Auckland
Regional Council
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Vegetative Soil Conservation Cover in the Auckland Region 2007

February TR 2009/014

Auckland Regional Council
Technical Report No.014 February 2009
ISSN 1179-0504 (Print)
ISSN 1179-0512 (Online)
ISBN 978-1-877528-21-7

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Date: 27 February 2009

Recommended Citation:

Thompson, A. J.; Hicks, D. L. (2009). Vegetative Soil Conservation Cover in the Auckland Region 2007. Prepared for Auckland Regional Council. Auckland Regional Council Document Type TR 2009/014.

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Contents

1 Introduction

This document summarises data and discusses results relevant to vegetative soil conservation cover, from a point sample survey of soil state (intactness and disturbance) from 2007 region-wide aerial photography. The survey has been carried out in accordance with the National Land Monitoring Forum's procedure for point sampling (NLMF, in prep.), and is similar to surveys carried out in the Manawatu-Wanganui, Auckland, Gisborne, Waikato, Wellington, Tasman and Bay of Plenty regions between 1997 and 2005.

Auckland's survey has been carried out primarily to provide information about soil state (intactness and disturbance) for state of environment reporting. Survey data are also expected to be useful for other purposes, such as providing detail about the region's land use; assessing the extent of vegetative soil conservation measures; and as a source of facts and figures for the Council's policy documents and publications.

The document is the fourth of four reports:

- Methods Used to Survey Soil State in the Auckland Region 2007,
- Soil State in the Auckland Region 2007,
- Vegetation Associated with Land Uses in the Auckland Region 2007, and
- Vegetative Soil Conservation Cover in the Auckland Region 2007.

2 Report Structure

Table 4.1 contains summary data about land use in the Auckland region in the year 2007, specifically:

- Percentage of sample points in each of nine broad uses (intensive, dairy, drystock, forest plantation, natural forest, natural scrub, exotic scrub, coastal grass and scrub, wetlands and mangrove swamps),
- Percentage of sample points in other use (buildings and yards, urban areas, water bodies and coastal features, points unclassified or lacking aerial photo cover).

Table 4.1 precedes Tables 4.2 to 4.10 which present two measures of whether soil conservation is needed:

- Percentage of land that is stable. Here dense primary vegetative cover is needed, to protect topsoil from erosion induced by land use; and
- Percentage of land that is unstable. Here extensive secondary vegetative cover is needed, to protect topsoil and subsoil from erosion by natural processes.

The tables also present two measures of the extent of soil conservation:

- For stable land, the percentage where primary cover is sparse, dense or harvested; and
- For unstable land, the percentage where secondary cover is absent, scattered or extensive.

Finally, the tables present two measures of whether soil conservation is effective:

- For stable land, the percentage of bare soil due to fresh disturbance by activities associated with land use. This percentage can be equated with topsoil exposed to risk of loss.
- For unstable land, the percentage of bare soil due to fresh disturbance by natural processes. This percentage can be equated with subsoil affected by erosion or deposition.

Cluster sampling has been used to measure bare soil. It entails measuring bare soil at 100 dots spaced in a one hectare square around each sample point where fresh disturbance is detected. The procedure gives more accurate percentages, with reduced error margins, than are obtainable from sample point counts (NLMF, in prep.)

Summary data are presented in table 4.1 to set the scene for discussions of vegetative soil conservation cover under each land use, which follow Tables 4.2 to 4.10.

Table 4.1

Land uses throughout the Auckland region, 2007

Land uses	Composition	Points	Points as % of sample	95% conf. lim.
Rural uses :		2883	54.6	1.3
Intensive cultivation	vineyards incl. kiwifruit	26	0.5	0.2
	orchards incl. avocado	33	0.6	0.2
	market gardens	66	1.3	0.3
	grain crops	34	0.6	0.2
	greenfeed crops	12	0.2	0.1
	sub-total	171	3.2	0.5
Permanent pasture	dairy, improved	591	11.2	0.9
	drystock, improved	1496	28.3	1.2
	drystock, unimproved	146	2.8	0.4
	sub-total	2233	42.3	1.3
Forest plantations	coniferous trees	475	9.0	0.8
	broadleaved trees	4	0.1	0.1
	sub-total	479	9.1	0.8
Conservation uses :		1406	26.6	1.2
Bush	natural forest	383	7.3	0.7
	natural scrub	758	14.4	0.9
	exotic scrub	122	2.3	0.4
	sub-total	1263	23.9	1.2
Coastal and wetland plants	coastal grass and scrub	29	0.5	0.2
	freshwater wetland	25	0.5	0.2
	saline wetland	89	1.7	0.3
	sub-total	143	2.7	0.4
Other uses :		939	17.8	1.0

Urban areas	residential	309	5.9	0.6
	industrial/commercial	99	1.9	0.4
	roads, railways, airfields	18	0.3	0.2
	open space	152	2.9	0.5
	sub-total	578	11.0	0.8
Rural buildings	farm buildings and yards	123	2.3	0.4
	industrial buildings and quarries	34	0.6	0.2
	roads, railways, airfields	5	0.1	0.1
	sub-total	162	3.1	0.5
Water bodies and coastal features	lake or pond	16	0.3	0.1
	inter-tidal estuary	101	1.9	0.4
	beach	31	0.6	0.2
	rock platform or cliff	51	1.0	0.3
	sub-total	199	3.8	0.5
Unclassifiable land :		49	0.9	0.3
Other	unclassified points in 2007	0	0.0	0.0
	points with no photos in 2007	49	0.9	0.3
	sub-total	49	0.9	0.3
All land in region :	total	5277	100.0	0.0

Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding.
Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding.
Note 3: confidence limits are not additive.

3 Soil Conservation Cover under Different Land Uses

3.1 Soil Conservation Cover under Intensive Land Uses

(Table 4.2)

Intensive uses occupy 3.2% of the Auckland region. 82% of the area under intensive use is on stable land:

- 31% of the stable land has sparse primary cover i.e. emerging crops, recently planted vines or fruit trees. Here 50% of soil is bared by land use-related disturbance.
- 61% is dense i.e. maturing crop, or vines and fruit trees in leaf. 5% of soil is bare.
- 8% is harvested i.e. crop stubble or fallow. Bare soil rises to 10%.

18% of the area is on unstable land:

- On 7% of unstable land secondary cover is absent; however soil is not exposed by natural processes of erosion or deposition.
- 48% of unstable land has grass as secondary cover, but again soil is not exposed by natural processes of erosion or deposition.
- 10% of unstable land has secondary cover of scattered trees and scrub. There is no bare soil exposed by natural processes amongst natural tree and scrub cover, and 5% amongst planted (just one sample point).
- 29% of unstable land has secondary cover of extensive trees and scrub. There is 1% bare soil exposed by natural processes amongst natural tree and scrub cover, and less than 1% bare soil amongst planted cover.

3.1.1 Comments

The sample size for this category is relatively small (n=171) resulting in wide confidence intervals for its smaller sub-samples (n<20), and so the percentages for bare soil do not reliably indicate true regional figures. At best they provide an approximate picture of what is happening by way of erosion under various soil conservation covers:

Table 4.2

Soil conservation cover amongst intensive uses (orchards, vineyards, vegetable crops, grain crops, fodder crops)

	sample points	% of region		sample points	% of land use		sample points	% of stable land	bare soil exposed by land use	
All land in use :	171	3.2	where stable :	140	81.9	where primary cover is :			% of category	95% conf. lim.
						sparse	43	30.7	49.51	9.49
						dense	86	61.4	5.22	2.71
						harvested	11	7.9	10.00	7.58
							140	100.0		
							sample points	% of unstable land	bare soil exposed by erosion	
			where unstable :	31	18.1	where secondary cover is :			% of category	95% conf. lim.
						absent	2	6.5	0.00	0.00
						grass and wetland	15	48.4	0.00	0.00
						scattered natural trees & scrub	2	6.5	0.00	0.00
						scattered exotic trees & scrub	1	3.2	5.00	0.00
						extensive natural trees & scrub	1	3.2	1.00	0.00
						extensive exotic trees & scrub	8	25.8	0.50	0.86
						non-vegetative	2	6.5	0.00	0.00
							31	100.0		

On stable land:

- Emerging crops, and freshly planted vines or orchard trees, do not provide much protection against exposure to topsoil loss.
- Dense crop cover, or established vines and orchards (together with their grass ground cover) provide a ten-fold reduction in exposure to topsoil loss compared with sparse plantings.
- Crop stubble affords a reasonable degree of protection against exposure to topsoil loss (10% exposure cf. 5% pre-harvest).

On unstable land:

- Where secondary cover is absent on unstable land, natural soil erosion is currently low or undetected.
- Where secondary cover is grass, natural soil erosion is also currently low or undetected.
- Generally, bare soil appears to be minimal at most sample points where secondary vegetation cover is scrub or trees. Exceptions are isolated sample points e.g. gully sides and sideling's adjacent to intensive uses.

3.2 Soil Conservation Cover in Dairy Pasture

(Table 4.3)

Dairy farms occupy 11.2% of the Auckland region. 56% of dairy pasture is on stable land:

- 21% of the stable land has sparse primary cover i.e. is heavily grazed. Here 3.8% of soil is bared by land use-related disturbance.
- 78% has dense primary cover i.e. lightly grazed or spelled. 2.9% of soil is bare.
- 1% has harvested primary cover i.e. cut for hay or silage. In this case, bare soil rises to 5.2%.

44% of the dairy pasture is on unstable land:

- On 33% of the unstable land, secondary cover is absent. Here 0.45% of soil is bared by natural processes of erosion or deposition.
- On 10% where secondary vegetation is rank grass, bare soil is absent.
- On 31% secondary cover is scattered trees or scrub. 1.00% of soil is bare amongst natural cover, and 1.20% amongst planted cover.
- On 24% secondary cover is extensive trees or scrub. Bare soil falls to 0.24% amongst natural cover and 0.42% amongst planted.

3.2.1 Comments

Sub-sample sizes are reasonably large except in one category (harvested for hay or silage). Bare soil percentages indicate reliable regional averages, though confidence intervals indicate differences in bare soil are significant amongst some, but not all categories of conservation cover:

On stable land:

- Sparse pasture provides reasonably good protection against exposure to topsoil loss by land use-related disturbance; however the percentage of bare soil is increased compared with dense cover.
- Dense pasture provides better protection against topsoil loss, but bare soil is still evident.
- Harvested ground has an elevated percentage of bare soil compared with dense cover (almost twice). This may be due to late-season haymaking when there is a more open sward under water deficit conditions.

On unstable land:

- In the absence of secondary cover, natural soil erosion is currently low, and is decreased even further where secondary vegetation cover is rank (ungrazed pasture) e.g. in drainage hollows and on streambanks.
- Scattered secondary cover (both natural and planted) has twice as much bare soil as where secondary cover is absent or rank grass, but at 1.00 - 1.20% is not significantly greater. The increase is possibly due to location of this scattered vegetation on steeper land including gullies and sideling's.
- Extensive secondary cover has slightly less erosion than where secondary cover is absent or rank grass. Again, the decrease is statistically insignificant. It may indicate some stabilization where woody vegetative cover has been retained or planted in drainage hollows or on stream banks.

Table 4.3

Soil conservation cover amongst dairy pasture

	sample points	% of region		sample points	% of land use		sample points	% of stable land	bare soil exposed by land use	
All land in use :	591	11.2	where stable :	328	55.5	where primary cover is :			% of category	95% conf. lim.
						sparse	68	20.7	3.84	1.91
						dense	255	77.7	2.89	0.50
						harvested	5	1.5	5.20	3.11
							328	100.0		
							sample points	% of unstable land	bare soil exposed by erosion	
			where unstable :	263	44.5	where secondary cover is :			% of category	95% conf. lim.
						absent	88	33.5	0.45	0.31
						rank grass and wetland	25	9.5	0.00	0.00
						scattered natural trees & scrub	30	11.4	1.00	0.84
						scattered exotic trees & scrub	51	19.4	1.20	0.71
						extensive natural trees & scrub	21	8.0	0.24	0.31
						extensive exotic trees & scrub	43	16.3	0.42	0.59
						non-vegetative	5	1.9	0.00	0.00
							263	100.0		

3.3 Soil Conservation cover in Drystock Pasture

(Table 4.4)

Drystock farms occupy 31.1% of the Auckland region. 41% of drystock pasture is on stable land:

- 25% of the stable land has sparse primary cover, i.e. is heavily grazed. Here 3.1% of soil is bared by land use-related disturbance.
- 73% is dense i.e. lightly grazed or spelled. 1.7% of soil is bare.
- 2% is harvested i.e. cut for hay or silage. 1.9% of soil is bare.

59% of drystock pasture is on unstable land:

- On 17% of the unstable land, secondary vegetation is absent. Here, 1.59% of soil is bared by natural processes of erosion or deposition.
- On 8%, rank grass and wetland are present as secondary cover. Here, 0.80% of soil is bare.
- On 35% secondary vegetation is scattered trees or scrub. 1.11% of soil is bare amongst natural cover and 0.94% amongst planted cover.
- On 35% secondary vegetation is extensive trees or scrub. Bare soil is 0.93% amongst natural cover, and 0.40% amongst planted.

3.3.1 Comments

Sub-sample sizes are sufficiently large except in one category (harvested for hay or silage) to provide reliable regional averages. The pattern of erosion under various soil conservation covers is similar to that for dairy pasture:

On stable land:

- Sparse pasture provides reasonably good protection against exposure to topsoil loss by land use-related disturbance, however the percentage of bare soil is increased compared with dense cover.
- Dense pasture provides better protection against topsoil loss, but bare soil is still evident.
- Harvested ground has a slightly elevated percentage of bare soil compared with dense cover. Similar to dairy farms, this may be due to late-season hay harvesting when there is a more open sward under water deficit conditions.

Table 4.4

Soil conservation cover amongst drystock pasture

	sample points	% of region		sample points	% of land use		sample points	% of stable land	bare soil exposed by land use	
All land in use :	1642	31.1	where stable :	669	40.7	where primary cover is :			% of category	95% conf. lim.
						sparse	169	25.3	3.05	1.08
						dense	487	72.8	1.68	0.25
						harvested	13	1.9	1.85	1.35
							669	100.0		
							sample points	% of unstable land	bare soil exposed by erosion	
			where unstable :	973	59.3	where secondary cover is :			% of category	95% conf. lim.
						absent	162	16.6	1.59	0.95
						rank grass and wetland	82	8.4	0.80	0.30
						scattered natural trees & scrub	167	17.2	1.11	0.38
						scattered exotic trees & scrub	175	18.0	0.94	0.50
						extensive natural trees & scrub	181	18.6	0.93	0.48
						extensive exotic trees & scrub	162	16.6	0.40	0.22
						non-vegetative	44	4.5	0.00	0.00
							973	100.0		

On unstable land:

- In the absence of secondary cover, natural soil erosion is presently low. It is even lower where secondary cover is rank grass and wetland, but the difference is not statistically significant.
- Where secondary cover is scattered scrub or trees, soil bared by natural disturbance is still low (about 1%), and not significantly different from where secondary cover is rank grass or absent.
- Where secondary cover is extensive scrub or trees, it provides slightly better protection against erosion compared with scattered secondary cover, though the difference is significant only for planted cover.

3.4 Soil Conservation Cover in Forest Plantations

(Table 4.5)

Forest plantations occupy 9.1% of the Auckland region. 18% of forest plantations are on stable land:

- 26% of the stable land has sparse primary cover i.e. young stands with open canopy. Here 4.1% of soil is bared by land use-related disturbance.
- 68% is dense i.e. maturing closed-canopy stands. 2.2% of soil is bare.
- 6% is harvested. Here bare soil rises to 12.8%.

82% of forest plantations are on unstable land:

- 26% of the stands on unstable land are dense closed-canopy, lacking secondary vegetation. Here 0.15% of soil is bared by natural processes of erosion or deposition.
- 7% are young stands (re-planted) where secondary cover is oversown rank grasses/legumes. Here, bare soil is 0.35%.
- 24% have scattered scrub or trees as secondary vegetation. These are young stands, with scrub regrowth (mostly exotic) around trees. No soil is bare amongst natural cover (just four sample points), and 1.93% is bare amongst induced/planted cover.
- 42% have extensive scrub or trees as secondary vegetation. These are a mix of older stands that have not yet closed canopy (still with scrub regrowth, mostly exotic), with mature closed-canopy stands that have scrub or trees (generally natural) in canopy gaps. Bare soil is 0.43% amongst natural cover, and 0.06% amongst induced/planted.

Table 4.5 Soil conservation cover amongst plantation forests

	sample points	% of region		sample points	% of land use		sample points	% of stable land	bare soil exposed by land use	
All land in use :	479	9.1	where stable :	87	18.2	where primary cover is :			% of category	95% conf. lim.
						sparse	23	26.4	4.09	1.65
						dense	59	67.8	2.15	1.32
						harvested	5	5.7	12.80	9.75
							87	100.0		
							sample points	% of unstable land	bare soil exposed by erosion	
			where unstable :	392	81.8	where secondary cover is :			% of category	95% conf. lim.
						absent	103	26.3	0.15	0.15
						grass and wetland	26	6.6	0.35	0.29
						scattered natural trees & scrub	4	1.0	0.00	0.00
						scattered exotic trees & scrub	91	23.2	1.93	1.54
						extensive natural trees & scrub	60	15.3	0.43	0.22
						extensive exotic trees & scrub	105	26.8	0.06	0.08
						non-vegetative	3	0.8	0.00	0.00
							392	100.0		

3.4.1 Comments

Sub-sample sizes are sufficiently large to provide reliable regional averages for most categories. However confidence intervals are wide for bare soil amongst harvested primary cover.

On stable land:

- Harvested areas present a high percentage of soil exposed to topsoil loss. Most of the soil exposure in harvested areas is attributable to roads, landing stages and haul-tracks. Many remain bare for several years after clear-felled sites are over-sown and re-planted; hence there is also an elevated bare ground figure for sparse compared with dense primary cover on stable land.

On unstable land:

- Incidence of natural soil erosion is presently low amongst mature closed canopy stands (secondary cover absent).
- It is also low (less than 1% by area) amongst young stands with all categories of secondary cover, except for scattered induced/planted scrub or trees.
- The bare soil here is 1.93% by area. Most sample points in this category are re-planted sites where exotic scrub is emerging through over sown grasses/legumes). The figure is significantly higher than other categories, and indicates somewhat more erosion due to natural disturbance on re-planted sites several years after harvest.

3.5 Soil Conservation Cover in Natural Forest

(Table 4.6)

Natural forest occupies 7.3% of the Auckland region. 25% of natural forest is on stable land.

- 14% of the stable land has forest with canopy gaps. Bare soil is 0.38% by area, and is attributed to disturbance by land use (see comments).
- 86% has close canopy forest or open canopy forest with a scrub under-storey. Here bare soil is 0.20%.
- 0% is recently harvested, so no bare soil has been measured for this category of primary cover.

Table 4.6

Soil conservation cover amongst natural forests

	sample points	% of region		sample points	% of land use		sample points	% of stable land	bare soil exposed by land use	
All land in use :	383	7.3	where stable :	95	24.8	where primary cover is :			% of category	95% conf. lim.
						sparse	13	13.7	0.38	0.46
						dense	82	86.3	0.20	0.23
						harvested	0	0.0	0.00	0.00
							95	100.0		
							sample points	% of unstable land	bare soil exposed by erosion	
			where unstable :	288	75.2	where secondary cover is :			% of category	95% conf. lim.
						absent	115	39.9	0.26	0.21
						grazed pasture	35	12.2	0.49	0.53
						rank grass	5	1.7	22.20	23.87
						wetland	0	0.0		
						natural scrub	117	40.6	0.09	0.08
						exotic trees & scrub	10	3.5	1.00	1.11
						non-vegetative	6	2.1	0.00	0.00
							288	100.0		

75% of the forest is on unstable land:

- 40% is close canopy forest without visible secondary vegetation. 0.26% of this category's soil is bared by natural processes of erosion or deposition.
- 12% has grazed pasture as secondary vegetation on forest edges. Here 0.49% of soil is bare.
- 2% has rank grass as secondary vegetation on forest edges. Here 22% of soil is bare (see comments).
- 41% has natural woody scrub, either as an understory or in canopy gaps. 0.09% of this category's soil is bare.
- 4% has exotic scrub or wildling trees in canopy gaps. Bare soil is 1.00% by area.

3.5.1 Comments

Sub-sample sizes are sufficiently large to provide reliable regional averages, apart from rank grass (n=5) and exotic scrub/trees (n=10). The pattern of erosion under various conservation covers is very different from commercial land uses:

- On stable land, exposure to topsoil loss by land use-related disturbance is minimal.
- Natural soil erosion is low - but measurable - on unstable terrain under closed-canopy forest.
- Where secondary cover is rank grass, incidence of erosion appears greatly elevated (22%) This is partly due to recent and recovering erosion scars or streambank deposits at some of the sample points, but is grossly inflated by a single point (forest and marram grass) next to an exposed estuarine sandbank. The high bare soil percentage must be regarded as anomalous (confirmed by the error margin).
- Erosion is low where forest canopy gaps are occupied by natural woody scrub, though not significantly lower than closed canopy forest. These are either open canopy forest with a scrub understorey; or sites of former disturbance by gullies or landslides, now at an advanced stage of plant succession.
- Erosion is slightly elevated (1%) where canopy gaps are occupied by exotic scrub or wildling trees. Again, these are disturbance sites - erosion scars in the ranges, and abandoned farmland on their edge. However, the elevated figure does not significantly differ from other categories (its error margin is wide due to small sub-sample size).

3.6 Soil Conservation Cover in Natural Scrub

(Table 4.7)

Natural scrub occupies 14.4% of the Auckland region. 33% of natural scrub is on stable land.

- 28% of the stable land has scrub with canopy gaps. Bare soil is 1.04% by area and is attributed to disturbance by land use (see comments).
- 72% has close canopy scrub or open canopy scrub with emerging forest trees. Here bare soil is 0.57%.
- 0% is recently harvested, so no bare soil has been measured for this category of primary cover.

67% of the scrub is on unstable land:

- 23% is close canopy scrub without visible secondary vegetation. 4.44% of this category's soil is bared by natural processes of erosion or deposition.
- 14% is scrub with grazed pasture, either as an understorey or at scrub edges. Here 0.66% of soil is bare.
- 3% is scrub with rank grass either as an under-storey or at scrub edges. Here 1.44% of soil is bare.
- 40% has natural forest trees emerging through scrub canopy. 0.31% of this category's soil is bare.
- 15% has exotic scrub or wildling trees occupying canopy gaps. Bare soil is 0.09% by area.
- 1.6% has wetland vegetation as secondary cover in canopy gaps, with 0.25% bare soil.

3.6.1 Comments

Sub-sample sizes are sufficiently large to provide reliable regional averages in all instances except wetland (n=8). Some secondary cover categories have wide error margins despite a large sub-sample size. This indicates a few sites with very high bare ground percentages e.g. large slope failures and gullies in the ranges.

Table 4.7

Soil conservation cover amongst natural scrub

	sample points	% of region		sample points	% of land use		sample points	% of stable land	bare soil exposed by land use	
All land in use :	758	14.4	where stable :	253	33.4	where primary cover is :			% of category	95% conf. limit
						sparse	71	28.1	1.04	0.54
						dense	182	71.9	0.57	0.27
						harvested	0	0.0	0.00	0.00
							253	100.0		
							sample points	% of unstable land	bare soil exposed by erosion	
			where unstable :	505	66.6	where secondary cover is :			% of category	95% conf. limit
						absent	115	22.8	4.44	2.16
						grazed pasture	71	14.1	0.66	0.48
						rank grass	16	3.2	1.44	1.93
						wetland	8	1.6	0.25	0.43
						natural trees	204	40.4	0.31	0.30
						exotic trees & scrub	78	15.4	0.09	0.11
						non-vegetative	13	2.6	0.00	0.00
							505	100.0		

The pattern of erosion under various conservation covers differs somewhat from what has been measured for natural forest:

- On stable land exposure to topsoil loss by land use-related disturbance is measureable It occurs where unsealed roads and unsurfaced access tracks pass through scrubland.
- Natural erosion is over 4% amongst closed canopy scrub on unstable land. It is attributable to a wide range of disturbance types - landslides, streambank scour and deposition, sheetwash and rockfalls.
- Erosion significantly reduces to 0.7% in open canopy scrub with grazed pasture as ground cover. Bare soil appears higher (1.4%) where rank grass is ground cover, but the difference is not significant (a wide error margin).
- Erosion further reduces to 0.3% where regenerating forest trees are emerging through scrub canopy. Compared with closed canopy scrub, there is little natural disturbance at these sites. Their level of erosion is similar to what has been measured in open canopy forest with a scrub under-storey (see Table 4.6).
- Where induced exotic scrub or wilding trees are present as secondary cover in canopy gaps, erosion is least (0.1%). These are sites of former natural disturbance, now at an advanced stage of reversion, where some exotic scrub or wilding trees still remain amongst natural scrub that is taking over.
- Wetlands and mangroves are present as secondary cover in scrub at a small number of sample points. Here, bare soil due to natural disturbance is low (0.25%). However this figure cannot be regarded as representative, because there are few sample points in the category, and the erosion is due to a single point where bank scour has been measured on a tidal creek.

3.7 Soil Conservation Cover is Exotic Scrub

(Table 4.8)

Exotic scrub occupies 2.3% of the Auckland region. 29% of exotic scrub is on stable land.

- 29% of the stable land has scrub with canopy gaps. Bare soil is 1.90% by area and is attributed to disturbance by land use (see comments).
- 71% has close canopy scrub or open canopy exotic scrub, through which natural scrub, forest trees, or wildling trees are emerging. Here bare soil is 0.76% by area.
- 0% is recently harvested, so no bare soil has been measured for this category of primary cover.

Table 4.8

Soil conservation cover amongst exotic scrub

	sample points	% of region		sample points	% of land use		sample points	% of stable land	bare soil exposed by land use	
All land in use :	122	2.3	where stable :	35	28.7	where primary cover is :			% of category	95% conf. limit
						sparse	10	28.6	1.90	2.07
						dense	25	71.4	0.76	1.20
						harvested	0	0.0	0.00	0.00
							35	100.0		
							sample points	% of unstable land	bare soil exposed by erosion	
			where unstable :	87	71.3	where secondary cover is :			% of category	95% conf. limit
						absent	7	8.0	0.43	0.72
						grazed pasture	11	12.6	0.00	0.00
						rank grass	24	27.6	0.75	0.78
						wetland	2	2.3	0.00	0.00
						natural scrub	27	31.0	0.37	0.40
						exotic trees & scrub	14	16.1	0.52	0.27
						non-vegetative	2	2.3	0.00	0.00
							87	100.0		

71% of exotic scrub is on unstable land:

- 8% is close canopy scrub without secondary cover. For this category, 0.4% of soil is bared by natural processes of erosion or deposition.
- 13% is scrub with grazed pasture as an understorey. Here 0% of soil is bare.
- 28% has rank grass as an under-storey. Here 0.8% of soil is bare.
- 31% is open canopy exotic scrub with emerging natural scrub. For this category, 0.4% of soil is bared by natural processes.
- 16% has wildling trees as secondary cover. Bare soil is 0.5% by area.
- 2.3% has wetland as secondary cover, with no measured bare soil.

3.7.1 Comments

Although sub-samples are rather small, error margins are narrow (<1%). However they remain large relative to bare soil percentages.

There is little pattern to erosion under various exotic scrub covers:

- On stable land, exposure to topsoil loss by land use-related disturbance is slightly elevated (<1% in open or close canopy scrub; >1% where there are canopy gaps) Most of the bare soil is due to tracks and earthworks, with the balance caused by ground exposure after spraying.

On unstable land:

- Natural erosion is low (<1%) where exotic scrub is closed-canopy (lacks secondary cover).
- It remains low (<1%), though somewhat variable, amongst the various secondary cover categories. They are not significantly different from one another, apart from the grazed pasture category (0%), and the wetland category (also 0% but too few points to be representative).

3.8 Soil Conservation Cover amongst Coastal Grass and Scrub

(Table 4.9)

Coastal grass and scrub occupies 0.5% of the Auckland region. None is on stable land.

Table 4.9

Soil conservation cover amongst coastal grass and scrub

	sample points	% of region		sample points	% of land use		sample points	% of stable land	bare soil exposed by land use	
All land in use :	29	0.5	where stable :	0	0.0	where primary cover is :			% of category	95% conf. limit
						sparse	0	0.0	-	-
						dense	0	0.0	-	-
						harvested	0	0.0	-	-
							0	0.0	-	-
							sample points	% of unstable land	bare soil exposed by erosion	
			where unstable :	29	100.0	where secondary cover is :			% of category	95% conf. limit
						absent	21	72.4	67.62	14.68
						grazed pasture	0	0.0		
						rank grass	0	0.0		
						wetland	1	3.4	43.00	0.00
						natural trees and scrub	1	3.4	6.00	0.00
						exotic trees & scrub	6	20.7	3.33	3.85
						non-vegetative	0	0.0		
							29	100.0		

Of all the coastal vegetation on unstable land:

- 72% is sparse and lacks any secondary cover. 68% of soil is bared by natural processes of erosion or deposition, mainly sand-blow.
- 3% has natural scrub or trees interspersed as secondary cover. Here 6% of soil is bare (however this is a single sample point).
- 21% has exotic scrub or trees interspersed as secondary cover. Here 3% of soil is bare.
- 3% has wetland vegetation as secondary cover, with 43% bare ground (however this is a single sample point next to a sandblow).

3.8.1 Comments

Sub-sample size is small, so error margins are wide for all categories. Bare ground percentages do not reliably indicate region-wide averages for secondary vegetation, but suffice to show secondary cover's effect on soil disturbance.

Few trends in erosion are observable under various coastal vegetation covers:

- Natural erosion is very high on unstable land where coastal grass and scrub lack other cover. These sites are coastal sand dunes and flats subject to wind erosion.
- Bare ground is greatly reduced on similar sites where either natural or exotic scrub and trees are establishing. This is due to the sand-binding effect of roots and protection from wind erosion by the canopy. Most such sample points are at the fringe of forest plantations.

3.9 Soil conservation cover amongst wetlands and mangrove swamps

(Table 4.10)

Wetlands and mangrove swamps occupy 2.2% of the Auckland region. None are on stable land.

100% of wetland and mangrove vegetation is on unstable land, of which:

- 62% is close canopy mangrove swamp without any secondary cover. For this category, 4.3% of soil is bared by natural processes of erosion or deposition.
- 20% is wetland or mangrove swamp, with grazed pasture as secondary cover on shorelines, or where drainage has been attempted. Here bare soil or exposed sediment is 0.6% by area.
- 2% has rank grass as secondary cover at similar sites, but with no bare soil measured.
- 8% has natural scrub or trees as secondary cover. Bare soil is 2.3% by area.

- 7% has exotic scrub or trees as secondary cover. Bare soil is 1.9% by area.

3.9.1 Comments

Sub-sample size is small so error margins are wide for most categories. Apart from close canopy mangrove swamp, and semi-drained wetlands/mangroves with secondary pasture, bare ground percentages do not reliably indicate region-wide averages.

Few trends in erosion are observable for different vegetation categories in wetlands and mangrove swamps:

- Bare ground in mangrove swamps where secondary vegetation is absent (4.3%), is due to measurement of exposed sand banks or mudflats at sample points where mangroves are sparse.
- Reduced bare ground in other sub-samples where secondary vegetation cover is present (0 to 2.3%), is due to a lower percentage of exposed sandbanks/mudflats, where sample points fall partly on mangrove swamps or wetlands, and partly on shoreline vegetation. However apart from the grazed pasture category, error margins are too wide for any differences in bare soil/sediment to be significant

Table 4.10

Soil conservation cover amongst wetlands and mangrove swamps

	sample points	% of region		sample points	% of land use		sample points	% of stable land	bare soil exposed by land use	
All land in use :	114	2.2	where stable :	0	0.0	where primary cover is :			% of category	95% conf. limit
						sparse	0	0.0		
						dense	0	0.0		
						harvested	0	0.0		
							0	0.0		
							sample points	% of unstable land	bare soil exposed by erosion	
			where unstable :	114	100.0	where secondary cover is :			% of category	95% conf. limit
						absent	69	60.5	4.28	3.49
						grazed pasture	22	19.3	0.64	0.74
						rank grass	2	1.8	0.00	0.00
						natural trees and scrub	9	7.9	2.33	2.38
						exotic trees & scrub	8	7.0	1.88	1.50
						non-vegetative	4	3.5	0.00	0.00
							114	100.0		

4 Summary

This section summarises key points from the preceding discussion of results. The conclusions apply to Auckland's soil in 2007, the year of aerial photographic coverage. They are based on a sample of one-hectare areas at 5277 points, taken from the coverage at one kilometre spacings throughout the region.

4.1 Response to pressure on soil - vegetative soil conservation cover

Tables 4.11 - 4.14 summarise two measures of soil conservation's extent:

- for stable land, the percentage where primary cover is dense; and
- for unstable land, the percentage where secondary cover is extensive.

4.1.1 Cover on stable land

(Table 4.11, summarising Tables 4.2 - 4.10)

On stable land in rural use, dense primary vegetation functions as a soil conservation cover, protecting against surface erosion by water and wind where soil is exposed by land use-related disturbance.

Table 4.11 Extent of vegetative soil conservation cover on stable land

	Stable land : as % of area in use	Crop, grass, scrub or tree canopy present as : dense primary cover (protecting soil from disturbance by land use) as % of stable land
Rural uses:		
Intensive uses	81.9	61.4
Dairy pasture	55.5	77.7
Drystock pasture	40.7	72.8
Forest plantation	18.2	67.8
Conservation uses:		
Natural forest	24.8	86.3
Natural scrub	33.4	71.9
Exotic scrub	28.7	71.4
Coastal grass and scrub	0.0	0.0
Wetland and mangrove	0.0	0.0

- It occupies 61.4% of the stable land under intensive use, 77.7% in dairy pasture, 72.8% in drystock pasture, and 67.8% in forest plantations.

On stable land in conservation use, dense primary vegetation can also be said to act as soil conservation cover, protecting against surface erosion by water and wind.

- It covers 86.3% of the stable land under natural forest, 71.9% under natural scrub and 71.4% under exotic scrub. There is no stable land under coastal grass and scrub, nor is there any under wetlands and mangroves.

4.1.2 Cover on unstable land

(Table 4.12, summarising Tables 4.2 - 4.10)

Table 4.12

Extent of vegetative soil conservation cover on unstable land

	Unstable land :	Woody vegetation present as :	
		dense primary cover	extensive secondary cover
	as % of area in use	as % of unstable land	as % of unstable land
Rural uses:			
Intensive uses	18.1	19.4	29.0
Dairy pasture	44.5	0.0	24.3
Drystock pasture	59.3	0.0	35.2
Forest plantation	81.8	26.3	42.1
Conservation uses:			
Natural forest	75.2	39.9	43.8
Natural scrub	66.6	22.8	55.8
Exotic scrub	71.3	8.0	47.1
Coastal grass and scrub	100.0	0.0	24.1
Wetland and mangrove	100.0	58.8	15.1

On unstable land in rural use, primary vegetation has limited value for stabilising soil against erosion by natural processes, except where it is woody vegetation capable of strengthening soil through root reinforcement and dewatering.

- Two primary vegetation covers meet this criterion - intensive use, where 19.4% of unstable land has orchard trees or deep-rooting vines; and forest plantation, where 26.3% has maturing trees (closed-canopy).

Extensive secondary vegetation, where woody and dense, can protect against natural erosion. This holds true whether the vegetation has been deliberately planted to control erosion, planted for commercial reasons, or merely retained on sites that are difficult to develop.

- Such cover is present on 29.0% of the unstable land under intensive use, 24.3% in dairy pasture, 35.2% in drystock pasture, and 42.1% in forest plantations.

On unstable land in conservation use, primary vegetation has value for stabilising soil against erosion by natural processes, provided it is woody and dense.

- This criterion is met by 39.9% of natural forest, 22.8% of natural scrub, 8.0% of exotic scrub on unstable land. There is no dense woody primary vegetation amongst coastal grass and scrub on unstable land, but there is 58.8% amongst wetlands and mangroves.

Extensive secondary vegetation where woody and dense - for instance trees emerging through scrub cover - indicates a degree of site recovery, so can protect against natural erosion. This holds true whether the vegetation has been reserved for ecological reasons, or merely left on land that is not wanted for commercial production.

- Such cover is present on an additional 43.8% of unstable land in natural forest, 55.8% in natural scrub, 47.1% in exotic scrub. Amongst coastal grass and scrub the additional percentage falls to 24.1%, and 15.1% amongst wetlands and mangroves.

The above definitions of soil conservation cover may seem broad, but they give a truer picture of the extent to which protective cover is maintained by landowners and public agencies in the Auckland region, than would be obtained by looking solely at vegetation planted specifically for soil conservation purposes i.e. poplars, willows and native riparian shrubs.

4.2 Effect of response - changes in soil disturbance

Tables 4.13 and 4.14 present two measures of whether soil conservation is effective:

- For stable land, the percentage of bare soil due to fresh disturbance by activities associated with land use. This percentage can be equated with topsoil exposed to risk of loss.

- For unstable land, the percentage of bare soil due to fresh disturbance by natural processes. This percentage can be equated with subsoil affected by erosion or deposition.

4.2.1 Bare soil on stable land

(Table 4.13, summarising Tables 4.2 - 4.10)

Table 4.13

Effect of vegetative soil conservation cover on stable land

	Bare soil due to land use on stable land, where primary cover is :		
	sparse as % of area in use	dense as % of area in use	harvested as % of area in use
Rural uses:			
Intensive uses	49.5	5.2	10.0
Dairy pasture	3.8	2.9	5.2
Drystock pasture	3.1	1.7	1.9
Exotic forest plantation	4.1	2.2	12.8
Conservation uses:			
Natural forest	0.4	0.2	-
Natural scrub	1.0	0.6	-
Exotic scrub	1.9	0.8	-
Coastal grass & scrub	-	-	-
Wetland and mangrove	-	-	-

On stable land in rural use, bare soil - exposure to risk of surface erosion - is:

- 49.5% where primary vegetation cover is depleted by cultivation under intensive land uses (orchards, vines, market gardens, grain crops, fodder crops). It drops to 5.2% with the transition to growing crops, but rises to 10.0% in harvested fields.
- 3.8% on dairy farms in sparse pasture, falling to 2.9% where dense pasture is maintained, and rising to 5.2% where it is harvested for hay and silage.
- 3.1% on drystock farms in sparse pasture, falling to 1.7% where dense, and rising to 1.9% where harvested for hay and silage.
- 4.1% in young forest plantations, declining to 2.2% as they close canopy, but rising to 12.8% at harvest.

Under conservation uses on stable land, bare soil - exposure to risk of surface erosion - is:

- 0.4% in natural forest where primary cover is sparse (has canopy gaps), falling to 0.2% where dense (close canopy forest and open canopy forest with scrub under-storey).
- 1.0% in natural scrub where primary cover is sparse (has canopy gaps), falling to 0.6% where dense (scrub with close canopy and/or emerging forest trees).
- 1.9% in exotic scrub where primary cover is sparse (has canopy gaps), falling to 0.8% where dense (scrub with close canopy and/or emerging natural scrub and trees).
- Un-measurable where primary cover is harvested, because this category is absent from conservation land in the Auckland region.

4.2.2 Bare soil on unstable land

(Table 4.14, summarising Tables 4.2 - 4.10)

Table 4.14

Effect of vegetative soil conservation cover on unstable land

	Bare soil due to natural erosion on unstable land, where woody vegetation is :				
	absent	dense primary cover (natural)	dense primary cover (planted)	extensive secondary cover (natural)	extensive secondary cover (planted or induced)
	as % of area in use	as % of area in use	as % of area in use	as % of area in use	as % of area in use
Rural uses :					
Intensive uses	0.0	-	0.0	1.0	0.5
Dairy pasture	0.5	-	-	0.2	0.4
Drystock pasture	1.6	-	-	0.9	0.4
Exotic forest plantation	0.4	-	0.2	0.4	0.1
Conservation uses :					
Natural forest	-	0.3	-	0.1	1.0
Natural scrub	-	4.4	-	0.3	0.1
Exotic scrub	-	0.4	-	0.4	0.5
Coastal grass & scrub	67.6	-	-	6.0	3.3
Wetland and mangrove	-	4.3	-	2.3	1.9

On unstable land in rural use:

- Where woody vegetation is absent, bare soil - due to natural erosion - is 0% for intensive uses and 0.5% for dairy pasture, rising to 1.6% for drystock pasture, and falling to 0.4% for forest plantations (harvested stands over sown with grass-legume ground cover).
- That these percentages are not large, reflects that on land in rural use, fresh erosion has been minimal in the year of aerial photographic survey (2007).
- Where woody vegetation is present as dense primary cover, fresh erosion remains minimal amongst intensive uses (orchards and vineyards), and reduces to 0.2% bare soil in forest plantations (mature closed-canopy stands).
- Where woody vegetation is present as extensive secondary cover, bare soil is variable:
- Amongst intensive uses there is 1.0% bare soil in presence of natural cover; and 0.5% in presence of planted cover.
- For dairy pasture the figures are 0.2% bare soil in natural cover and 0.4% in planted.
- In drystock pasture figures are somewhat higher - 0.9% amongst natural cover and 0.4% amongst planted.
- In forest plantations, there is 0.4% bare soil where natural cover is present, and 0.1% in presence of planted.

On unstable land under conservation uses:

- There is just one category - coastal grass and scrub - where woody vegetation is absent from a proportion of sample points. Here bare soil, sand and rock - due to natural erosion - is 67.6% by area.
- For the other categories, woody vegetation is present as dense primary cover at many sample points. Here fresh erosion rises from 0.3% bare soil in natural forest to 4.4% in natural scrub but falls to 0.4% in exotic scrub. Bare soil, sand and mud are 4.3% by area amongst wetlands and mangroves.
- Where woody vegetation is present as extensive secondary cover, bare soil is variable.
- In natural forest, 0.1% has been measured amongst natural secondary cover, rising to 1.0% amongst induced secondary cover (exotic scrub and wildling trees).
- A different pattern prevails in natural scrub, with 0.3% bare soil amongst natural secondary cover, falling to 0.1% amongst induced.

- The difference for exotic scrub is less marked. There is 0.4% bare soil for natural secondary cover, rising to 0.5% for induced.
- A reverse trend is evident for coastal grass and scrub. Here there is 6.0% bare soil where secondary cover is natural; 3.3% where it is induced or planted (seaward margins of forest plantations).
- A reverse trend is also evident for wetlands and mangroves. These have 2.3% bare soil where secondary vegetation is natural; 1.9% where it is induced or planted (wetland margins and estuary shores).

4.3 Conclusions

The conclusions for Auckland's land in rural uses are that:

- Planted primary cover is effective at reducing soil's exposure to surface erosion by land use-related disturbance, so long as it is kept dense; but substantial exposure occurs where it is either sparse or harvested.
- Planted primary cover may help keep natural erosion low (though its apparent effect may be due to a low incidence of natural erosion in the year of survey).
- Extensive natural secondary cover reduces bare soil in dairy pasture and drystock pasture, though not amongst intensive uses or forest plantations.
- Extensive planted secondary cover reduces bare soil in dairy pasture, drystock pasture and forest plantations, though not amongst intensive uses.

The conclusions for Auckland's land under conservation uses are that:

- Natural primary cover is effective at reducing soil's exposure to surface erosion by land use-related disturbance, if forest or exotic scrub; though natural scrub appears less effective.
- Natural primary cover keeps natural erosion low in the case of forest and exotic scrub. However natural scrub does not provide as good protection.
- Extensive natural secondary cover reduces bare soil amongst all conservation uses.
- Extensive planted or induced secondary cover (exotic) does not provide any additional reduction in bare soil for natural forest or scrub, though does so where present amongst coastal grass and scrub, or on the margins of wetlands and mangrove swamps.