many gaps with consequent low-quality marginal trees and much malformation. Even without full crown closure, this area has been dried out by the tree crop quite successfully and the earth flow on the southern side of the lower catchment, which in 1960-1961 was soft, wet and would not support radiata pine, now has a logging road running across and along the flow site for some chains. See Fig. 2.

It is also evident that the developing forest has slowed down the rate of earth flow movement in the Homestead Creek plantings. A flow under grass to the north of Compt. 4 has been measured periodically as has a similar flow into Homestead Creek planted to radiata pine. The results as derived by Holloway (1970) are as shown in Table 2.

TABLE 2

	Tree Flow	*Grass Flow*
Rate of movement		
Mar.-Aug., 1962	1.85 ft/mon	5.27 ft/mon
Jul 1968-Mar. 1970	0.12 ft/mon	0.47 ft/mon
1962 per inch of rainfall per month	0.33 ft/in./mon	0.95 ft/in./mon
1970 rainfall per month	0.03 ft/in./mon	0.47 ft/in./mon

Three soil pits dug in the wettest sector of the latter flow show that the depth of dry soil is shallow, averaging 2 ft 6 in. with the underlying crushed mudstone still very wet.

As previously noted, sediment load in the stream has been reduced and the stream is now actively degrading.

(8) An analysis of hydrological literature shows that, although there is agreement that trees reduce erosion, there is some disagreement as to how. Water use by a tree crop appears to be rather dependent on the climate, soil type and species. Forest trees probably deplete soil moisture more thoroughly and rapidly than other types of vegetation. One of the major mechanisms is by transpiration which appears to be a factor of growth and proportional to the leaf area or weight (Kittredge, 1962). The maximum water loss can be expected in climates marked by a number of light small storms separated by clear weather where interception of up to 0.2 in. of rain from a 2 in. fall and infiltration of, say, 3 in. may be stored to be drawn back up out of the soil by either direct evaporation or by transpiration through roots and canopy. In such circumstances, where continuous water is available, water consumption will be a maximum. The above author refers to a Drakensberg (South Africa) experiment where young radiata transpired 35 in. of rainfall per annum. Blackmore (1962) suggests that a clay soil may have a moisture-holding capacity of up to 4.5 in. of rainfall per foot of depth. In his view, water used by trees may vary from 18 in. per annum in high cool mountains to 60 in. in hot desert areas where water is not limiting. In a more typical situation such as the southern U.S. where water may be limiting, consumption by pine species varies from 10 in. to 35 in. of rainfall per annum. Kittredge (1954) reports that runoff is reduced by change from grassland to trees but only showed a relationship of 0.6 in. in annual runoff value of *Pinus canariensis* litter at age 20 compared with 2.8 in. from undisturbed grassland. The change of grassland runoff from a grazed to an undisturbed regime is noted in the literature but not quantified for our conditions. Nordbye and Campbell (1961) have reported infiltration rates of 3.5 in. and 0.5 in. of rain per hour for forest and grass respectively in Hawke's Bay.

The most which can be made from the above data is that conditions in Homestead Creek are probably close to optimum, for maximization of transpiration losses. A. B. Willis (pers. comm.) reports that trees apparently have no period of nil growth at Mangatu. An analysis of mean daily soil and air temperatures for a similar station reported by Pullar (1962) shows that the temperature at which transpiration stops, 5° C, (Kittredge, 1962) is rarely if ever reached. Rainfall in Homestead Creek probably averages 55 in. per annum on about 150 days per year with a high proportion of falls not exceeding 2 in. per 24 hours. As moisture is evidently non-limiting on earth flows particularly, fertility generally high on developed soils, and growth rarely limited by air and soil temperature, Mangatu can be expected to provide very high growth rates and thus high transpiration rates which will increase up to the time of crown closure. Air humidities are generally low in the period September to March and thus evaporation and transpiration will tend towards a maximum such as the Drakensberg 35 in. per annum. Under similar conditions grass could be expected to consume somewhat less than this, primarily owing to lower interception and infiltration storage capacity and smaller transpiration surface. The experiment which has been commenced at Compt. 120 under the auspices of the International Hydrological Decade is expected to assist in quantifying this difference under Mangatu conditions slightly less favourable than those in Homestead Creek.

What appears to be occurring in grass areas planted to trees is rapid drying out of steeper stable slopes and reduction of seepage flows on to the faces of neighbouring gullies. In this sector we now require much heavier rainfall to generate conditions of saturation associated with loss of mechanical strength and slumping. On earth flows the situation appears more complex. Todd (1965) in his "dowel" experiment with posts sunk into the plane of sliding underlying the Ihungia flow, has demonstrated that very small changes in the mechanical qualities of the flow structure are required to slow the movement down effectively. Thus a tree crop perched on the upper three feet or so of the flow has apparently already taken sufficient water mass out of the flow to stop its movement and, by consumption of interception and infiltration storage in the first foot or so of the flow profile, prevented further water entry into the flow in all except exceptional rainfall circumstances. We might well expect further root penetration into the profile and a continuing process of moisture removal and drying.

(9) Protection of downstream values is the *raison d'etre* of Mangatu and we appear to be registering some gains in this respect. However, we will need a much greater area under an adequate tree crop before sediment load in the Waipaoa upstream of Whatatutu is reduced to an acceptable level. We have already noted that engineering works to the value of almost $2,000,000 have to be protected from the aggradation effects so prevalent in the upper sectors of the river. Subsequent to the success of the flood control engineering works, the local Gisborne economy has reacted to the environment of protection. Todd (1964) notes that capital value of the protected land increased from $3,520,000 to $9,520,000 in the period 1953-1964. An analysis of a sample of station holdings in the Upper Waipaoa shows that unimproved valuation on hill country rose by 1.7% annually in the period 1949 to 1967 while a sample of lower Waipaoa land protected by the flood control scheme rose by 7.6% annually for the same period. The Department of Agriculture in their 1969 Annual Report noted the increases in intensive use of flat land on the Gisborne flats (refer Table 3).

Whereas on the hills, for an annual expenditure of $100,000 on gully erosion control measures, the same report noted these trends (refer Table 4).

TABLE 3

Land Use	Area in Acres 1961	1965	1969
Orchards	360	482	800
Market Garden	198	628	550
Nurseries	48	95	140
Wheat	135	21	76
Barley	472	691	2,700
Maize	4,186	6,000	18 000
Potatoes	121	120	100
Vegetables for processing	977	1,750	4,000
Grapes	—	67	700

TABLE 4

Stock Type	Stock Numbers 1961	1965	1969
Total sheep	2,137,000	1,231,900	1,249,600
Total ewes	1,296,000	139,700	170,200
Total cattle	374,500	367,900	446,200
Total cows	137,000	138,000	158,900

It can be fairly said, therefore, that Mangatu, when all the 40,000 acres of the catchment recommended by the Taylor Report are included in the forest, will have a protection value of considerable economic dimension.

(10) Production values will also be significant. Exotic forest can be established on approximately 80% of the gross area in the first rotation. Within the stocked area some 20% will be less than fully stocked and for radiata pine stands only approximately 100 s.p.a. can be selected in most stands for high pruning, with a minimum knotty core of 12 in. Severe malformation, apparently correlated with available nitrogen in the upper 8 in. of soil on wind exposed sites, is a major cause of stand degrade. The remainder of the crop have a deviation from straight of more than 3.5 in. for the butt log length of 20 ft (Willis, 1970). In terms of the values derived for the Maraetai Study (Fenton and Grainger, 1966) and updated for the Forest Development Conference (Fenton *et al.*, 1968) Mangatu can be demonstrated to have a land expectation value of $84 per acre at 7% compound, including social costs. However, although Mangatu in the older planting has a demonstrated Site Index of 110, compared with the Maraetai Site Index of 95, full stocking is usually achieved on only some 64% of the site as versus Maraetai 83%. Thus L.E.V. for Mangatu stocking and stem characteristics is probably of the order of $65 per acre when planted to radiata pine.

Using Ward *et al.* (1966) data for Maraetai at a carrying capacity of 5 ewe equivalents per acre and using 1968 prices, Orsmann (1969) shows that agriculture will give only 4% yield at zero L.E.V. if social costs are excluded. On Mangatu soils, present carrying capacity is calculated to be of the order of 3.0 to 3.5 ewe equivalents on this soil and erosion type.

Therefore, measured purely in terms of production, return on investment in forests is much greater than farming as currently practised in this type of hill country. Thus the regional economy will be strengthened by converting grazing land to forest.

CONCLUSION

Our techniques during the first decade at Mangatu were less efficient and more expensive than the situation required. We should have regard for these lessons during the next decade at Mangatu and Ruatoria. With efficient forest practice we can achieve the protection targets desired and also provide wood at an economic price for a Gisborne-based export-oriented industry which should be able to commence on an economic scale of production in about 1985. To this end and for optimum protection gains, we should plant radiata pine at the maximum rate practicable for at least the next 5 years. This should be leavened with a proportion of high quality species suitable for veneer manufacture as sites allow and of sufficient volume to enable an economic scale of utilization.

In 10 years we have made remarkable progress. The 1,600 acres of the Homestead Creek catchment, previously an eroding ugly area distressing to contemplate, now provides a most attractive entry to the forest and backdrop to the forest headquarters. Our plantings of poplar among the radiata pine have added an inadvertent amenity aspect which we intend to conscientiously foster as an important aspect of development at Mangatu. We have a long struggle ahead of us to provide clear water for the Waipaoa River. In the process we will continue to enhance the economic and environmental prospects of this part of New Zealand.

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