

Soil Conservation Survey of the Mangarama Catchment

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Introduction

These notes summarise the results of a survey carried out in May-June 2005 at the request of Environment Waikato. The survey's purpose is to ascertain extent of vegetative soil conservation cover in the Mangarama catchment, and measure what reductions have accrued from them. This information is required for a 5-year review of soil conservation in the Upper Waipa sub-catchments.

The Mangarama has been selected by Environment Waikato staff because they regard it as typical of the Upper Waipa sub-catchments in its terrain, land use, and soil conservation measures. It is 59 square kilometres in extent, draining north from the Mokau watershed near Te Kuiti and entering the Mangapu, a slightly larger tributary of the Waipa. The western headwaters are an undulating limestone plateau full of sinkholes and caves, with surface drainage in valley bottoms where streams have cut down to underlying greywacke. West of the Waipa fault, mudstone is dissected into moderate footslopes descending from the limestone plateau to the catchment's middle reaches which are a broad valley floor infilled by alluvial terraces, floodways and drained swamps. The Mangarama's eastern and southern rims are short steep hill country, formed from alternating beds of mudstone, sandstone and limestone. All landforms in the catchment are mantled by volcanic ash - patchy on the hills, deep on the plateau and footslopes, re-sorted by water on the terraces and floodways.

The survey brief is to :

- Identify how much land needs soil conservation,
- Ascertain whether such land has vegetative soil conservation measures. These may be spaced tree plantings in pasture, close afforestation with commercial tree species, or natural vegetation (retained, reverting or planted),
- Obtain measurements of any changes in soil erosion or disturbance where vegetative soil conservation measures are present.

Doing this does not entail mapping exact locations and types of measure on all land in the Mangarama - to do so would take a great deal of time - rather, to obtain reliable summary measurements for the catchment from 2002 aerial photographs. These should be in a format consistent with previous identification of target land for soil conservation (Project Watershed 2001), and comparable with an earlier survey from 1992 aerial photographs.

Method

Survey design is similar to the earlier survey (Hicks 2001). It combines two elements of state-of-environment survey :

- point sampling,
- recording of land as either stable, unstable, recently eroded or freshly eroded,

with four elements of soil conservation effectiveness survey :

- whether land needs treatment,
- what type of treatment is required,
- what treatment is present,
- whether its extent is sufficient.

Retaining these features enables data to be compared with results from the earlier survey, despite changes in measurement method detailed below.

Measurement method incorporates technical improvements made possible by Environment Waikato's (EW's) 2002 aerial photographic coverage. This is colour aerial photography, rectified to fit a map grid, scanned, and installed as a layer in EW's geographic information system (GIS). It enables :

- random selection of sample points (ten per square kilometre),
- photo-interpretation of landform stability and vegetative soil conservation cover, from prints at a scale of 1:10000,
- measurement of bare ground due to erosion or other soil disturbance, within a one hectare area around each sample point,
- data entry into an Excel spreadsheet (convertible to a GIS attribute layer).

847 points were sampled. Data were checked for consistency and corrected where necessary, then sorted into categories. Point counts were carried out for each category and converted to percentages of the sample. Sample averages and standard errors were calculated where appropriate.

Results

Table 1: Landform Stability, Mangarama Catchment

	All landforms			Stable n	Unstable inactive n	Unstable recently eroded n	Unstable freshly eroded n	
	n	% of catchment	+ - 2 s.e.					
Streambanks	44	9.1	1.9		29	5	10	
Floodways	59	12.2	2.2	4	55			
Terraces	30	6.2	1.6	24	6			
Downlands	85	17.6	2.6	36	38	3	8	
Footslopes	110	22.8	2.8	19	60	8	23	
Hillslopes	360	74.7	2.9	48	203	47	62	
Ridges	159	33.0	3.2	106	33	8	12	
	n	847	100.0	0.0	237	424	71	115
	% of catchment stable or unstable :			28.0	50.1	8.4	13.6	
	+ - 2 s.e. :			3.0	3.4	1.9	2.3	

28% of the catchment is occupied by stable landforms, not at risk from natural erosion, such as ash-mantled limestone ridges and plateaux, moderate hillslopes or footslopes slopes in mudstone or sandstone, and valley-bottom downlands or terraces away from watercourses.

The proportion of unstable land is 72%. These are landforms such as swales on downlands (risk of tunnel or gully erosion), terrace scarps (risk of gullies or small landslides), steep hillslopes (risk of landslides or slumps), moderate footslopes (risk of earthflows), streambanks (risk of bank scour), and floodways (risk of scour or siltation).

Out of the 72%, 50% shows signs of past erosion but is currently inactive and well-vegetated. 8% shows signs of recent erosion now revegetating. Another 14% shows signs of fresh erosion i.e. patches of bare ground interspersed amongst vegetation.

Note that the 14% is land where erosion is present in some of its area. Actual percentage of bare ground is considerably less (see Soil Disturbance section). Table 1 gives margins of error, and a more detailed break-down of data by landform.

Table 2: Need For Soil Conservation Measures, Mangarama Catchment

	All landforms			Landforms needing measures :							
	n	% of catchment	+ - 2 s.e.	None	Spaced trees	Spaced trees + spaced trees	Spaced trees + ground cover	Close trees	Close trees + spaced trees	Close trees + ground cover	Ground cover
				n	n	n	n	n	n	n	n
Stable landforms:	237	28.0	3.0								
Unstable landforms:	610	72.0	3.0								
Reason for measures:											
None :	103	12.2	2.2	103							
Streambank erosion	21	2.5	1.0		21						
Streambank deposition	12	1.4	0.8		4						8
Streambank erosion & deposition	23	2.7	1.1		14		9				
Streambank and other erosion	2	0.2	0.3				2				
Tunnel erosion	78	9.2	1.9		78						
Tunnel and other erosion	2	0.2	0.3			1	1				
Gully erosion	57	6.7	1.7		57						
Gully and other erosion	19	2.2	1.0			14	2	2	1		
Landslide erosion	86	10.2	2.0		33			53			
Landslide and other erosion	18	2.1	1.0		3	1		5	8	1	
Slump erosion	123	14.5	2.4		117			6			
Slump and other erosion	53	6.3	1.6		9	41			3		
Sheetwash and rock outcrops	13	1.5	0.8								13
n	610	72.0	3.0	103	336	57	14	66	12	1	21
as % of unstable landforms :				16.9	55.1	9.3	2.3	10.8	2.0	0.2	3.4
+ - 2 s.e. :				3.0	3.9	2.3	1.2	2.5	1.1	0.3	1.4

This was assessed for each of the 610 unstable points (U, R and E), using the following criteria :

No fresh or recent erosion :	no soil conservation cover needed
Streambank erosion :	spaced trees in pasture
Streambank deposition :	dense ground cover
Streambank erosion and deposition (combined) :	spaced trees with dense ground cover
Streambank and other erosion :	as above, with either extra spaced trees, or close trees, depending on erosion type
Tunnel erosion :	spaced trees in pasture
Tunnel and other erosion :	as above, with either extra spaced trees, or close trees, depending on erosion type
Gully erosion :	spaced trees where slight, extra spaced trees or close trees where severe
Gully and other erosion :	as above, with either extra spaced trees, or close trees, depending on erosion type
Slip erosion :	spaced trees where slight, close trees where severe
Slip and other erosion :	as above, with either extra spaced trees, or close trees, depending on erosion type
Slump erosion :	spaced trees in pasture where slight, extra spaced trees or close trees where severe
Slump and other erosion :	as above, with either extra spaced trees, or close trees, depending on erosion type

Note that these are optimal measures - another measure or some combination, though not as good, may be acceptable for erosion control. Also note that the assessment need not always entail planting exotic vegetation - it makes provision for retained or reverting natural cover where already present.

Out of 610 unstable points, 103 (17%) are well-vegetated and do not appear to have been active for a very long time, so have been rated as not requiring treatment.

507 points show signs of erosion within recent decades - old scars which have re-grassed, reverted to scrub or wetland, or been planted with trees.

Of these, 336 (55%) have been rated as needing spaced trees in pasture, to control streambank erosion, tunnels (soil pipes), gullies, or slump and earthflow erosion. A further 57 (9%) have been rated as needing additional spaced trees to control streambank erosion associated with gullies, gully erosion associated with slumps, or severe slump erosion. Another 14 (2%) have been rated as needing dense ground cover to control deposition associated with streambank or gully erosion.

66 (11%) have been rated as needing close trees, either commercial timber species or soil conservation species or native tree and shrub cover, to control landslide erosion or extreme slump erosion. A further 12 (2%) have been rated as needing a combination of close trees with spaced trees to control additional gully or streambank erosion. Just 1 (<1%) has been rated as needing a combination of close trees with dense ground cover (to control deposition in a gully downslope of landslides).

21 (3%) have been rated as needing dense ground cover alone - to control streambank deposition in floodways.

Table 2 gives sample error margins, and a more detailed break-down of data by erosion risk.

Table 3: Extent of soil conservation measures, Mangarama catchment

Stable landforms : 237
 Unstable landforms, no measures needed : 103
 Unstable landforms, measures needed : 507

	Spaced trees	Spaced trees + spaced trees	Spaced trees + ground cover	Close trees	Close trees + spaced trees	Close trees + ground cover	Ground cover	Totals	%	+/- 2 s.e.
Needed:	336	57	14	66	12	1	21	507	100.0	0.0
Present:										
No measures	98	21	3	13	1		9	145	28.6	3.9
Spaced trees:	85	8	5	4	2			104	20.5	3.5
+ extra spaced trees	2	3						5	1.0	0.9
+ ground cover	13	4					3	20	3.9	1.7
Close trees:	2			3	1			6	1.2	0.9
+ spaced trees	1			1				2	0.4	0.5
+ ground cover								0	0.0	0.0
Natural cover::										
spaced trees or shrubs	110	14	4	38	4		6	176	34.7	4.1
close trees or shrubs	3	2		4	2			11	2.2	1.3
ground cover (wetlands)	14	4	2			1	3	24	4.7	1.8
ground cover (exotic weeds)	8	1		3	2			14	2.8	1.4
Total present:	n 238	36	11	53	11	1	12	362	71.4	3.9

Secondary vegetation has been recorded at any sample points where it is present, together with the nature of cover i.e. trees, shrubs or ground cover, scattered or extensive, exotic or natural. At the 237 stable and 103 unstable but inactive points, secondary vegetation is likely to have been planted or retained for other reasons e.g. commercial or amenity value. At the 507 unstable points where soil conservation measures are needed, the vegetation may or may not be intentionally planted :

- 22% have spaced tree plantings (including points with extra spaced trees),
- 4% have spaced tree plantings with associated ground cover,
- 2% have close tree plantings (including <1% with additional spaced trees),
- 0% have close tree plantings with associated ground cover,
- 44% have natural cover, of which 35% is spaced trees or shrubs (in pasture), 2% is close-canopy trees or shrubs (in bush), 4% is wetland plants, and 3% is exotic weeds.

Overall 71% of the unstable points that need vegetative soil conservation cover, have it in some form. Just 29% lack any measures. Almost half of the Mangarama's soil conservation cover is natural vegetation that has been retained on pockets of unfarmed land - or is regenerating in rough hill pasture. Planted measures occur at just under three-tenths of unstable points - along streambanks in the valley floor; or on tunnels, gullies and mass movement scars in the better-farmed hills. Table 3 gives sample error margins, together with a more detailed break-down of the match between measures needed and measures present.

Table 4: Adequacy of soil conservation measures, Mangarama catchment

Stable landforms :		237					
Unstable landforms, no measures needed :		103					
Unstable landforms, measures needed :		507					
		Totals	Absent	Inap- propriate	Mis- placed	Insufficient	Sufficient
Present :							
No measures		145	145				
Spaced trees		104			5	64	35
+ extra spaced trees		6				1	5
+ ground cover		18		2	2	9	5
Close trees		7					7
+ spaced trees		1					1
+ ground cover		0					
Natural cover :							
spaced trees or shrubs		176		7	14	100	55
close trees or shrubs		14			1	1	12
ground cover (wetlands)		21		8		12	1
ground cover (exotic weeds)		15		12			3
Totals :	n	507	145	29	22	187	124
	%	100.0	28.6	5.7	4.3	36.9	24.5
	+/- 2 s.e.	0.0	3.9	2.0	1.8	4.2	3.7

At the 501 unstable points where measures are needed, vegetation's soil conservation value has been rated as absent (a), present but inappropriate (x), present but misplaced (m), present but insufficient (i), or present and sufficient (s). Criteria for assessing measures were :

Streambank erosion, streambank deposition :

These features are linear, typically passing through a sample area from one side to the other, so about 10% cover is needed for effective erosion control.

If needed cover not there :	absent
If not on streambanks :	misplaced
If close tree plantings :	inappropriate
If scattered spaced tree plantings or scrub reversion or retained natural cover :	insufficient
If extensive spaced tree plantings or scrub reversion or retained natural cover :	sufficient

Tunnel erosion, gully erosion :

These features are semi-linear i.e. branch but rarely pass through a sample area. Typically between 10 and 20% cover is needed for effective erosion control.

If needed cover not there :	absent
If not on tunnels or gullies :	misplaced
If close tree plantings :	inappropriate
If scattered spaced tree plantings or scrub reversion or retained natural cover :	insufficient
If extensive spaced tree plantings or scrub reversion or retained natural cover :	sufficient

Landslide erosion

These features are non-linear and dotted anywhere through a sample area. Greater than 90% cover is generally needed for effective erosion control.

If needed cover not there :	absent
If not on landslides :	misplaced
If spaced tree plantings :	inappropriate (except on sites where erosion is slight)
If scattered close tree plantings or scrub reversion or retained natural cover :	insufficient
If extensive close tree plantings or scrub reversion or retained natural cover :	sufficient

Slump erosion, earthflow erosion

These features are non-linear and dotted anywhere through a sample area. Greater than 90% cover is generally needed for effective erosion control.

If needed cover not there :	absent
If not on slumps or earthflows :	misplaced
If spaced tree plantings :	appropriate (except on sites where erosion is severe)

If scattered close tree plantings or scrub insufficient
reversion or retained natural cover :

If extensive close tree plantings or scrub sufficient
reversion or retained natural cover :

Where land is unstable (for whatever reason) and in need of measures :

- 145 (29%) of sites need vegetative soil conservation but have not yet been planted.
- 29 (6%) have vegetative cover inappropriate for the type of erosion that occurs.
- 22 (4%) have appropriate vegetative cover, but misplaced i.e. not on the part which is erosion-prone.
- 187 (37%) have vegetative cover that is appropriate but insufficient in extent.
- 124 (24%) have planted, reverting or retained vegetative cover that appears sufficient to control the type of erosion present.

Overall 61% have measures that can be regarded as adequate for erosion control. However 24% of this - the insufficient category - needs inter-planting to increase its effectiveness. Table 4 gives error margins and additional break-downs for points in each category.

Table 5a: Soil disturbance by natural erosion, Mangarama catchment

	Number of sample sites n	Streambank erosion %	Streambank deposition %	Tunnels %	Gullies %	Landslides %	Slumps %	Rock outcrops (sheetwash & rockfall) %	All natural erosion %	+ 2 s.e.
Cover present :										
None :	145.00	0.01	0.05	0.07	0.23	0.19	0.65	0.19	1.39	0.39
Planted cover :										
spaced trees	110.00	0.09	0.09	0.14	0.07	0.18	0.43		1.00	0.45
spaced trees + close trees	1.00								0.00	0.00
close trees	7.00								0.00	0.00
spaced trees + ground cover	18.00	0.15			0.30				0.45	0.49
close trees + ground cover	0.00								0.00	0.00
Natural cover :										
spaced trees or shrubs	140.00	0.03		0.06	0.12	0.24	0.41	0.22	1.08	0.41
close trees or shrubs	14.00	0.36			0.43	0.50			1.29	1.58
trees or shrubs + ground cover	36.00	0.05	0.17		0.25	0.08	0.22		0.77	0.59
ground cover (wetlands)	21.00				0.48		0.74		1.22	0.98
ground cover (exotic weeds)	15.00	0.18				0.64			0.82	0.83
All	507.00	0.05	0.04	0.07	0.18	0.19	0.43	0.11	1.07	0.19

Table 5b Bare soil as percentage of area in specified standard of cover :

	Number of sample sites	Streambank erosion	Streambank deposition	Tunnels	Gullies	Landslides	Slumps	Rock outcrops (sheetwash & rockfall)	All natural erosion	+ - 2 s.e.
	n	%	%	%	%	%	%	%	%	
Cover rated:										
Absent	145.00	0.01	0.05	0.07	0.23	0.19	0.65	0.19	1.39	0.39
Mis-placed	22.00	0.54			0.27	0.27	0.45		1.53	0.84
Inappropriate	29.00	0.07			0.46	0.25	0.68		1.46	0.87
Insufficient	187.00	0.05	0.08	0.10	0.20	0.29	0.51	0.14	1.37	0.36
Sufficient	124.00	0.01		0.07	0.03	0.02	0.07	0.04	0.24	0.14

Bare soil, whether due to natural erosion or land use, has been measured by counting 100 points overlaid on a one hectare area at each sample point. Type of natural erosion or land disturbance has been recorded in each instance.

For natural erosion on unstable land, the following are bare soil percentages, averaged for each category of soil conservation cover :

Absent :	1.4%
Planted cover :	
Spaced trees	1.0%
Spaced trees + ground cover	0.5%
Close trees	0%
Close trees + spaced trees	0%
Close trees + ground cover	0%
Natural cover :	
spaced trees or shrubs	1.1%
close trees or shrubs	1.3%
trees or shrubs + ground cover	0.8%
ground cover (wetlands)	1.2%
ground cover (exotic weeds)	0.8%

When all categories of soil conservation cover are combined, bare soil occupies 1.1% of unstable land. This equates to 0.6% of the catchment's area. Table 5a gives sample error margins and also the types of natural erosion present.

Natural erosion appears to be lower where soil conservation cover has been planted or retained, than where it is absent. This holds true whatever the cover. However because the percentage of bare soil is low in all instances, error margins overlap i.e. the differences are not statistically significant. Zero figures for close-planted trees should be treated with caution because sub-sample sizes in the Mangarama are small. Measurements in other Waikato sub-catchments where close-planting is more extensive indicate that residual erosion is 0.3 to 0.9% (Hicks 2005a, 2005b).

The pattern becomes clearer when data are re-analysed according to standard of conservation cover (Table 5b) :

No cover :	1.4% bare soil
Inappropriate cover :	1.5%
Misplaced cover :	1.5%
Insufficient cover :	1.4%
Sufficient cover :	0.2%

Plantings rated misplaced or inappropriate have slightly more erosion than sites which remain unplanted. Plantings rated insufficient have slightly less. Those rated sufficient have about a sixth as much. The difference is statistically significant only in the third instance. Here it indicates that soil conservation plantings - and retained natural cover - in the Mangarama are very effective at control of natural erosion - provided dense cover is present on most of the susceptible area.

The data also indicate that soil conservation plantings - and retained natural cover - are ineffective for erosion control where trees are scattered, or where they are not present on most of the affected area. However these results may be a consequence of natural erosion in the Mangarama being currently at a low level. A significant difference between the insufficient category and the unplanted category might be expected, if a survey were to be carried out after a storm or wet winter.

Table 6: Soil disturbance by land use, Mangarama catchment)

	Number of sample sites	Farm or forest tracks	Farm or forest earthworks	Farm drainage	Tree harvest	Stock trampling	Cultivation	Harvest	All disturbance	+ 2 s.e.
	n	% of area	% of area	% of area	% of area	% of area	% of area	% of area	% of area	
Landforms :										
Stable	237.00	1.63	1.17	0.09		0.75	1.07	0.44	5.15	1.79
Unstable inactive	103.00	2.30	0.19	0.37		0.94			3.80	1.11
Unstable active	507.00	1.25	0.24	0.08		0.66		0.48	2.71	0.54
All	847.00	1.49	0.50	0.12		0.72	0.31	0.41	3.55	0.13

Exposure of soil by land-use-related activities is more extensive. These are farm or forestry tracks, earthworks associated with farming or forestry, drain excavation or cleaning, soil bared by timber harvest, stock trampling or cultivation. Most such disturbances are temporary and rectified within the space of a year by re-grassing or tree planting.

For land use disturbance, the following are bare soil percentages within each category of landform stability (differences amongst categories of soil conservation cover on unstable land are not given - they are not to be expected because the cover has no effect on incidence of bulldozing etc.) :

Stable land	5.2%
Unstable inactive land	3.8%
Unstable active land	2.7%
All land	3.6%

Table 6 gives sample error margins, and also the different types of land-use-related disturbance.

Almost half of the land use disturbance is tracking. Note that the dataset does not differentiate metalled from unsurfaced tracks (this distinction cannot be made consistently on the aerial photos). A fifth is stock trampling or heavy grazing. Cultivation is just under a tenth, and soil exposure by harvest of crops hay or silage, or by spraying for pasture renewal, just over a tenth. Earthworks and drainage collectively account for the balance of exposed soil. Soil disturbance by timber harvest is currently absent.

Soil disturbance by land use appears highest on stable land, but not significantly more than on unstable inactive land (the high error terms are due to data variability - several sample points where there is 100% soil exposure due to cultivation or harvest). On unstable land where erosion is active, the incidence of land-use disturbance is less than on unstable inactive land, though not significantly so.

Changes in the catchment between 1992 and 2002

Comparisons with 1992 data are limited by several features of the 1992 photography - it is black-and-white, scale 1:27500, un-rectified, not scanned, and not in the GIS. Also 1992 assessments were only carried out for hill country within the Mangarama, at Environment Waikato's request, for Project Watershed in 2001.

Soil stability

Assessed for whole catchment at both dates, but using improved version of point sampling method on the 2002 photographs.

Stable land :	1992	26% of catchment;	2002	28%
Unstable inactive land :	1992	60% of catchment;	2002	50%
Unstable land containing recent erosion :	1992	9% of catchment;	2002	8%
Unstable land containing fresh erosion :	1992	5% of catchment;	2002	14%
Bare soil due to fresh erosion :	1992	4.8%;	2002	0.7%

Comment : The leap in unstable land containing fresh erosion is due to the change in sampling method. In 1992 the fresh erosion category only included

scars directly under sampling points. In 2002 the category included scars disseminated within 1 hectare areas around sampling points. The decline in bare soil 1992 - 2002 is however real, as both figures have been determined by point count. There was extensive slipping, slumping and streambank damage in the Mangarama during wet winters between 1990 and 1992, still visible on the 1992 photography. On the 2002 photography most of these scars have re-grassed. Others have opened up within recent years but are not as large or as widespread.

Need for conservation measures

Assessed only for hill country from 1992 photographs (at EW's request for Project Watershed in 2001). Assessed for whole catchment from 2002 photographs.

None required :	1992	34% of unstable hill country;	2002	17% of unstable land in catchment
Spaced pole planting :	1992	48% of unstable hill country;	2002	64% of unstable land
Block afforestation :	1992	2% of unstable hill country;	2002	11% of unstable land
Retirement and reversion :	1992	15% of unstable hill country;	2002	8% of unstable land

Comment : Substantial change in assessed need. Including the downlands, terraces and floodways has brought in a lot of land with tunnels and streambanks that need spaced planting. On the hill country, a greater proportion has been assessed as needing block afforestation rather than retirement and reversion. The 2002 assessment criteria do not distinguish retirement and reversion as a separate category, but it approximates points assessed as needing both close and spaced planting, plus points that need ground cover.

Extent of measures

None present :	1992	67% of unstable hill country;	2002	29% of unstable land needing measures
Spaced pole planting :	1992	17% of unstable hill country;	2002	25% of unstable land
Block afforestation :	1992	2% of unstable hill country;	2002	2% of unstable land
Retirement and reversion :	1992	14% of unstable hill country;	2002	44% of unstable land

Comment : Substantial change in extent of installed measures is partly due to expanding the 2002 survey downstream, rather than additional planting on the hill country. Including the downlands and terraces has picked up a lot of poles along watercourses and tunnels, additional to poles on slumps and earthflows detected by the 1992 survey. The leap in natural cover includes some podocarp forest stands and remnant wetlands on floodways. However most of the natural cover detected, is scattered scrub or remnant forest trees on hill country. So there appears to be a

genuine increase in natural cover, due to lighter grazing and fencing off of steep faces or gullies, over the decade.

Adequacy of measures

Absent :	1992	67% of unstable hill country;	2002	29% of unstable land needing measures
Inappropriate :	1992	not assessed	2002	6%
Misplaced :	1992	not assessed	2002	4%
Insufficient :	1992	18% of unstable hill country;	2002	37%
Sufficient :	1992	15% of unstable hill country;	2002	24%

Comment : Including downlands and terraces has boosted percentage of land where measures are present (as explained above). There has been a consequent increase in pole plantings rated as adequate (these show up in both the insufficient and sufficient categories), though a portion of the insufficient category's rise is also attributable to scrub reversion on hill faces 1992 - 2002.

Erosion under different types of conservation measure

None present :	1992	14% bare soil due to fresh erosion on unstable hill country ;	2002	1.4% bare soil on unstable land needing measures
Spaced pole planting :	1992	6% bare soil due to fresh erosion;	2002	1.0%
Block afforestation :	1992	0% bare soil due to fresh erosion;	2002	0.0%
Retirement and reversion :	1992	2% bare soil due to fresh erosion;	2002	0.8% to 1.3%

Comment : Three effects interact here. Greater precision of the point sampling method has improved detection of bare soil amongst soil conservation plantings (this can be best explained by reference to 2002 error margins which are 0.19% to 1.58% for bare soil cf. 4 to 6% for the 1992 data). Including downstream parts of the catchment has greatly dropped the percentage of bare soil on un-planted land (un-planted unstable land downstream currently doesn't have much erosion). Third, there appears to have been a genuine drop in bare soil 1992 - 2002 on planted and unplanted ground alike, due to fewer storms in the late 1990s & early 2000s.

Erosion under different standards of conservation measure

Measures absent :	1992	14% bare soil due to fresh erosion on unstable hill country;	2002	1.4% bare soil on unstable land needing measures
Measures misplaced or inappropriate :	1992	not assessed separately;	2002	1.5% bare soil
Measures insufficient :	1992	4% bare soil due to fresh erosion;	2002	1.4% bare soil
Measures sufficient :	1992	3% bare soil due to fresh erosion;	2002	0.2% bare soil

Comment : Drops in bare soil between 1992 and 2002 are explained by the three factors already discussed (see preceding section), including greater catchment stability in the late 1990s - early 2000s. What the data show at both dates - conclusively in 2002 due to better error margins - is that it doesn't matter whether poles or pines are planted, or whether native reversion is allowed as an alternative. What matters is planting (or retaining) enough of whatever woody vegetation cover, in the right places on erodible land.

Soil disturbance by land use

Not measured from 1992 photographs. 2002 data are :

Cultivation :	0.3% bare soil catchment-wide
Grazing pressure :	0.7%
Crop or pasture harvest :	0.4% (this figure may come down if pasture harvest is excluded)
Timber harvest :	0%
Farm or forest tracks :	1.5%
Drainage :	0.1%
Earthworks :	0.5%

Comment : In 2002 3.6% of the catchment's soil was exposed by land use-related activities. This compares with 0.7% exposed by natural erosion.

Conclusions

72% of the Mangarama catchment is unstable land, showing evidence of past erosion.

Much of this land is inactive i.e. there has been no fresh or recent erosion. On 17% of the unstable land (12% of catchment area) there is no foreseeable need for soil conservation measures.

The other 83% of unstable land (60% of catchment area) needs vegetative soil conservation measures to protect against streambank erosion or deposition, tunneling (soil piping), gullies, landslides, slumps and earthflows.

Vegetative soil conservation measures have been installed or retained on 71% of the land where they are needed (43% of catchment area). Another 29% of unstable land (17% of catchment area) remains to be planted.

10% of installed measures have been rated as inappropriate or misplaced 37% of installed measures have been rated as appropriate but insufficient in extent. 24% have been rated as appropriate and sufficient.

Bare soil due to natural erosion is 1.4% by area, on unstable land where vegetative soil conservation measures are absent. Bare soil is slightly higher at 1.5%, amongst soil conservation measures that are inappropriate or misplaced. It declines to 1.4% amongst soil conservation measures that are appropriate but insufficient in extent, and 0.2% amongst sufficient measures. When all categories are combined (including stable land with no erosion), natural erosion currently affects 0.7% of the catchment's area.

Soil disturbance by land use is currently 3.6% of the catchment's area. 1.5% is farm and forest tracking, a proportion of which is metalled rather than bare soil. 0.7% is soil exposure by stock trampling or heavy grazing. Cultivation and harvest, of crops, hay or silage, occupy 0.3% and 0.4% of the catchment. Other land use-related disturbance - earthworks, drainage, and timber harvest - are currently minor or absent. With the exception of tracking, these forms of soil disturbance are short-term. At any one site they are remedied within months by revegetation carried out in the normal course of farming or forestry. However it may be of interest to know that sites bare at any one time add up to a measureable percentage of catchment area - currently larger than sites bared by natural erosion.

Between 1992 and 2002 natural erosion has declined throughout the catchment, from 4.8% to 0.7% by area. Most of the decline appears due to healing of scars from storms 1990-1992 that were widespread on the 1992 photographs; together with a low incidence of erosion in the years prior to 2002 photography.

Soil disturbance by land use was not measured from the 1992 photographs. In 2002 3.6% of the catchment's area had exposed soil; most accounted for by farm and forest tracking or livestock grazing pressure. The percentage is lower than for other Waikato sub-catchments that are more intensively used e.g. Pokaiwhenua and Matahuru.

References

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