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Rural Land Use on Auckland's Soils

A Survey of Current Land Use in 1999

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Rural Land Use on Auckland's Soils: A Survey of Current Land Use in 1999

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Contents

1 Introduction

This contract report presents findings from a survey of rural land use in the Auckland region. The survey was commissioned by Auckland Regional Council, to help meet its statutory responsibility for monitoring state of the environment in its region (Section 35, Resource Management Act, 1991). The survey has been undertaken by Dr. Douglas Hicks, a member of Ecological Research Associates N.Z. Inc., who has been based in the Auckland region for some years.

The survey has been designed as a sample, to ascertain extent of different land uses on the region's various soils. Because it is a sample, it does not provide a region-wide identification of all sites where soil is at risk from a current use. It would be unfair to target a property-owner where land use and soil type are presently mis-matched simply because sample points have fallen on his/her property, when there are other un-sampled properties in the vicinity with the same - or more severe - mis-matches. Therefore, the database to be supplied to ARC records each site's soil and land use, but not its location or ownership.

What the survey does, is identify extent of each land use on soils which have differing degrees of risk from degradation - nutrient loss, structural breakdown, or physical erosion. Landowners who realise that they are practising such a use on one of the susceptible soils, may wish to consider implementing management practices - fertiliser application, reduced tillage, carefully timed grazing, soil conservation plantings - which will reduce future incidence of soil degradation. Information from the survey may also prove helpful for informing the public about land uses which may be safely practised on particular soils, without risking undue degradation. In particular, purchasers of properties may wish to consider this information when deciding what to do with their new land.

Survey results could be used by the Council, as evidence to help justify regulatory control of certain land uses by the proposed Land and Water Plan. However, I suggest that the Council may achieve better conservation of soil, if findings are widely publicised. Informing landowners about land use's nature and extent within the region can help correct some common misconceptions about the effects of land use on soil quality. Educating new property owners, and the rising generation, can help the transition to land uses which can be sustained without damaging the land.

2 Brief and methods

The Council's brief dated 23 December 1999 was to quantify current rural land use in the Auckland region.

Its preferred source of information was 1:10,000 colour enlargements, from aerial photo coverage taken earlier in 1999. These provided an opportunity for up-to-date measurement, free of the limitations inherent in other data sources such as satellite images or postal surveys of landholders. Any measurements should be compatible with:

- Other ARC initiatives to measure land use or vegetation cover; for instance ecologically significant areas,
- Other sources of information about land use, such as Agribase (MAF's record of land use by holding) and LCDB (Landcare Research's maps of land use classified from satellite images).

Background information about the reasons for these decisions is given in ARC's brief. The rest of this section outlines how each objective in the brief has been met.

2.1 Objective 1

To recommend, document and implement a simple, practical and robust (scientifically and statistically defensible) methodology for monitoring current land use activities in the Auckland region. Monitoring methodology must be able to be repeated in subsequent years and representative of the Auckland region where samples of areas are assessed.

A point sample network was established at one kilometre intervals on all soil groups recorded on rural land (see map Susceptibility of Auckland Soils to Degradation, Hicks, Shepherd and Parfitt 1996). This entails approximately 4,200 points. Reasons for undertaking a point sample are that:

- It can supply the information required,
- It can be measured quickly and at low cost,
- It is repeatable,
- It provides estimates that are representative of each soil group, to within acceptable error limits.

Technical appendix 1 (Hicks, 2000) contains design parameters, time and cost estimates, and statistical calculations which support these four assertions.

Technical appendix 2 (Hicks, 2000) describes the point sample method so that it can be replicated by other personnel in future years if the survey is repeated.

In the second respect, a point sample presently remains superior to alternative methods such as area measurement of the entire region from aerial photographs; and in the second and fourth respects, to digital computer classification of satellite images. It is likely that in another 10 year's time, technology will have improved sufficiently for accurate measurements of land use to be obtained at reasonable cost, from either orthophotos (rectified aerial photographs) or satellite images. Technical appendix 4 (Hicks, 2000) outlines how point sample data may be compared with a future re-survey by alternative means.

The disadvantage of a point sample is that, while providing a statistically robust estimate of land use on each soil group, it does not indicate exactly what land use is where. Should ARC particularly wish to obtain a derived map of land use (i.e. a single region-wide map with different land uses colour-coded) then the simplest way to obtain one would be:

- Utilise Rodney District's map, recently produced from 'Agribase', for the northern rural area,
- Commission equivalent Agribase-derived maps for Franklin District (the southern rural area), together with rural land within the boundaries of Waitakere City and Papakura District.

These should suffice for depicting the region's rural land use at a small scale, suitable for illustrating state-of-environment or planning documents.

Agribase-derived maps have the disadvantage of showing predominant use within each property boundary i.e. don't depict small patches of land used for other purposes particularly conservation. This need not be a problem, because ARC's enlargements are in themselves, first-class 'photo-maps', which show land uses' location relative to soils, vegetation and property boundaries in the year 1999. 'Photo-maps' like these will be more accurate as records, and far more useful for providing advice about environmental management to individual property-owners, than will colour-coded maps derived by whatever means.

2.2 Objective 2

To measure the current spatial prevalence and distribution of predominant land uses, using readily available aerial photographs as far as practical.

1:10,000 enlargements of ARC's aerial photographs, taken by Air Logistics in summer 1999, were used. Points on the NZMS260 one kilometre map grid were manually overlaid on each enlargement. For each point, land use was visually interpreted from the photographs.

Data were recorded manually on a check-sheet, then stored in an Excel-format spreadsheet to facilitate access and re-analysis by ARC staff in future years. Soil types were ascertained subsequently, by overlaying the NZMS 260 grid on DSIR Soil Bureau maps, and added to the spreadsheet. Soil types were assigned to the same groups as are depicted on the map Susceptibility of Auckland Soils to Degradation (op. cit.).

Technical appendix 2 (Hicks, 2000) includes comments on map grid overlay, ease or otherwise of photo-interpretation, interpretation of soil maps, and time taken to carry out each stage of the survey.

The main text of this report summarises survey findings about land use for the region as a whole. Further discussion of land use patterns on individual soil groups, together with results of statistical analyses to test representativeness of the sample, are appended.

3 Definitions of soil and land use

Terms used when recording data are defined in technical appendix 2 (Hicks, 2000). Its definitions are sufficiently relevant to interpretation of this report, to warrant repeating here, so as to avoid constant cross-reference. Readers are referred to technical appendix 2, for a discussion of the reasons for choosing them.

3.1 Soils

In 1995, Auckland's 132 soil types were consolidated into 18 groups with similar susceptibility to degradation (see report by Hicks, Shepherd and Parfitt 1996). This was done to facilitate future survey of Auckland soils for state-of-environment reports.

The groups are:

Arable lowland soils	
I1a	Susceptible to slight nutrient loss if intensively farmed
I1b	Susceptible to slight nutrient loss, structural breakdown or surface erosion if intensively farmed
I2a	Susceptible to moderate nutrient loss if intensively farmed
I2b	Susceptible to moderate nutrient loss, structural breakdown or surface erosion if intensively farmed
I3a	Susceptible to severe nutrient loss if intensively farmed
I3b	Susceptible to severe nutrient loss, structural breakdown or surface erosion if intensively farmed
Non-arable lowland soils	
L2	Susceptible to severe structural breakdown on account of waterlogging
L3	Susceptible to severe surface erosion on account of sandy texture
H3c	Susceptible to severe subsoil erosion on account of locally steep slope
Grazeable footslope soils	
H1a	Susceptible to slight nutrient loss if intensively grazed
H1b	Susceptible to slight nutrient loss, structural breakdown or surface erosion if intensively grazed
H2a	Susceptible to moderate nutrient loss, structural breakdown or surface erosion if intensively grazed
H2b	Susceptible to severe nutrient loss, structural breakdown or surface erosion if intensively grazed
Grazeable hill soils	

H3a1	Hill phases of H1a; additionally susceptible to subsoil erosion
H3a2	Hill phases of H1b; additionally susceptible to subsoil erosion
H3b1	Hill phases of H2a; additionally susceptible to subsoil erosion
H3b2	Hill phases of H2b; additionally susceptible to subsoil erosion
Non-grazeable hill soils	
S2	Susceptible to severe structural problems on account of stony or rocky texture
S3	Susceptible to severe subsoil erosion on account of steep slope

For the purpose of this report, 'a' 'b' and 'c' groups have been amalgamated, as differences in their land use patterns appear slight, compared with contrasts between '1' '2' or '3' groups.

Detailed accounts of each soil group, including the constituent soils, are given in the report Susceptibility of Auckland Soils to Degradation (op. cit.).

3.2 Land use

After some discussion of land use issues with ARC's staff, it was decided simply to record land uses that ARC is interested in from the point of view of their environmental impacts on soil, rather than implement a classification geared towards land use planning or ecological protection. The chosen classes were:

Orchards and vineyards	O
Market gardens	H
Grain and greenfeed crops	C
Dairy pasture	D
Improved drystock pasture	I
Unimproved drystock pasture	U
Lifestyle blocks	L
Exotic scrub	X
Exotic forest	E
Natural scrub	S
Natural forest	F
Wetland vegetation	W
Coastal vegetation	M

This classification while basic proved practical when photo-interpreting land use. Comments about its ease of use are given in technical appendix 2 (Hicks 2000). Three modifications were necessary.

- At many sample points, a secondary land use inter-mingles with the principal use. A lower-case letter has been added to indicate where this is the case. For instance, Is denotes improved drystock pasture with clumps of natural scrub.
- Differentiation of lifestyle blocks from other land uses proved pointless. Some are under intensive horticultural use. The majority are under drystock pasture, both improved and unimproved. Many are in natural scrub or forest. 'Lifestyle block' really describes property size, not land use; and for the purpose of this survey it is more sensible to amalgamate them with similar land uses on larger properties.
- A few points were surrounded by extensive bare earth, sand or rock. Here, the bare ground clearly could not be attributed to a surrounding land use. These points were classified as 'bare ground' caused by some site-specific natural process or human activity. Examples are sand drifts, coastal cliffs, quarries, landing stages in harvested plantation forest, road re-alignments, and building construction sites.

4 Presentation of survey results

4.1 Analysis of sample

The rural land use sample contains 3918 points, divided into 10 soil groups and 13 land use classes. Codes stored in the spreadsheet enable each category to be further subdivided according to soil group or type, land use or vegetation structure, erosion status or erosion form.

The purpose of this contract is simply to ascertain current extent of different land uses on rural soils. This can be conveyed by:

- A relatively simple presentation of summary data for each land use, in chapter five.
- More detailed discussions of land use patterns on individual soil groups, in an appendix A.

4.2 Area covered

Data covers all rural-zoned land within district and city boundaries on the region's mainland, together with inner islands of the Hauraki Gulf. It excludes:

- Land under rural use but currently zoned urban, within the boundaries of cities and district towns. The area of such land is not great, relative to the total hectarage of land zoned rural. There seems little point in recording the details of rural use on it, as the land is likely to be converted to urban use before any future re-survey.
- Great Barrier and Little Barrier Islands. ARC's 1999 photo-enlargements do not cover the outlying gulf islands. Air Logistics (the aerial survey company which took ARC's 1999 coverage) has photo-enlargements which cover Great Barrier and Little Barrier, so data for them could be added to the sample if ARC acquires copies.

The spreadsheets also contain incomplete data for a further 300 points (soil type only for 75 points on two photo enlargements which cannot be found in ARC's office; vegetation and erosion status only for 225 points in mangrove swamps where no soil type was recorded on the published maps).

4.3 Representativeness

Representativeness of data, for the region as a whole, has been ascertained by applying three statistical tests (see technical appendix 1). The most conservative (based on standard error of a proportion) indicates:

Land use	Area of rural land %	95% confidence limits +-%
Orchards and vineyards	1.2	0.3
Market gardens	2.4	0.5
Grain and fodder crops	1.3	0.4
Dairy pasture	15.2	1.1
Improved drystock pasture	36.4	1.5
Unimproved drystock pasture	5.9	0.7
Exotic forest	11.8	1.0
Natural forest	7.5	0.8
Exotic scrub	2.0	0.4
Natural scrub	13.4	1.1
Wetland vegetation	1.4	0.4
Coastal vegetation	0.8	0.3
Bare ground	0.7	0.3

In short, there is 95% confidence that the sample percentage of land in each class is within +- 1.5% or better of the true region-wide figure.

The same tests have been applied to land use classes within each soil group. Results are presented in appendix A of this report.. Margins of error are small i.e. the sample gives an accurate portrayal of land use-soil group combinations region-wide in 1999. Test results also indicate the number of points change which would need to be recorded in a future re-survey, before concluding that each land use had expanded or contracted on a particular soil group.

5 Land use in Auckland's rural areas

5.1 Orchards and vineyards

4,600 hectares are occupied by orchards and vineyards, representing 1.2% of the region's rural land. Its distribution across different soil groups is:

Soil group	Percentage of use on soil group
I1	43%
I2	24%
I3	11%
L2	-
L3	-
H1	-
H2	15%
H3c	2%
H3a	4%
H3b	-
S2	-
S3	-

43% is on I1 soils, where the use can be sustained with negligible risk of soil degradation, provided adequate maintenance fertiliser is applied. Percentages decline moving onto the I2 and I3 soils, which have increasing requirements for maintenance fertiliser; also some need for subsoil drainage to counteract structural limitations to tree growth (I2b), and for ground cover to protect against surface erosion of topsoil (I3b).

Interestingly, 15% of orchards and vineyards are on H2 soils. Most of the area is accounted for by recent vineyard development in the vicinity of Warkworth and Matakana; also on Waiheke Island. To sustain the use here requires fertilisation to counteract nutrient loss; sub-soil drainage to counteract winter wetness, and grass ground cover to protect against surface erosion.

The small percentages on H3c and H3a are a surprise. Examination of the individual points on aerial photographs suggests that they are small pockets of better soil (I3 and H1 respectively) not differentiated on the soil maps.

5.2 Market gardens

9,500 hectares are used for market gardens, occupying 2.4% of the region's rural land. This includes field crops - onions, brassicas, potatoes - as well as small, diversified ventures which have outdoor vegetable plots associated with greenhouses. The distribution of market garden land on different soils is:

Soil group	Percentage of use on soil group
I1	61%
I2	29%
I3	3%
L2	1%
L3	-
H1	-
H2	3%
H3c	1%
H3a	1%
H3b	-
S2	-
S3	-

Market gardens are clearly concentrated on the I1 soils, where they can be sustained by maintenance fertiliser, without risking any more than slight nutrient loss, structural deterioration, or topsoil erosion. However, 29% are on the I2 soils which require heavier fertilisation; also care in timing and nature of cultivation (I2b). A further 3% are on I3 land where heavy fertilisation is needed to avoid nutrient loss. The I3 soils are weathered sands usually with admixture of volcanic ash, so have few structural problems if cultivated. However the I3b soils in particular are erodible, requiring soil conservation practices to control surface erosion.

6% of market gardening land is on soil where the use would be difficult to sustain without major impacts. However, the situation is not as grave as appears. The 1% on L2 is a single point. The 3% on H2 are small horticultural blocks with greenhouses i.e. indoor cultivation of plants in potting mix, rather than attempts at commercial vegetable growing on heavy clay. The 1% on H3c and H3a, on examining the photos, are single points which appear to be on small pockets of better soil (I3 and H1) undifferentiated on the soil maps.

5.3 Grain and fodder crops

5,100 hectares are cultivated ground occupied by grain crops, fodder crops, or freshly sown pasture. This is just 1.3% of the region's rural land. Its distribution is:

Soil group	Percentage of use on soil group
I1	43%
I2	12%
I3	4%
L2	8%
L3	-
H1	6%
H2	14%
H3c	6%
H3a	8%
H3b	-
S2	-
S3	-

59% of grain crops, fodder crops and freshly sown pastures are on lowland soils where cultivation can be sustained. As with market gardens, the bulk are on I1 soils which require little other than maintenance fertiliser to sustain cropping. Those on I2 require heavier fertilisation, and also care with cultivation to avert structural deterioration (I2b). The small percentage on I3 require even heavier fertilisation, together with soil conservation measures to minimise surface erosion of topsoil (I3b).

Surprisingly, 6% is on L2 soils, heavy clays subject to waterlogging, where there is severe risk of structural breakdown during cultivation. These are fields cultivated for maize on dairy farms; likely to be single crops in course of pasture renewal.

22% of cultivated ground is on the footslope phases of hill soils (groups H1 and H2). The points here are fodder crops and freshly sown pasture i.e. occasional uses which may be safely practiced, though moderate to severe risk of structural breakdown on the heavier soils (H1b and H2b) necessitates careful timing of cultivation, to avoid periods of wet weather.

6% of cultivated ground on H3c soils, and 8% on H3a, are surprisingly high. Some of the points are small pockets of the equivalent footslope soils, not differentiated by the soil maps. Examination of the aerial photographs also indicates some are instances of cultivation for pasture renewal (possibly accompanied by fodder cropping) on moderately steep slopes, where hill soils are highly susceptible to surface erosion of topsoil.

Cultivation for pasture renewal is not currently being attempted on the less fertile hill soils (H3b) or steepland soils (S2, S3).

5.4 Dairy pasture

59,500 hectares are occupied by dairy farms, 15.2% of Auckland's rural land.

Soil group	Percentage of use on soil group
I1	27%
I2	19%
I3	8%
L2	5%
L3	2%
H1	11%
H2	20%
H3c	2%
H3a	3%
H3b	3%
S2	-
S3	-

54% of dairy pasture is on lowland soil groups where intensive grazing can be sustained; albeit with increasing requirements for maintenance fertiliser to counteract nutrient loss, and care in grazing to counteract structural breakdown and/or surface erosion, with the transition from I1 to I3.

7% of dairy pasture is on lowland soils which are highly susceptible to either structural breakdown (L2) or wind erosion of topsoil (L3).

21% is on the footslope soil groups H1 and H2, where intensive grazing can be sustained, provided adequate maintenance fertiliser replaces nutrient losses, and care is taken with timing and duration of grazing on the heavier soils (H1b and H2b) to avert structural breakdown.

8% is on hill soils where intensive grazing cannot be sustained. However, the extent of dairying here does not have as serious implications as appears. This land is generally steep country used as winter run-off, at the back of farms predominantly on better soil (I3, H1 or H2). Some points are also on small pockets of better soil, not differentiated from hill phases on the soil maps.

Dairying is not currently being attempted on the steepland soils (S2 and S3).

5.5 Improved drystock pasture

142,800 hectares are improved pasture grazed by beef cattle, sheep, deer, or exotic animal breeds (though instances of the latter are uncommon). This amounts to 36.4% of the region's rural land. Its distribution is quite different from dairy pasture.

Soil group	Percentage of use on soil group
I1	15%
I2	13%
I3	6%
L2	2%
L3	2%
H1	12%
H2	16%
H3c	5%
H3a	18%
H3b	5%
S2	2%
S3	4%

Just 34% is on the lowland soils where intensive grazing can be sustained; not because these soils are unsuitable, but because drystock farms have been displaced by other uses. As with dairy farming, there is an increasing requirement for maintenance fertiliser moving from I1 to I3, along with a need for care in grazing to counteract structural breakdown and/or surface erosion.

Another 4% is on lowland soils where intensive grazing is hard to sustain, due to high susceptibility to structural breakdown (L2) or wind erosion (L3).

28% is on footslope phases of hill soils (groups H1 and H2), where intensive grazing can be sustained provided adequate maintenance fertiliser replaces nutrient losses, and care is taken with timing and duration of grazing on the heavier soils (H1b and H2b) to avert structural breakdown.

Another 28% of improved pasture is on hill soils. Here intensive grazing, although impactive, can be sustained by measures to counteract soils' high susceptibility to nutrient loss (H3b), structural breakdown (heavy soils in the H3a and H3b groups), and erosion of subsoil by mass movement or gullies (all three soil groups).

A final 6% is on steepland soils where intensive grazing is being attempted in the face of low pasture production due to shallow or stony structure (S2), or loss of pasture by frequent mass movement and gullying (S3). It is doubtful whether intensive grazing can be sustained here long-term.

5.6 Unimproved drystock pasture

23,100 hectares, 5.9% of the region's rural land, is unimproved pasture. This category rarely encompasses entire farms. Typically it is accounted for by undeveloped

paddocks on rough ground, surrounded by improved pasture on the remainder of a property.

Soil group	Percentage of use on soil group
I1	4%
I2	6%
I3	4%
L2	4%
L3	8%
H1	11%
H2	14%
H3c	5%
H3a	24%
H3b	8%
S2	2%
S3	9%

Its distribution differs from both dairy and improved drystock pasture. Surprisingly, 14% is on the lowland I soils, where one would have expected all pasture to be improved. Less surprisingly, 12% is on lowland soils which are capable of supporting poor pasture for light grazing, without adverse impacts on fertility or structure or erosion.

Also surprisingly, 25% of unimproved pasture is on the footslope soil groups, where one might also have expected all pasture to be improved. Examining the photos, at least some points appear to be deterioration of pasture on lightly grazed, unfertilised lifestyle blocks. However this is not typical; the majority of small lifestyle blocks appear intensely grazed and well-fertilised. Many of the remainder are as-yet-unimproved paddocks on gumland soils (H2b).

As expected, the highest percentage of the region's unimproved pasture, 37%, is on hill soils. Here, some points are paddocks which appear never to have been improved. However, a high proportion are deteriorating through lack of fertilisation, lax grazing management, or erosion.

Finally, 11% is on steepland soils, where farmers would have difficulty in establishing and maintaining improved pasture. Here soil is unlikely to suffer nutrient loss or structural breakdown under light grazing, but remains highly susceptible to erosion in the absence of tree root reinforcement.

5.7 Exotic forest plantations

46,100 hectares, 11.8% of rural land, are planted with exotic timber trees. As well as the extensive commercial pine forests at Hunua, Riverhead, Woodhill, Dome Hills and

Mangawhai, this category includes small private pine plantations and farm woodlots. The latter encompass other exotic timber species; principally cypress, also gum and wattle. Exotic forest is variably distributed across most of the region's soils:

Soil group	Percentage of use on soil group
I1	2%
I2	1%
I3	2%
L2	-
L3	30%
H1	-
H2	10%
H3c	1%
H3a	28%
H3b	10%
S2	-
S3	16%

5% on lowland soils capable of intensive agriculture are farm woodlots together with the margins of commercial pine plantations (on I3/L3 boundaries). The small percentages here are not a surprise.

Planted forest is absent from the L2 soils, where tree growth is limited by poor structure and winter waterlogging. In contrast, 30% of the region's exotic forest is on L3 soils, where it has been planted to stabilise sand soils highly susceptible to wind erosion. The soils are at low risk beneath growing forest, but require prompt revegetation to avert windblows when they are temporarily bared by timber harvest.

Surprisingly, no farm woodlots were recorded on the better footslope soils (H1), while 10% of the region's forest was recorded on weathered or leached footslope soils. This is accounted for by afforestation at Riverhead, and similar gumland soils (H2b) farther north, together with forest margins which extend onto H2a soils in the Dome Hills.

39% of exotic forest is on the hill soils. On hill country, foresters appear to have located their plantations on the weathered H3a soils (19% of rural land area) in preference to the leached H3b (6%). The small percentage on H3c reflects both this group's limited extent (3%), and absence of large commercial plantations from it. Hill soils are at low risk of erosion under growing trees, and risk of surface erosion remains low during harvest provided low-impact logging techniques are used on steep slopes. However care is needed with construction/maintenance of forest roads and landings, to avert surface erosion, gullying and mass movement.

Exotic forest is absent from stony or shallow steepland soils (S2); perhaps a response to these soils' perceived limitations for tree growth. However commercial forest plantations in the Hunuas and Dome Hills extend from hill soils onto skeletal steepland soils (S3), amounting to 16% of the region's exotic forest. S3 soils have slight nutrient limitations to tree growth, and moderate structural limitations (in many places, rock in the subsoil impedes root development). Despite tree root reinforcement, the subsoil remains moderately susceptible to erosion by landslides or debris avalanches.

5.8 Natural forest

29,400 hectares of natural forest remain in the region, occupying 7.5% of its rural land. This category encompasses old-growth forest together with cut-over forest where a proportion of forest canopy remains, and regenerating forest where emergent trees occupy over half the canopy.

Soil group	Percentage of use on soil group
I1	2%
I2	2%
I3	-
L2	-
L3	-
H1	-
H2	2%
H3c	2%
H3a	23%
H3b	5%
S2	17%
S3	46%

Natural forest stands have almost disappeared from the better lowland soils, though clumped or scattered trees remain an element in their landscape (see Appendix). Due to limitations for tree growth, L2 and L3 soils have never supported forest cover.

Natural forest stands have likewise almost disappeared from the intensively farmed footslope soils. 23% of the region's remaining bush is located on H3a soils (19% of rural land), but only 5% on H3b, and 2% on H3c. This is partly explained by lesser extent of H3b and H3c soils (6% and 3% of rural land respectively). However some H3b soils are so podsolised that they can no longer support natural tree cover.

17% of the region's natural forest is located on stony or shallow steepland soils (S2), surviving here because the soils are perceived as unsuitable for agriculture or commercial forestry. 46% of the remnant forest is on skeletal steepland soils (S3). As parts of these soils have been cleared for farming or planted in pines, the survival of

so much forest seems fortuitous - much of their area is located within the Waitakere and Hunua water supply reserves. Elsewhere, many small patches of forest survive in the midst of farmland or pine forest, on faces that have been recognised as too unstable to attempt clearance.

5.9 Exotic scrub

7,800 hectares of Auckland's rural land, 2.0% of the area, are covered by exotic scrub dense enough to form a closed canopy. The category includes gorse, flannel weed, brush wattle, pampas, boxthorn - all recognisable on aerial photographs - but excludes exotic weeds in amongst or beneath other plant cover e.g. wild ginger, old man's beard.

Soil group	Percentage of use on soil group
I1	1%
I2	4%
I3	1%
L2	5%
L3	3%
H1	6%
H2	8%
H3c	4%
H3a	40%
H3b	8%
S2	4%
S3	17%

The percentage of exotic scrub on I soils while low, is surprising, as better weed control might have been expected on these intensively used soils. In view of the low number of points on all three soil groups, no significance should be attached to the differences between them. Examination of the photos suggests all points are small pockets of shrubby weed infestation on un-used ground next to watercourses or estuarine shores.

Given predominance of extensive grazing and forestry on the L2 and L3 soils respectively, poorer weed control is to be expected here. The pockets of exotic weed infestation on L2 are mainly gorse and brush wattle - possibly also shrubby acacias - around estuaries of the Kaipara Harbour. On L3, the principal weed is boxthorn; stands of gorse and brush wattle are also present. Tree lupin, an exotic shrub widely planted for sand stabilisation in former years, has almost disappeared due to lupin blight.

6% and 8% of the region's exotic scrub are on H1 and H2 soils respectively. Given the predominance of intensive grazing on these soils, it is also surprising that so many

pockets of scrubby weed remain here. Typically they are broken-canopy clumps in pasture, though a few are closed-canopy clumps along watercourses.

The distribution of exotic weeds on hill country soils - 40% on H3a, 8% on H3b, 4% on H3c - closely mirrors the patterns of natural forest and drystock pasture. Weed infestation here is as much associated with disturbance of natural forest, as with productive land use (see appendix for further discussion).

21% of the region's exotic scrub is on steepland soils, 4% on S2 and 17% on S3. As in the hill country, it is associated with disturbed forest or scrub cover as much as productive land use (see appendix).

5.10 Natural scrub

52,600 hectares of natural scrub is present in Auckland's rural land, 13.4% of the area. The category encompasses successional stands of manuka or kanuka scrub on abandoned farmland, as well as species-diverse broadleaved scrub growing on sites where forest has been clear-felled but farm development not attempted. It also includes coastal scrub dominated by species such as karo and flax.

Soil group	Percentage of use on soil group
I1	1%
I2	1%
I3	1%
L2	0%
L3	4%
H1	3%
H2	8%
H3c	4%
H3a	28%
H3b	11%
S2	15%
S3	24%

A negligible proportion of the region's natural scrub stands remain on I soils (though scattered scrub is still present - see appendix). Surprisingly, none were recorded on L2 soils, where all the scrub that remains is scattered. Closed-canopy scrub stands persist on the sandy L3 soils, amounting to 4% of the region's scrub cover.

3% and 8% of scrub cover are on the H1 and H2 soils respectively; a surprising amount considering how the bulk of these soils have been developed into improved pasture. These are generally located along gullies and watercourses.

43% of Auckland's scrub is located on the hill soils. Its distribution - 28% on H3a, 11% on H3b, 4% on H3c - is proportionately somewhat higher on the first two categories, than what might be expected in view of these soils' extent (19%, 6% and 3% of rural land respectively). Being less fertile than the H3c soils, a greater degree of scrub reversion on abandoned farmland is the most likely reason; though podsolised soils in the H3b group would have had a high ratio of scrub to forest cover under natural conditions.

Two-fifths the natural scrub cover is on steepland soils (S2 and S3). The reasons for its survival here are similar to those for forest - perceived unsuitability of the S2 soils for agriculture or commercial forestry; reservation of much S3 land for water supply; and elsewhere, recognition that many small patches of S3 are too unstable to clear. One difference is that the places where scrub cover has been recorded on S2 or S3 soils, are where forest cover has been disturbed sufficiently for its canopy to be removed. Disturbance is likely to have been clear-felling for timber in the 19th century or early years of the 20th. Sites with more localised disturbance e.g. where scrub has colonised landslide scars or gullies, are recorded as natural forest cover with scrub in canopy gaps (see appendix).

5.11 Wetland vegetation

5,500 hectares, 1.4% of the region's rural land, is swamp with wetland vegetation. The category includes disturbed wetland, invaded by water-tolerant pasture grasses and weeds, as well as intact swamp.

Soil group	Percentage of use on soil group
I1	13%
I2	20%
I3	9%
L2	4%
L3	9%
H1	0%
H2	24%
H3c	5%
H3a	11%
H3b	2%
S2	2%
S3	2%

42% of Auckland's remaining wetlands are small pockets of undrained land on the intensively farmed I soils; an indication that many farmers prefer to retain wet hollows as wildfowl habitat, rather than attempt drainage.

Only 4% of the wetlands are on the poorly-drained L2 soils; a consequence of repeated attempts to drain larger swamps and estuarine flats in the belief that moist, flat sites can be developed into good pasture. 9% are on the sandy L3 - poorly-drained hollows which have escaped farm development because they are surrounded by unstable dune ridges, and have escaped afforestation because they are too wet for trees to grow.

Wetland distribution on the footslope soils is puzzling. None were recorded on H1; 24% of the region's wetlands were recorded on H2; yet both groups have been subject to similar land development for intensive grassland farming. The H2 soils, being leached or podsolised, are slow-draining so the area of wetlands here is consistent with farmers' retention of wildfowl habitat in wet valley bottoms. The H1 soils, while freer-draining, also have wet valley bottoms where wetland retention might be expected for the same reason.

This situation is reversed in the hill country, where 11% of the region's wetlands are located in valley bottoms amongst the freer-draining H3a soils, while 2% remain amongst the slower-draining H3b. It is a greater difference than can be explained by the lesser extent of H3b (6% of rural land) cf. H3a (19%). In contrast, H3c soils (3%) have 5% of the wetlands in their valley bottoms.

A likely explanation for these anomalies is that the published soil maps do not differentiate small pockets of gleyed soil beneath swamps in hill country valley bottoms or on damp footslopes. These certainly do not have hill soil beneath them. Exactly what soils are under the hill and footslope wetlands, cannot be verified without field inspection, but they are likely to be small pockets of soil in the I2 or L2 groups - widely mapped in valley bottoms throughout Auckland's hill country, where wide enough to be depicted on 1:50,000 maps.

The same pattern - small pockets or ribbons of un-mapped I2 or L2 soil in valley bottoms - is likely to be the case for 4% of the region's wetland recorded on S2 and S3 soils - the latter are unlikely as these soils' structural characteristics would not permit swamps to form on them.

5.12 Coastal vegetation

3,000 hectares along Auckland's coastline are occupied by coastal vegetation; 0.8% of its rural land by area. This category is dominated by the exotic sand-binding grass marram. It includes land where coastal scrub species e.g. pohuehue, toitoi, flax are present in the marram, but excludes land where they form a closed canopy (included in natural scrub). It also includes a few areas of saltmarsh where saline water infiltrates soil along estuarine shores, but excludes mangrove swamps below the high tide mark.

Soil group	Percentage of use on soil group
I1	7%
I2	3%

I3	-
L2	13%
L3	77%
H1	-
H2	-
H3c	-
H3a	-
H3b	-
S2	-
S3	-

The number of points recorded as coastal vegetation is small, but they are concentrated in just four soil groups. 23% of coastal vegetation is saltmarsh along the shores of estuaries. 13% is on L2 soils - a group which includes saline gleys and shelly sands. 10% is on soil depicted by maps as I group, but more likely to be undifferentiated strips of L2 soil.

77% of coastal vegetation is marram on L3 soils. Originally planted to stabilise foredunes along the coast and also transverse dunes migrating inland from the coast, the marram is now a self-perpetuating element in Auckland's coastal vegetation. Other coastal sand-binding grasses e.g. spinifex and pingao are known to be locally present, but are nowhere dense enough to be detectable on the aerial photographs.

Saltmarsh and marram are, as expected, absent from the footslope and hill soils.

5.13 Bare ground

2,600 hectares, 0.7% of Auckland's rural land, is currently bare ground. This category includes mobile sand dunes, sand flats between the dunes, quarries, earthworks, road construction and tracking. It excludes fields temporarily bared by cultivation or harvest; also small patches of soil exposed by fresh erosion or sedimentation. The latter are recorded as such, within surrounding vegetation (see separate reports on soil erosion).

Soil group	Percentage of use on soil group
I1	-
I2	4%
I3	4%
L2	4%
L3	46%
H1	-
H2	15%

H3c	-
H3a	8%
H3b	12%
S2	4%
S3	4%

The number of points in this category is too small to make observations for individual soil groups, other than L3.

46% of bare ground in Auckland's rural land is on L3 soils. It is mobile dunesand or sandflat, as already described.

Of the balance region-wide, 30% is earthworks for house sites, road construction, or new farm tracks. 24% is quarries.

6 Conclusions

The point sample indicates that at the close of the 20th century, Auckland's pattern of rural land use is complex, as is to be expected on the fringes of a large city, and in a landscape with diverse types of soil. Due to the sample's size, margins of error are small, and in most cases there is 95% confidence that sample data are within +-1% of true figures for the region (see Technical Appendix A tables). Particular features which the survey highlights are:

6.1 Concentration of intensive uses on the better soil types

78% of orchards and vineyards, 93% of market gardens and 59% of grain and fodder crops are on lowland soils where these uses can be sustained (I1, I2 or I3); albeit with an increasing requirement for soil management to counteract degradation, with the transition from I1 through I2 to I3.

85% of dairy pasture and 62% of improved drystock pasture are on soils where intensive grazing can be sustained (I1, I2, I3, H1, H2); again with an increasing requirement for soil management, with the transition from each soil group to the next.

6.2 Limited areas where intensive use is likely to have adverse impacts on soil

22% of orchards and vineyards, 7% of market gardens, and 41% of grain and fodder crops are on footslope soils (H1 or H2), where these uses can only be sustained by heavy fertilisation, good drainage, and great care when cultivating; or on small pockets of lowland soil in the hill country, undifferentiated by soil maps.

7% of dairy pasture is on lowland soils that are highly susceptible to structural breakdown (L2) or wind erosion (L3). The balance of 8% is on hill soils used for winter run-off.

4% of improved drystock pasture is on L2 or L3 soils. 28% of drystock pasture is on hill soils where intensive grazing can be sustained by moderate to heavy fertilisation (H3b), carefully timed grazing to avoid structural breakdown (heavier soils in H3a and H3b), and soil conservation measures to control erosion of subsoil by landslides or gullies (H3a, H3b, H3c). 6% of improved drystock pasture is on steepland soils where it will be hard to sustain long-term, even if these measures are applied.

6.3 Low-intensity uses are well-matched to soils where they are practised

26% of unimproved pasture is on lowland soils. Here, light grazing can be sustained without adverse impacts on soil. A further 62% is on footslope or hill soils where light grazing can be sustained, though there will be ongoing disruption of hill soils by

erosion, in the absence of tree root reinforcement. 11% of drystock pasture is on steepland soils, where light grazing is unlikely to impact adversely, but soil characteristics (shallow, free-draining profiles and susceptibility to mass movement) make light grazing marginal.

30% of exotic forest plantations are on sandy lowland soils (L3) where forestry does not have adverse impacts, though care still needs to be taken to revegetate promptly after forest harvest, in view of these soils' high susceptibility to wind erosion. A further 65% are on hill or steepland soils. Here, tree growth does not have adverse impacts but again, care needs to be taken at harvest - with harvesting methods so as to avoid surface erosion of topsoil; and with forest road and landing stage construction, so as to avoid both surface erosion and mass movement.

Exotic scrub, while strictly speaking not a land use, is associated with low-intensity use of land. It actually has beneficial effects on soil nutrient status, structure, and erosion. However, its presence generally indicates soil which has been abandoned because of nutrient loss, or structural breakdown, or erosion, under a former use - either an attempt at farm development, or timber-cutting. There are small pockets of such land on all the region's soil groups.

Coastal vegetation, principally the exotic grass marram, is also associated with low-intensity land use; in this case, sand reclamation prior to exotic forestry. It also benefits soil - as well as stabilising sand, it enables other plants to colonise, and topsoil to form. As with exotic scrub, marram's presence indicates soil which has been abandoned because of erosion under a former use - unsuccessful pasture development, or depletion of established pasture by heavy grazing. It is restricted to the L3 soil group, except for small pockets on L2 soils adjacent to estuaries.

6.4 Natural vegetation cover is scarce on lowland soils

Lowland soils occupy 36% of Auckland's rural land, yet only 4% of intact forest stands and 7% of intact scrub stands are located here. However, scattered forest trees or scrub cover are still a significant element of the lowland landscape, present in 15% of its pasture.

Forest and scrub cover does not have any adverse impacts on fertile, well-structured lowland soils (I1) in the short-term. However, some lowland soils are less fertile, or less well-structured (I2 and I3). This is only in part due to characteristics of the sediments from which they have formed. Over thousands of years, their fertility and structure have deteriorated beneath forest cover. Other lowland soils - L2 and L3 - occur on sites where forest cover has been destroyed by environmental change. Here, peat or sand has buried older soils.

53% of wetlands are on the lowland soils, but a large proportion have broken plant canopies invaded by water-tolerant grasses and weeds. Considered as a land use, wetlands have beneficial effects on soil - they accumulate nutrients, and structure generally improves as a layer of peat or peaty sediment forms on top of slow-draining subsoil.

6.5 Natural vegetation is still widespread in the hill country and steeplands

42% of the region's wetland is on soils mapped as hill country, with a further 4% on soils mapped as steepland. However as explained in the text, these are more likely to be small pockets of unmapped I2 and L2 soil in valley bottoms. Here, wetlands have the same beneficial effects, as described for larger areas of the same soils mapped in the lowlands.

Hill country soils, 28% of Auckland's rural land, have 32% of its natural forest and 54% of its natural scrub. Steepland soils, 15% of the region, have 63% of the forest cover and 39% of the scrub. Scattered forest trees and scrub cover are present in 33% of hill country pasture and 42% of steepland pasture. Despite much clearance for farmland, the hill country and steeplands are still well-treed landscapes.

Natural forest or scrub are not commonly thought of as 'land uses', or as adversely impacting on soil. There are undoubtedly good grounds for retaining them - watershed management, biodiversity, scenery - but people need to be aware that soil does not improve under these vegetation covers. In the long term on all the hill country and steepland soils (H1, H2, H3, S2, S3), there is greater nutrient loss and structural breakdown in soil under bush, than under pasture. One reason why scrub is so widespread in Auckland's hill country is not that forest has been cleared by timber-cutting or burning or unsuccessful attempts at farming. It is that some soils have simply become too leached and/or too impervious to support trees; while others are too shallow, or too unstable, for trees to grow on a large part of their area.

7 Acknowledgements

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8 References

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9 Appendix A: Land use of different soil groups

9.1 Group I1

These are Auckland's best arable soils with negligible (I1a) or slight (I1b) susceptibility to degradation. Nevertheless they need adequate maintenance fertiliser to avoid nutrient loss, when in vegetable crops, grain crops, or intensively grazed pasture. I1b additionally require careful timing of cultivation, to counter-act structural deterioration.

Sample data for I1 soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	20	0.5	0.2	9
Market gardens	58	1.5	0.4	14
Grain and fodder crops	22	0.6	0.2	9
Dairy pasture	159	4.1	0.6	20
Improved drystock pasture	209	5.3	0.7	22
Unimproved pasture	9	0.2	0.2	6
Exotic forest	9	0.2	0.2	6
Natural forest	6	0.2	0.1	5
Exotic scrub	1	<0.1	0.1	2
Natural scrub	3	0.1	0.1	3
Wetland vegetation	7	0.2	0.1	5
Coastal vegetation	2	0.1	0.1	5
Bare ground	0	0	0.1	5

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on I1 soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	2000	4
Market gardens	5800	12
Grain and fodder crops	2200	4
Dairy pasture	15900	32
Improved drystock pasture	20900	41
Unimproved pasture	900	2
Exotic forest	900	2
Natural forest	600	1
Exotic scrub	100	<1
Natural scrub	300	<1
	Area in hectares	*% of soil in group*
Wetland vegetation	700	1
Coastal vegetation	200	<1
Bare ground	0	0

93% of I1 soil is under some form of intensive use; mainly intensive grazing, as just 20% is used for horticulture or cropping. Of the balance, 4% is occupied by low-intensity uses (unimproved pasture or exotic forest), and the rest is un-used land under an assortment of natural vegetation covers, none of which exceeds 1% by area.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	20	0.75	0
Market gardens	58	0.15	0
Grain and fodder crops	22	0	0
Dairy pasture	159	0.20	0.11
Improved drystock pasture	209	0.27	0.18
Unimproved pasture	9	0.33	0.33
Exotic forest	9	0	0
Natural forest	6	0.33	0
Exotic scrub	1	0	1.00
Natural scrub	3	0	0.33

Wetland vegetation	7	0.71	0
Coastal vegetation	2	0	0
Bare ground	0	-	-

The above table shows secondary vegetation covers associated with each land use. Farm shelter is widespread in orchards and vineyards; less so on dairy farms or beef cattle and sheep farms. Retained bush or scrub, as clumped or scattered trees, is a greater element in pasture on beef cattle and sheep farms, than on dairy farms. High proportions of secondary vegetation in canopy gaps within natural forest and scrub remnants suggests that many are degraded by wildling trees or shrubby weeds; however the number of points is too few to regard the proportions as representative.

9.2 Group I2

These are the region's next-best arable soils, with moderate susceptibility to degradation, which does not however preclude intensive use. These soils need heavier fertilisation to avoid nutrient loss. When cultivated, the I2b soils require greater care in timing and nature of cultivation to avoid structural deterioration. They additionally require care in timing and duration of grazing, to avoid structural deterioration when intensively grazed pasture.

Sample data for I2 soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	11	0.3	0.2	6
Market gardens	28	0.7	0.3	10
Grain and fodder crops	6	0.2	0.1	5
Dairy pasture	113	2.9	0.5	18
Improved drystock pasture	183	4.7	0.7	19
Unimproved pasture	15	0.4	0.2	7
Exotic forest	6	0.2	0.1	5
Natural forest	5	0.1	0.1	4
Exotic scrub	3	0.1	0.1	3
Natural scrub	4	0.1	0.1	4
Wetland vegetation	11	0.3	0.1	6
Coastal vegetation	1	<0.1	0.1	2
Bare ground	1	<0.1	0.1	2

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on I2 soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	1100	3
Market gardens	2800	7
Grain and fodder crops	600	2
Dairy pasture	11300	29
Improved drystock pasture	18300	47
Unimproved pasture	1500	4
Exotic forest	600	2
Natural forest	500	1
Exotic scrub	400	1
	Area in hectares	*% of soil in group*
Natural scrub	1100	1
Wetland vegetation	100	3
Coastal vegetation	100	<1
Bare ground	100	<1

88% of I2 soil is under some form of intensive use; mainly intensive grazing, with 12% used for horticulture or cropping; a lesser percentage than I1. Of the balance, 6% is under low-intensity use, and the rest un-used land under an assortment of natural vegetation covers, of which wetland is the largest at 3%.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	11	0.73	0
Market gardens	28	0.29	0.04
Grain and fodder crops	6	0	0
Dairy pasture	113	0.21	0.04
Improved drystock pasture	183	0.42	0.16
Unimproved pasture	15	0.0	0.20
Exotic forest	6	0	0

Natural forest	5	0.20	0.20
Exotic scrub	3	0	0.67
Natural scrub	4	0	0.50
Wetland vegetation	11	0.91	0
Coastal vegetation	1	0	0
Bare ground	1	0	0

The same secondary vegetation covers are associated with different land uses, as is the case for I1 soils. Farm shelter is equally widespread in orchards and vineyards, and more common on dairy farms, beef cattle and sheep farms. Retained bush or scrub, while present on dairy farms, beef cattle and sheep farms, is less common. Also as for I1, high percentages of secondary vegetation within natural forest and scrub remnants suggests that many are degraded by wildling trees or shrubby weeds; but point numbers are too few to regard the proportions as representative.

9.3 Group I3

These are lowland soils with high susceptibility to degradation. Heavy fertilisation is needed to avoid nutrient loss, if I3 soils are used for horticulture or cropped; maintenance fertiliser requirements remain substantial if they are intensively grazed. The soils are weathered sands usually with admixture of volcanic ash, so have few structural problems if cultivated or grazed except for the I3b sub-group, which has loose-structured topsoil over a subsoil hardpan. I3b soils are also erodible, requiring soil conservation practices to control surface erosion if in vegetable, grain or fodder crops; and care in pasture management if grazed.

Sample data for I3 soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	5	0.1	0.1	4
Market gardens	3	0.1	0.1	3
Grain and fodder crops	2	<0.1	0.1	3
Dairy pasture	45	1.2	0.3	11
Improved drystock pasture	92	2.4	0.5	13
Unimproved pasture	10	0.3	0.2	6
Exotic forest	8	0.2	0.1	5
Natural forest	0	0	0.1	2
Exotic scrub	1	<0.1	0.1	2
Natural scrub	6	0.2	0.1	5

Wetland vegetation	5	0.1	0.1	4
Coastal vegetation	0	0	0.1	2
Bare ground	1	<0.1	0.1	2

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on I3 soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	500	3
Market gardens	300	2
Grain and fodder crops	200	1
Dairy pasture	4500	25
Improved drystock pasture	9200	52
Unimproved pasture	1000	6
Exotic forest	800	5
Natural forest	0	0
Exotic scrub	100	1
Natural scrub	600	3
Wetland vegetation	500	3
Coastal vegetation	0	0
Bare ground	100	1

Differences in land use cf. the I1 and I2 groups are that of the 83% intensively used, just 6% is currently cultivated. The balance between dairy pasture and drystock grazing shifts further in favour of the latter. Low-intensity uses at 11% are more significant - though still small - elements of land use. Natural vegetation remnants, while still small, are also a larger component, mainly wetlands and scrub stands.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	5	0.80	0
Market gardens	3	0.33	0
Grain and fodder crops	2	0	0
Dairy pasture	45	0.09	0.09

Improved drystock pasture	92	0.15	0.24
Unimproved pasture	10	0.10	0.40
Exotic forest	8	0	0.25
Natural forest	0	-	-
Exotic scrub	1	0	0
Natural scrub	6	0.50	0
Wetland vegetation	5	0.60	0
Coastal vegetation	0	-	-
Bare ground	1	0	0

The number of points is too small for proportions in this table to be regarded as representative of secondary vegetation except for pasture. Compared with I1 or I2, about the same proportion of farm shelter appears to be present where horticulture is practiced on I3 soils, but the proportion on grazed country whether dairy or sheep and beef is much lower. The proportion of pasture with bush or scrub remnants increases. A quarter of exotic forest stands contains scrub remnants in unplanted canopy gaps. About half the natural scrub and wetland remnants include exotic trees or shrubs indicative of degradation.

9.4 Group L2

These are soils where frequent water-logging (and salinity on some soils) is likely to preclude horticulture and cropping, and may also restrict grazing and forestry. Some of the soils are moderately fertile, so only need moderate maintenance fertiliser to avoid nutrient loss if in pasture. All require great care in timing and duration of grazing to avoid structural breakdown.

Sample data for L2 soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	0	0	0.1	2
Market gardens	1	<0.1	0.1	2
Grain and fodder crops	4	0.1	0.2	4
Dairy pasture	32	0.8	0.3	9
Improved drystock pasture	31	0.8	0.3	9
Unimproved pasture	10	0.3	0.2	6
Exotic forest	0	0	0.1	2
Natural forest	0	0	0.1	2
Exotic scrub	4	0.1	0.1	4
Natural scrub	2	0.1	0.1	3

Wetland vegetation	2	0.1	0.1	3
Coastal vegetation	4	0.1	0.1	4
Bare ground	1	<0.1	0.1	2

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on L2 soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	0	0
Market gardens	100	1
Grain and fodder crops	400	4
Dairy pasture	3200	35
Improved drystock pasture	3100	34
Unimproved pasture	1000	11
Exotic forest	0	0
Natural forest	0	0
Exotic scrub	400	4
Natural scrub	200	2
Wetland vegetation	200	2
Coastal vegetation	400	4
Bare ground	100	1

Surprisingly, 74% of L2 soil is intensively used. 5% is under horticulture or cropping. 69% is intensively grazed, split equally between dairying and drystock. Low-intensity use occupies 11%; entirely unimproved pasture, as exotic forests are absent. Of the 13% un-used, 4% is exotic scrub, 4% coastal vegetation (saltmarsh), with the balance split between natural scrub and wetland.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	0	-	-
Market gardens	1	0	0
Grain and fodder crops	4	0	0
Dairy pasture	32	0.09	0
Improved drystock pasture	31	0.23	0.07
Unimproved pasture	10	0.10	0.33

Exotic forest	0	-	-
Natural forest	0	-	-
Exotic scrub	4	0	0.25
Natural scrub	2	0	0
Wetland vegetation	2	1.00	0
Coastal vegetation	4	0	0
Bare ground	1	0	0

The number of points is too small for proportions to be representative of secondary vegetation with the exception of pasture. The proportion of pasture with farm shelter is low; undoubtedly a consequence of difficulty in tree establishment. Remnant scrub has been almost entirely cleared from dairy pasture and improved drystock pasture, but remains a significant component of unimproved pasture. A quarter of exotic scrub has canopy gaps occupied by natural scrub. Wetland vegetation is depleted throughout, with growth of pasture, weeds and scrub in the gaps.

9.5 Group L3

On L3 soils, lack of structure and wind erosion hazard preclude horticulture or cropping. They necessitate great care in pasture management if these soils are grazed - excessively-free drainage restricts grass growth; pasture depletion exposes topsoil to wind. The soils are moderately fertile but leach fast, so require adequate maintenance fertiliser to avoid nutrient loss if in pasture; and possibly also in the long term under forestry.

Sample data for L3 soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	0	0	0.1	2
Market gardens	0	0	0.1	2
Grain and fodder crops	0	0	0.1	2
Dairy pasture	11	0.3	0.2	6
Improved drystock pasture	30	0.8	0.3	10
Unimproved pasture	18	0.5	0.2	8
Exotic forest	137	3.5	0.6	16
Natural forest	1	<0.1	0.1	2
Exotic scrub	2	0.1	0.1	3
Natural scrub	20	0.5	0.2	8
Wetland vegetation	5	0.1	0.1	4
Coastal vegetation	23	0.6	0.2	9
Bare ground	12	0.3	0.2	7

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on L3 soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	0	0
Market gardens	0	0
Grain and fodder crops	0	0
Dairy pasture	1100	4
Improved drystock pasture	3000	12
Unimproved pasture	1800	7
Exotic forest	13700	53
Natural forest	100	<1
Exotic scrub	200	1
Natural scrub	2000	8
Wetland vegetation	500	2
Coastal vegetation	2300	9
Bare ground	1200	5

Big differences in land use are apparent between this group, and the other lowland soils. Horticulture and cropping are, as expected, absent. Just 15% is in improved pasture, with a further 7% unimproved. 60% of L3 soil is in low-intensity use, overwhelmingly exotic forest. 25% is un-used. The natural scrub component is greater than other lowland soils at 8% and wetland similar at 2%. Unlike other lowland soils, the L3 group has moderate areas under coastal vegetation (mainly marram) or bare, drifting sand.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	0	-	-
Market gardens	0	-	-
Grain and fodder crops	0	-	-
Dairy pasture	11	0	0
Improved drystock pasture	30	0.10	0.37
Unimproved pasture	18	0.17	0.17

Exotic forest	137	0.07	0.01
Natural forest	1	0	0
Exotic scrub	2	1.00	0
Natural scrub	20	0.15	0
Wetland vegetation	5	0.60	0
Coastal vegetation	23	0	0
Bare ground	12	0	0

As secondary vegetation on L3 soils, exotic shelter is limited in extent, reflecting difficulty of tree establishment in windswept open pasture near the coast. Scattered scrub remains present in about a third of improved pasture, and a fifth of unimproved, offering some shelter for stock. 8% of exotic forest has canopy gaps, generally occupied by marram, with just 1% occupied by scrub or other natural vegetation remnants. Larger patches of natural scrub are reasonably intact; just 15% have canopy gaps occupied by exotic vegetation (usually grass). Point numbers in natural forest, exotic scrub and wetland are too few to regard proportions as representative of secondary exotic vegetation (rough pasture and weeds). Although no secondary cover could be detected in coastal vegetation on the aerial photos, coastal scrub species are known to be present in the marram.

9.6 Group H1

These are the best footslope soils in Auckland - high to medium-fertility, situated on rolling land, their susceptibility to degradation is negligible or slight. They require low to moderate applications of maintenance fertiliser to avoid nutrient loss when in intensively grazed pasture. The heavier soils (H1b) also require carefully timed grazing to avert structural deterioration when wet. Occasional fodder crops are possible, but soil conservation practices are needed to control surface erosion. Where there is no drainage limitation, these soils can be used for orchards or vineyards.

Sample data for H1 soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	0	0	0.1	2
Market gardens	0	0	0.1	2
Grain and fodder crops	3	0.1	0.1	3
Dairy pasture	64	1.6	0.4	14
Improved drystock pasture	178	4.5	0.7	16
Unimproved pasture	26	0.7	0.3	10
Exotic forest	0	0	0.1	2

Natural forest	1	<0.1	0.1	2
Exotic scrub	5	0.1	0.1	3
Natural scrub	18	0.5	0.2	8
Wetland vegetation	0	0	0.1	4
Coastal vegetation	0	0	0.1	9
Bare ground	0	0	0.1	7

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on H1 soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	0	0
Market gardens	0	0
Grain and fodder crops	300	1
Dairy pasture	6400	22
Improved drystock pasture	17800	60
Unimproved pasture	2600	9
Exotic forest	0	0
Natural forest	100	<1
Exotic scrub	500	2
Natural scrub	1800	6
Wetland vegetation	0	0
Coastal vegetation	0	0
Bare ground	0	0

83% is under intensive use, overwhelmingly pasture, with 22% of it dairy farms. Unimproved pasture occupies 9% of H1 footslopes. Exotic forest is absent. Un-used land is mainly occupied by natural scrub, with a small fraction exotic scrubby weeds (gorse and flannel weed). Natural forest remnants are negligible, as are wetlands.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	0	-	-

Market gardens	0	-	-
Grain and fodder crops	3	0	0
Dairy pasture	64	0.25	0.25
Improved drystock pasture	178	0.20	0.34
Unimproved pasture	26	0.27	0.27
Exotic forest	0	-	-
Natural forest	1	0	0
Exotic scrub	5	1.00	0
Natural scrub	18	0.22	0.50
Wetland vegetation	0	-	-
Coastal vegetation	0	-	-
Bare ground	0	-	-

A feature of secondary cover on H1 soils is that over half of pasture has either exotic trees (farm shelter, soil conservation plantings on streambanks) or natural tree and scrub remnants. Over 70% of natural scrub has canopy gaps, occupied by diverse vegetation - exotic weeds, wildling pines, and significantly, regenerating forest trees. This suggests that around half the scrub is in good condition and at an advanced stage of regeneration. Exotic scrub has canopy gaps throughout, occupied by pasture. Though number of points is too small to regard the proportion as representative, its canopy gaps reflect the scrub's nature i.e. shrubby weed infestation on grazed land.

9.7 Group H2

These are Auckland's next-best footslope soils - medium to low fertility on rolling land, their susceptibility to degradation ranges from moderate (H2a) to severe (H2b). These soils require regular heavy fertilisation and liming to counteract nutrient loss if grazed; and particular care in timing and duration of grazing to control structural deterioration, when in intensively grazed pasture. If occasionally cultivated for fodder-crops or pasture renewal, soil conservation measures are needed to avert surface erosion. The better soils in this group (H2a) can support orchards and vineyards, but the poorer (H2b) are either too infertile, or too seasonally wet, or both. The poorer soils include podsols, which even require maintenance fertiliser to counter-act nutrient loss under extensive grazing and forestry.

Sample data for H2 soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	7	0.2	0.1	5
Market gardens	3	0.1	0.1	3

Grain and fodder crops	7	0.2	0.1	5
Dairy pasture	121	3.1	0.5	19
Improved drystock pasture	229	5.8	0.7	22
Unimproved pasture	33	0.8	0.3	11
Exotic forest	48	1.2	0.3	13
Natural forest	7	0.2	0.1	5
Exotic scrub	6	0.2	0.1	5
Natural scrub	40	1.0	0.3	12
Wetland vegetation	13	0.3	0.2	7
Coastal vegetation	0	0	0.1	3
Bare ground	4	0.1	0.1	4

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on H2 soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	700	1
Market gardens	300	<1
Grain and fodder crops	700	1
Dairy pasture	12100	23
Improved drystock pasture	22900	44
Unimproved pasture	3300	6
Exotic forest	4800	9
Natural forest	700	1
Exotic scrub	600	1
Natural scrub	4000	7
Wetland vegetation	1300	3
Coastal vegetation	0	0
Bare ground	400	1

H2 soils display some interesting differences in land use compared with H1. The small percentage under vineyards, orchards, or market gardens reflects recent location of the former on better-drained soils near Warkworth and Matakana. The market gardens are associated with greenhouses or polyhouses, more likely to be on small pockets of

alluvial soil (I1 or I2) not depicted on the soil maps, than on H2. The percentage in improved pasture at 68% is lower than H1, but the ratio of dairying to drystock is higher; possibly reflecting Rodney dairy farmers' preference for heavy clay soils which, although wet in winter, stay moist for longer into the summertime. Unimproved pasture drops to 6% of the group. Exotic forest becomes a noticeable component of the H2 landscape at 9.3%; much of this is Riverhead Forest on gumland soils, with the balance small private plantations on similar soil throughout Rodney; also margins of Mahurangi Forest which extend onto H2 footslopes. Un-used land (16%) is again dominated by natural scrub, though wetland makes an appearance. Exotic scrub cover remains small. 1% of H2 soil is bare ground disturbed by quarrying, earthworks road construction or tracking.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	7	0.57	0.14
Market gardens	3	0.33	0
Grain and fodder crops	7	0	0
Dairy pasture	121	0.22	0.09
Improved drystock pasture	229	0.24	0.26
Unimproved pasture	33	0.30	0.12
Exotic forest	48	0.08	0.15
Natural forest	7	0.29	0.29
Exotic scrub	6	0.33	0.33
Natural scrub	40	0.20	0.35
Wetland vegetation	13	0.77	0
Coastal vegetation	0	-	-
Bare ground	4	0	0

Orchards, vineyards and market gardens on H2 soils have considerable planted shelter, but little retention of natural trees or shrubs. As with H1, a high percentage of pasture has shelter belts, soil conservation trees along watercourses, and scattered natural tree or shrub cover. A quarter of exotic forest has canopy gaps, occupied either by pasture (.08 - agroforestry stands) or unplanted patches of scrub or bush (.15 - commercial plantations). Natural scrub has canopy gaps, .20 occupied by unimproved pasture, exotic scrub or wildling pines (scrub at early stage of regeneration); .35 occupied by regenerating forest trees (advanced regeneration). Three-quarters of the small remnant wetlands are degraded, with pasture or exotic trees and shrubs. The number of points under other land uses is too small for proportions to be representative of secondary cover but indicates some trends. Exotic scrub still has a high proportion of canopy gaps, but unlike on H1, a third of them are occupied by patches of bush or scrub i.e. a proportion of exotic scrubby weed infestations on H2 are in unused land rather than farmland. Over half the natural forest has canopy gaps,

occupied by a diversity of vegetation - unimproved pasture, exotic scrub, wildling pines, natural scrub - suggesting recovery after widespread disturbance.

9.8 Group H3a

Hill phases of H1 soils. Susceptibility to nutrient loss and structural breakdown are similar to H1, as are maintenance fertiliser and structural management requirements if under pasture. However the hill phases are highly susceptible to erosion. Heavy grazing exposes topsoil to surface erosion; conservation practices are needed to control mass movement erosion in subsoil.

Sample data for H3a soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	2	0.1	0.1	3
Market gardens	1	<0.1	0.1	2
Grain and fodder crops	4	0.1	0.1	4
Dairy pasture	19	0.5	0.2	8
Improved drystock pasture	263	6.7	0.8	25
Unimproved pasture	55	1.4	0.4	14
Exotic forest	129	3.3	0.6	20
Natural forest	69	1.8	0.4	15
Exotic scrub	31	0.8	0.3	11
Natural scrub	148	3.8	0.6	21
Wetland vegetation	6	0.2	0.1	5
Coastal vegetation	0	0	0.1	2
Bare ground	2	0.1	0.1	3

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on H3a soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	200	<1
Market gardens	100	<1
Grain and fodder crops	400	1
Dairy pasture	1900	3

Improved drystock pasture	26300	36
Unimproved pasture	5500	8
Exotic forest	12900	18
Natural forest	6900	10
Exotic scrub	3100	4
Natural scrub	14800	20
Wetland vegetation	600	1
Coastal vegetation	0	0
Bare ground	200	<1

The pattern of land use on H3a soils is very different from H1. Very small cultivated areas are likely to be small pockets of alluvial or footslope soil (I1, I2 or H1) not differentiated on the soil maps. Intensively grazed pasture occupies just 39% of H3a, and dairying has almost disappeared; the small percentage is winter run-off at the back of farms that are predominantly H1. Unimproved pasture at 8% occupies a similar proportion of land as on the footslope soils. Exotic forest currently covers almost a fifth of H3a soils. Un-used land jumps to 35%, with natural scrub covering a fifth. Exotic scrub and natural forest also occupy a higher fraction of the landscape than on H1. When the forest and scrub covers are combined, over half the H3a landscape is treed.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	2	0.50	0.50
Market gardens	1	0	1.00
Grain and fodder crops	4	0	0
Dairy pasture	19	0.32	0.47
Improved drystock pasture	263	0.17	0.45
Unimproved pasture	55	0.26	0.51
Exotic forest	129	0.12	0.14
Natural forest	69	0.19	0.23
Exotic scrub	31	0.29	0.55
Natural scrub	148	0.20	0.54
Wetland vegetation	6	0.67	0
Coastal vegetation	0	-	-
Bare ground	2	0	0

As regards secondary vegetation present amongst land uses, the trends appearing on H1 soils are amplified on H3a. There are too few points for tree cover amongst cultivated ground to be viewed as representative. In pasture, the proportion of farm shelter, soil conservation plantings and remnant natural cover increases. About a quarter of exotic forest has canopy gaps, occupied by pasture or exotic scrub (in young stands) and natural scrub or trees (unplanted patches in maturing stands). Exotic scrub

has a high proportion of its canopy gaps occupied by rough pasture, natural scrub or bush trees, indicating over half the exotic weed infestations are on un-used ground. Three-quarters of natural scrub has other vegetation present, with the balance shifting in favour of gap occupancy by emerging bush trees (advanced regeneration). About two-fifths of natural forest has canopy gaps; mainly landslide scars or gullies colonised by rough grass or successional scrub. Number of points on wetland is too small to view the proportion with canopy gaps as representative, but does suggest that the hill country wetland is invaded by exotic grasses and weeds.

9.9 Group H3b

Hill phases of H2 soils. Susceptibility to nutrient loss and structural deterioration are similar to H2, as are maintenance fertiliser and structural management requirements if under pasture. The hill phases are highly susceptible to erosion: heavy grazing exposes topsoil to surface erosion; conservation practices are needed to control mass movement erosion of subsoil, if in pasture.

Sample data for H3b soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	0	0	0.1	2
Market gardens	0	0	0.1	2
Grain and fodder crops	0	0	0.1	2
Dairy pasture	18	0.5	0.2	8
Improved drystock pasture	71	1.8	0.4	14
Unimproved pasture	19	0.5	0.2	8
Exotic forest	45	1.2	0.3	12
Natural forest	14	0.4	0.2	7
Exotic scrub	6	0.2	0.1	5
Natural scrub	60	1.5	0.4	13
Wetland vegetation	1	<0.1	0.1	2
Coastal vegetation	0	0	0.1	2
Bare ground	3	<0.1	0.1	3

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on H3b soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	0	0
Market gardens	0	0
Grain and fodder crops	0	0
Dairy pasture	1800	8
Improved drystock pasture	7100	30
Unimproved pasture	1900	8
Exotic forest	4500	19
Natural forest	1400	6
Exotic scrub	600	3
Natural scrub	6000	25
Wetland vegetation	100	<1
Coastal vegetation	0	0
Bare ground	300	1

As with H1 compared with H2, some interesting contrasts between land use on H3b and H3a appear soil-related. The percentage intensively grazed is similar at 38%, but the proportion occupied by dairy farm run-offs increases; perhaps a consequence of dairy farmers' preferential location on the heavy H2 soils. Unimproved pasture occupies much the same percentage of land, as does exotic forest, while the percentage of exotic scrub declines slightly. The percentage of land un-used is much the same at 36%, but the balance between natural forest(now 6%) and scrub (now 25%) shifts in favour of the latter. Possible reasons for this are inability of the more leached H3b soils to support climax forest; or a greater amount of forest clearance followed by scrub reversion; the former explanation is more likely. Wetlands while still present in valley bottoms are an insignificant component of the landscape. Ground disturbed by quarrying, earthworks, roading and tracking is still measurable.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	0	-	-
Market gardens	0	-	-
Grain and fodder crops	0	-	-
Dairy pasture	18	0.22	0.17
Improved drystock pasture	71	0.28	0.44
Unimproved pasture	19	0.37	0.42
Exotic forest	45	0.16	0.16
Natural forest	14	0.14	0.21
Exotic scrub	6	0.33	0.67
Natural scrub	60	0.18	0.42
Wetland vegetation	1	1.00	0

Coastal vegetation	0	-	-
Bare ground	3	0	0

Trends in secondary vegetation, moving from H2 to H3b soils, are similar to those moving from H1 to H3a. Over three-quarters of pasture now has tree or shrub cover present; a substantial proportion is still soil conservation trees or wildling pines, but the majority scattered bush or scrub cover. The percentage of exotic forest with canopy gaps induced by landslides or gullies is higher, at 32%. 60% of natural scrub has canopy gaps; two-thirds with emergent forest trees i.e. advanced regeneration indicates the scrub is in good condition. 35% of natural forest has canopy gaps induced by landslides or gullies, colonised by rough grass, exotic scrub weeds, or successional scrub. Point numbers in exotic scrub and wetland are too few for proportions to be representative, but they suggest that most exotic scrub is on un-used land.

9.10 Group H3c

Hill phases of lowland arable soils (Group I). Susceptibility to nutrient loss and structural breakdown are the same as for the respective I categories i.e. range from low (I1a - recent volcanics) to high (I3b - leached sands). Unlike their lowland phases, what the H3c soils have in common is that erosion hazard precludes all forms of horticulture and cropping; also exposing them to surface erosion by water (and in some cases wind) if intensively grazed. Their derivation from unconsolidated sediments, combined with locally steep slopes, makes them highly susceptible to mass movement erosion and gullying of subsoil, necessitating additional conservation measures.

Sample data for H3c soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	1	<0.1	0.1	2
Market gardens	1	<0.1	0.1	2
Grain and fodder crops	3	0.1	0.1	3
Dairy pasture	12	0.3	0.2	6
Improved drystock pasture	68	1.7	0.4	11
Unimproved pasture	11	0.3	0.2	6
Exotic forest	5	0.1	0.1	4
Natural forest	6	0.2	0.1	5
Exotic scrub	3	0.1	0.1	3
Natural scrub	22	0.6	0.2	8
Wetland vegetation	3	0.1	0.1	3
Coastal vegetation	0	0	0.1	2
Bare ground	0	0	0.1	2

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on H3c soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	100	1
Market gardens	100	1
Grain and fodder crops	300	2
Dairy pasture	1200	9
Improved drystock pasture	6800	50
Unimproved pasture	1100	8
Exotic forest	500	4
Natural forest	600	4
Exotic scrub	300	2
Natural scrub	2200	16
Wetland vegetation	300	2
Coastal vegetation	0	0
Bare ground	0	0

Small areas of intensive cultivation, apparently on H3c soil, are mostly accounted for by pockets of I soil not shown on soil maps; though there are one or two points where maize cultivation or fodder crops extend onto moderately steep H3c. 59% of H3c is intensively grazed pasture; a higher percentage than either H3a or H3b. The balance is heavily in favour of drystock pasture; reflecting the high percentage of sand soils in H3c, droughty and unsuited to dairying. Low-intensity land uses occupy just 12% of H3c, with exotic forest a surprisingly small component at 4%. Of the 24% un-used, just over 2% is exotic scrub, either gorse or brush wattle or boxthorn. Natural scrub is the largest component at 16%. The low percentage of natural forest is a consequence of its removal from sand soils by fires and timber-cutting. A small though measurable percentage of wetland, apparently on H3c soil in valley bottoms, is more likely to be L2 soil not depicted on soil maps.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	1	1.00	0
Market gardens	1	0	1.00
Grain and fodder crops	3	0	0
Dairy pasture	12	0.08	0.25

Improved drystock pasture	68	0.16	0.38
Unimproved pasture	11	0.18	0.36
Exotic forest	5	0	0.20
Natural forest	6	0	0.33
Exotic scrub	3	0.67	0.33
Natural scrub	22	0.41	0.14
Wetland vegetation	3	0.67	0
Coastal vegetation	0	-	-
Bare ground	0	-	-

Orchards and market gardens, where present on H3c soils, have associated secondary cover but no significance can be attached to proportions, given the small number of points. Pasture has limited exotic shelter or soil conservation trees; surprising as the H3c soils are in sheltered valleys where they could be established. However, between a quarter and two-fifths have scattered remnant natural trees or shrubs. Most of the natural scrub cover has canopy gaps; predominantly occupied by pasture, indicating that stands are located within grazed pasture, so likely to be in poor condition. Number of points in other uses is too small to attach any significance to the proportion of secondary vegetation within each, but may indicate trends. Canopy gaps in exotic forest are occupied by natural scrub i.e. unplanted patches. Exotic scrub has more canopy gaps occupied by pasture than by natural plant communities i.e. dense infestations are associated with grazed land. The small number of points in wetlands are for the most part disturbed, with rough pasture and weeds in the gaps.

9.11 Group S2

These are skeletal soils, where stoniness and excessive drainage preclude all forms of horticulture or cropping, and may also restrict grazing and forestry. They are concentrated in two areas: Rangitoto Island (recent lava flows), and Waitakere Ranges (plateau remnants on andesitic breccia). Small pockets are also found on volcanic cones and lava flows through Franklin district.

Sample data for S2 soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	0	0	0.1	2
Market gardens	0	0	0.1	2
Grain and fodder crops	0	0	0.1	2
Dairy pasture	0	0	0.1	2
Improved drystock pasture	23	0.6	0.2	9

Unimproved pasture	5	0.1	0.1	4
Exotic forest	2	0.1	0.1	3
Natural forest	50	1.3	0.3	12
Exotic scrub	3	0.1	0.1	3
Natural scrub	79	2.0	0.4	13
Wetland vegetation	1	<0.1	0.1	2
Coastal vegetation	0	0	0.1	2
Bare ground	1	<0.1	0.1	2

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on H2 soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	0	0
Market gardens	0	0
Grain and fodder crops	0	0
Dairy pasture	0	0
Improved drystock pasture	2300	14
Unimproved pasture	500	3
Exotic forest	200	1
Natural forest	5000	31
Exotic scrub	300	2
Natural scrub	7900	48
Wetland vegetation	100	1
Coastal vegetation	0	0
Bare ground	100	1

Land use on S2 soils is clearly different from the H groups. Only 14% is intensively used; all of it drystock pasture. Unimproved pasture is just 3%, and exotic forest 1%. 82% is unused land, overwhelmingly natural scrub and forest.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	0	-	-
Market gardens	0	-	-

Grain and fodder crops	0	-	-
Dairy pasture	0	-	-
Improved drystock pasture	23	0.04	0.35
Unimproved pasture	5	0	0.40
Exotic forest	2	0	0.50
Natural forest	50	0	0.54
Exotic scrub	3	0.67	0
Natural scrub	79	0.05	0.33
Wetland vegetation	1	1.00	0
Coastal vegetation	0	-	-
Bare ground	1	0	0

Pasture on S2 soils is almost devoid of exotic shelter or soil conservation trees, but a high proportion has scattered natural tree or shrub cover. This is in keeping with its position on the margins of extensive bush. About half the natural forest has canopy gaps occupied by scrub - this is successional forest in the Waitakere Ranges, on sites cut over for timber last century. The one-third of natural scrub with canopy gaps is mostly in the Waitakeres, at an earlier stage of regeneration; though a few points on Rangitoto Island are scrub with bare lava flows in the gaps. Points under other uses are too few for secondary vegetation in canopy gaps to be representative.

9.12 Group S3

These are steepland soils, on flanks of the Auckland region's ranges: valleys in the Waitakeres and Hunuas; also locally steep slopes at Kaipara Hills and the Dome Hills eastwards to Leigh. Shallow depth and mass movement erosion hazard preclude all forms of horticulture or cropping, are also likely to preclude grazing in the long term, and may restrict forestry. These soils additionally require adequate maintenance fertiliser to avoid nutrient loss, when in pasture or forestry.

Sample data for S3 soils are:

	No. of points	% of rural land	Confidence limits	
			+ - %	+ - n
Orchards and vineyards	0	0	0.1	2
Market gardens	0	0	0.1	2
Grain and fodder crops	0	0	0.1	2
Dairy pasture	1	<0.1	0.1	2
Improved drystock pasture	51	1.3	0.3	13
Unimproved pasture	20	0.5	0.2	9
Exotic forest	72	1.8	0.4	15
Natural forest	135	3.5	0.6	19
Exotic scrub	13	0.3	0.2	7

Natural scrub	124	3.2	0.6	18
Wetland vegetation	1	<0.1	0.1	2
Coastal vegetation	0	0	0.1	0
Bare ground	1	<0.1	0.1	2

The confidence limits indicate:

- percentage by which true figure for the region may differ from sample data,
- number of points increase/decrease in a future re-survey, before change can be regarded as significant.

From the above data, current land use on H2 soils is estimated as:

	Area in hectares	% of soil in group
Orchards and vineyards	0	0
Market gardens	0	0
Grain and fodder crops	0	0
Dairy pasture	100	<1
Improved drystock pasture	5100	12
Unimproved pasture	2000	5
Exotic forest	7200	17
Natural forest	13500	32
Exotic scrub	1300	3
Natural scrub	12400	30
Wetland vegetation	100	<1
Coastal vegetation	0	0
Bare ground	100	<1

Agricultural land use on S3 soils is similar to S2 - just 12% improved pasture, almost entirely drystock. The small fraction in dairy pasture is just a single point on a steep slope at back of one farm, otherwise on footslope and lowland soils. Unimproved pasture, at 5%, is also similar in extent to S2; forestry is however more extensive at 17%, planted on land that was formerly in pasture or regenerating scrub. Consequently the percentage of un-used land on S3 soil is lower, at 66%. Except for small areas of exotic scrub, it is overwhelmingly under natural tree or scrub cover.

	Number of points	Proportion with:	
		Other exotic trees or shrubs present	Other natural trees or shrubs present
Orchards and vineyards	0	-	-
Market gardens	0	-	-

Grain and fodder crops	0	-	-
Dairy pasture	1	0	1.00
Improved drystock pasture	51	0.18	0.49
Unimproved pasture	20	0.35	0.30
Exotic forest	72	0.14	0.25
Natural forest	135	0	0.53
Exotic scrub	13	0.39	0.62
Natural scrub	124	0.07	0.44
Wetland vegetation	1	1.00	0
Coastal vegetation	0	-	-
Bare ground	1	0	0

A moderate proportion of pasture on S3 soils has exotic trees present, either soil conservation plantings or wildling pines, while a higher proportion has remnant natural tree or scrub cover. Two-fifths of exotic forest has canopy gaps occupied by diverse vegetation - rough pasture or exotic scrub in young stands; patches of natural bush or scrub in maturing ones. Canopy gaps in exotic scrub indicate two-fifths is infestation in pasture, with the balance infestation in disturbed scrub or bush. Over half the natural forest has canopy gaps occupied by natural scrub - some is regenerating on cut-over sites, but most is on landslide scars or gullies. About half the natural scrub cover has canopy gaps occupied by emergent forest trees; this is generally terrain cut over for timber last century and now at an advanced stage of regeneration. The single point in wetland cannot be viewed as representing secondary vegetation.