ASPECTS OF THE REVEGETATION OF CLEARFELLED AREAS IN KIELDER FOREST

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1. Objectives

To investigate aspects of the revegetation of clearfelled areas by;

a. investigating whether gradients of colonization from nearby seed sources occur,

b. investigating the effects of microhabitats on the distibution of species within restock areas (including soil type, slope and drainage).

2. Method

Ideally the problem of how clearfelled areas are recolonized by vegetation would best be answered by a long term experimental approach. By being present near the time of felling, seed traps and permanent quadrats could be set up, and investigations into germination of buried seed could be made at a range of sites on different soils. The importance of seed sources could be studied at sites both adjacent to, and remote from unplanted areas of land. It would also be interesting to look at the effects of felling at times of the year when different seeds are dispersed.

It is arguable however, that by visiting a range of sites on different soils, at different stages of revegetation, and by incorporating sites both open to and remote from unplanted areas, major trends in recolonization could be detected. Limited time and resources meant that this second option was the only course open to us.

It was felt that a rigorously structered sampling scheme was an inefficient way of tackling what was essentially an exploratory exercise, and a more subjective approach was deemed more appropriate. By visiting a range of sites we would begin to aquire a 'feel' for the processes at work, and adopt the recording methods best suited to capturing the phenomena encountered.

From the 1987 survey, the locations of sites of a range of vegetation types was already known, all of which where felled at least 3 years ago. It was decided to re-visit a range of these along with more newly felled sites learned of from FC staff at Kielder. Inspection of the complete 1984 air photograph cover of the forest revealed the locations of a number of sites where felling had been carried out adjacent to areas of unplanted land, and some of these were also included in the itinerary.

All sites visited were scrutinized for evidence of colonization gradients and effects of microhabitats, any such phenomena encountered were recorded in an appropriate manner. The extent of revegetation at each site was documented, and where appropriate a photographic record kept.

3. Results.

In all 20 sites were visited, descriptions and details of data collected at each are given in the Appendix. This section deals with the general observations made during the visit, along with more detailed analysis of the data collected at more informative sites. It is split into 2 subsections according to the objectives of the visit given at the beginning.

3.1 Colonization Gradients.

One of the first impressions we gained was that species inappropriate to the soil and management conditions prevalent in a clearfelled area were unlikely to invade from an adjacent unplanted area. At a restock near Harelaw (site 20) species from an adjacent Calluna/Eriphorum mire were present only along a 50m wide strip of flat peaty ground adjacent to the mire. Where the ground started to slope away steeply an abrupt vegetation change occured from M19a to MG9a (Deschampsia cespitosa coarse grassland), this was found to coincide with a change in soil from a peaty gley to a non-peaty gley. No Deschampsia cespitosa was found on the peaty soil, and no Calluna or Eriophorum were found on the mineral soil. Similarly at nearby site 7 where on a long undulating slope the soil changed from non-peaty gley through peaty gley to a deep peat as the gradient decreased. The vegetation in the clearfelled area reflected the underlying soil conditions and there was no evidence of species from an adjacent area of improved pasture having invaded. Where roads with associated mineral soils pass close to clearfelled areas dominated by peaty soil we found no evidence of migration of species from one to the other.

We visited many sites that had been felled more than 4 years previously, and where the vegetation of the clearfelled area was of similar character to adjacent unplanted vegetation. No evidence of colonization gradients from unplanted areas was encountered. For example, at site 3 near Archy's Rigg we examined a large clearfelled area adjacent to an unmanaged heather moor and replanted with Sitka in 1983. The character of the vegetation here was unchanged thoughout the whole area, being dominated by Calluna which was well past flowering age, Eriophorum vaginatum and Sphagnum spp. Similar phenomena were encountered on mineral soils also. At site 1, a large area restocked

between 1978 and 1982 adjacent to a wide unplanted streamside, and site 18 (sample station 2501 in the 1987 survey) next to an area of unplanted lake shore, Deschampsia cespitosa was dominant in both areas and showed no gradients from the unplanted MG9a vegetation.

In areas remote from unplanted land also we encountered more mature restocks again showing no evidence of gradients, or indeed any lack of vegetation despite their isolation. Examples of such sites would be site 6, a large restock approaching canopy closure near Pope's Hill, dominated by flowering Calluna throughout, and site 13 (station 2906 in 1987, near Pithouse Crags) exhibiting a mosaic of peaty and mineral soils and corresponding vegetation.

There seems little doubt that any clearfelled area, whether adjacent to unplanted land or not will, by the time canopy re-closure occurs be vegetated to a large degree. However, we also visited more recently felled sites and were able to learn a little about how re-colonization occurs.

South East of Earl's Seat (site 14) we encountered an area felled within the last 12 months and adjacent to a Calluna/Eriophorum mire. The crop was previously largely Sitka with some Pine and had been planted at 360m on a deep peaty gley with some deep peat. No obvious regeneration had occured even at the edges closest to the mire.It seems likely that Calluna would originally have been present over the whole area.

A short distance down slope from the site mentioned above was an extensive area (site 15) felled probably a year earlier, again on a peaty gley soil. This site though largely bare did posess a thin scattering of seedling plants. Juncus squarrosus and Calluna were common especially where patches of bare

peat were exposed. Also present were Epilobium angustifolium (asociated with stumps), Agrostis canina, Juncus effusus, Digitalis purpurea, Deschampsia flexuosa, Molinia (flowering), Galium saxatile, Carex echinata, Potentilla erecta, Eriophorum vaginatum, E. angustifolium, Betula pubescens, Luzula multiflora and Anthoxanthum. Many of these species were present on an adjoining roadside, along with Holcus mollis and Deschampsia cespitosa, but significantly not Calluna. There was no sign of the Holcus or D. cespitosa advancing into the restock, or of any other gradients of colonization.

If these species had invaded from the roadside, their seeds must have been dispersed to all areas of the restock during the same season. This is a significant fact when it is considered that this area was fairly well isolated from any extensive areas of unplanted land. In the case of Calluna it is likely that the seedlings originated from buried seed that had remained viable throughout the previous crop rotation. It would be interesting to test whether as is suggested here by its association with patches of bare peat, buried Calluna seed germinates more easily when needle litter is scraped away leaving the surface bare.

Recently felled sites on mineral soils were also visited. Two of these sites were completely unvegetated, site 19 adjacent to the public road along Kielder Water, and site 17 near Pundershaw. However, a third newly felled area, site 12, proved to have been stocked with thinned Norway Spruce, exhibited a remnant ground flora of Oxalis and Mnium hornum. Seedlings found were especially plentiful on disturbed ground and included Digitalis, Carex spp., Juncus effusus, Epilobium angustifolium, Agrostis canina, A. capillaris,

Luzula multiflora, Galium saxatile, Athyrium felix femina, Dryopteris dilitata, Deschampsia cepitosa and Holcus lanatus. No gradients from the edge open to the unplanted shore of Bakethin Reservoir were detected however.

One major problem which presented itself to us was that of how, on non-peaty gley soils, Deschampsia cespitosa spread to cover whole sites in such a short time. As yet we had only observed sites where at best only a few seedlings were present, and others where it was dominant throughout and flowering in profusion. We subsequently encounered site 7 near The Forks which was felled between April and June 1988, and provided an insight into the mechanism of this species' colonization capacity.

The site was not adjacent to a large unplanted area, but a road ran alongside containing Deschampsia cespitosa and other mesotrophic grassland species. Though this site was very variable both in its vegetation cover and soils, it contained one large continuous area of non-peaty gley soil which was in the process of re-colonization. The site as a whole consisted large patches of bare ground with scattered plants, both flowering and young seedlings. A transect of 30 2x2m quadrats placed every 5m across a section of the restock was recorded. Species presence/absence, soil type, and brash depth on a 4 point scale revealed that although Deschampsia cespitosa plants were not particularly numerous, they exhibited no sign of a colonization gradient. However two factors limited their spread, they did not occur where the soil exhibited a peaty surface, nor were they found where the brash was thickest. A subsequent group of 10 2x2m quadrats placed in the area of ground dominated by non-peaty gley soil showed that young non flowering plants of the grass

outnumbered flowering specimens by a ratio of more than 3:1. Considering it's isolation and that it had only been felled a year previously, it is not difficult to imagine how such sites could quickly become dominated by the tussock forming Deschampsia cespitosa.

We must conclude therefore, that no evidence of colonization gradients from adjacent unplanted land was detected by us, and that clearfelled areas on both peaty and mineral soils are revegetated to the same degree even if they are isolated from extensive nearby seed sources.

3.2 Effects of Microhabitats.

There are two possible effects of microhabitats on the flora of a clearfelled area; the local enhancement or deterioration of the existing flora, and the provision of specialized habitats leading to the inclusion of new species in the flora of an area. There are many possible factors which could concievably lead to the formation of microhabitats in clearfelled areas. Underlying local variations in environmental factors such as soil type and depth, slope and drainage, which could have effected the composition of the original pre-crop vegetation, are likely also to influence composition of any re-colonizing flora. Management imposed factors such as bench felling, drainage ditches, ploughing, vehicle disturbance,line thinning of the crop and localized unplanted areas, as well as the general presence of cut stumps and variable brash depth could all compound any natural variability at a given site. Add to these the effects of any remnant ground flora that may have survived the crop rotation, or of a localized premature reopening of the canopy such as that caused by a windthrow event, and the possible outcome could be complex indeed.

It was felt that a systematic investigation of each of these possible variables was beyond the scope of the present study. However the effects of several were continually encountered and have been studied in some detail, whereas others were much more infrequent and are mentioned here only briefly.

3.2.1 Bench Felling, Brash depth and Cut Stumps.

Areas of brash covered ground and rows of cut stumps are an integral part of clearfelled areas in conifer plantation foresty. Bench felling is a management practice that was ecountered in 65% of the sites we visited. It produces alternating strips of deep brash (sometimes over 1 metre thick) and brash free areas. It is instantly recognizable in areas that have been felled for several years because the brash free strips become solidly vegetated, while the felling benches remain largely unvegetated. Where bench felling is not practiced brash lies with variable depth over the whole site.

Previous work by Mark Hill has shown that brash cover inhibits the revegetation of clearfelled areas. Our experiences during this visit seem to confirm his findings. Table 1 shows how the mean number of species per quadrat generally decreases with increasing brash depth. This effect seems common to both peaty and mineral soils, but is more marked on more recently felled sites. This seems to indicate that brash free areas are colonized first.

We also noticed how some species seem to be associated with brash free areas while others are preferential to brash cover. Tables 2 and 3 show the distribution of species between areas under different brash depth on two different soil types at the recently felled site 7 near The Forks. It can be seen how the constancies of vascular plants decrease on both mineral and peaty

soils as brash depth inceases, and that the only plants found under the deepest brash are bryophytes. It is suspected that these mosses, rather than being colonists, are in fact survivors from the time when the crop was standing. Table 4 incates that the situation changes little as the vegetation becomes more established, but notice here how Epilobium angustifolium seems also to show some preference for brash cover. This phenomenon was not an isolated occurence, Table 5 presents the results of a series of quadrats recorded in an area of site 4 near The Haining Farm dominated by peaty gley soil. Varibles recorded were brash cover (DOMIN) and presence/absence of Molinia and Epilobium angustifolium. The occurence of Molinia can be seen to decrease dramatically as brash cover increases, while Epilobium angustifolium shows especial preference for the areas with the thickest brash.

Bench felled areas provide an opportunity to observe these associations more clearly. At site 18, a peaty gley site felled for over 4 years, we recorded a series of 30 50x50cm quadrats on each of; a brash covered felling bench, a brash free strip, and a line of cut stumps (see Table 6). The typical plants of canopy closure, Plagiothecium undulatum, Dicranum scoparium, Hypnum jutlandicum, Mnium hornum, Lophocolea cuspidata and Dryopteris dilitata, are all largely confined to the felling bench, along with several other mosses. Epilobium angustifolium shows a remarkable distinction between the felling bench and the brash free strip, all other vascular plants at this site being excluded from the felling bench.

The species complement of the brash free strip consists of the species that characterize this site as being an example of NVC community M19a. Although there are substantial areas of bare ground, well established Calluna, Erophorum vaginatum and Deschampsia flexuosa plants are abundant, along with

Molinia, Erica tetralix, Vaccinium myrtillus, Juncus squarrosus and Sphagnum. Some mosses such as Campylopus piriformis and C. introflexus show a tendancy to shy away from the dense brash, the first having a definite preference for the open areas, while the other is found equally on cut stumps.

Although it is clear that the stronghold of the vascular plants are the brash free areas, most also occur occasionally on cut stumps, especially Epilobium angustifolium. Some bryophytes also exhibit an association with cut stumps, especially Ceratodon purpureus and Brachythecium rutabulum. A further set of five quadrats were recorded on cut stumps at site 3, the results are presented in Table 7. Similar species were encountered here, appart from Polytrichum formosum and Plagiothecium undulatum which avoided cut stumps at site 18.

The association of Epilobium angustifolium with brash (especially felling benches) and cut stumps was not limited to the examples mentioned. This phenomenon was encountered time and again on mineral as well as peaty soils, though very occasionally on recently felled sites the association was not so clear. Three other species were seen to exhibit at least some affinity with brash. Corydalis claviculata was only encountered at site 13 where it was found growing over the brash of the felling benches exclusively. Galium saxatile and Digitalis purpurea were more frequently encountered, and in areas where most of the available bare ground was choked with well established vegetation, were found to be the only species (along with Epilobium angustifolium) able to colonize the thickest brash.

In the case of Galium and Digitalis at least, the answer to this distribution is probably one of competition, since they both occasionally occupied groundfree from brash where other vegetation was sparse. However Epilobium is

more problematical. Even where there was plenty of available bare ground for colonization, this species showed a much greater tendency towards brash and stumps. Is it that this species has specific germination requirements that are met at these sites only under brash and around stumps, or do brash and stumps somehow form a trap for the wind blown seeds, perhaps even when the crop is still standing? An investigation was obviously beyond the scope of this visit.

It can be seen therefore that brash (or it's absence) can have a dramatic local effect on the flora of a clearfelled area. It is difficult to assess however, whether the practice of bench felling is more advantageous in terms of revegetation. It certainly enables 50% or so of a clear felled area to become quickly recolonized, but the felling benches remain largely unvegetated even up to canopy re-closure. On the other hand the more conventional practice is more slowly recolonized, but the more evenly distributed brash seems to be more easily broken down with time, eventually perhaps allowing a more complete vegetation cover.

3.2.2 Soil Type, Slope and Drainage.

At sites 4 and 20, discussed in the section on colonization gradients, these three variables were found to be inextricably linked. As slope decreased the drainage became more slow allowing the formation of peat, and vice versa. Many of the more extensive sites we visited exhibited evidence of this kind of change, usually abrupt transitions from Deschampsia flexosa, Molinia or such like to dense tussock Deschampsia cespitosa, always proving to coincide with

the disappearance of a peaty soil surface. Examples of such changes were captured in transects of quadrats at the sites near The Forks (site 7) and near Pithouse Crags (site 13), and as would be expected the vegetation always reflected the underlying soil conditions.

Also at site 7, we noted two distinct areas of flushed vegetation consisting largely of Juncus spp. and Deschampsia cespitosa on a non-peaty gley soil. They were situated on a steep slope which otherwise had a peaty surface and carried appropriate vegetation.

On two occasions we encountered local areas of flatter ground where drainage was obviously slower than in nearby areas and the peaty soil was wetter than that usually encountered. At both sites we felt there was sufficent evidence to state that there had been poor performance of the crop locally, and that this had affected the composition of the ground flora beneath the standing crop. In one area, a section of site 4, the wet deep peat supported a vegetation of the character of M19a, with extensive Sphagnum cover, along with Calluna, Eriophorum vaginatum, E. angustifolium, Deschampsia flexuosa, Erica tetralix, Vaccinium mytrillus and V. oxycoccos. The other area was within site 7 where again there was extensive Sphagnum cover (but here much of it was in very poor condition), this time with Deschampsia flexuosa, Molinia and Vaccinium myrtillus. We feel that a high proportion of the vegetation in these two areas had survived through the crop rotation.

3.2.3 Crop Management.

Significant vegetation can also sometimes survive a crop rotation because of management practices. Very near to the area at site 7 mentioned above, we

encountered an area where line thinning of the crop had produced a very similar situation. Again extensive Sphagnum cover was predominant, and in this case the moss had grown to completely cover the cut stumps of the trees extracted at thinning. It is felt however that this occured under exceptional circumstances, where some Sphagnum at least was present before thinning took place.

Another site where thinning is known to have taken place (site 12, near Bakethin Reservoir), and exhibiting a remnant ground flora of Oxalis has already been dealt with in the section on colonization gradients, but some crops have an inherently thin canopy and allow substantial vegetation growth even without thinning of the crop. We observed many felled stands of Pine where the remnant grassy ground flora was flourishing, and again at sites 4 and 7 we found two more discrete examples of the residual effects of a thin canopy. At site 4 we noticed an area some 20m wide adjacent to the edge of the plantation where the brash was generally thinner, the ground somewhat drier and Agrostis canina was present in some quantity. Beyond this strip the grass was largely absent, but as Molinia was present only on either side of the Agrostis, we feel confident that this was not an example of a colonization gradient. Rather, we believe it to be the remnant of some edge effect due to a thinner canopy along the edge of the coup. At the site 7 the situation was clearer; a strip of Larch had been growing alongside a crop composed largely of Spruce, and some remnants of it's Holcus mollis dominated ground flora were observed to be distinctly different to that growing in the remainder of the clearfell.

3.2.4 Windthrow.

Windthrow is a common occurence at Kielder and causes local reopening of the canopy, but we were able to visit only one area that was included in a clearfelled coup. Site 17 near Pundershaw, was very recently felled on a peaty gley soil and largely devoid of vegetation. The windthrow area was near one edge of the coup where a Molinia/Juncus ride carried a line of telegraph poles. Where mineral soil had been brought to the surface around the poles Deschampsia cespitosa and Digitalis purpurea grew. The area is thought to have been cleared a short while before the coup as a whole was felled (perhaps up to two years), but the extent of revegetation was not very great. The area was very confused and heavily disturbed with large areas of bare ground. The vegetation comprised colonies of Digitalis and Holcus lanatus, Dryopteris dilitata (probably a remnant around blown stumps), ocasional Galium saxatile, Luzula multiflora, Molinia, Eriophorum vaginatum, Anthoxanthum and Potentilla erecta, with sporadic Juncus effusus, Epilobium angustifolium, Carex pilulifera, Agrostis canina and Deschampsia cespitosa. The Deschampsia was found to be associated with disturbed areas where mineral soil was exposed at the suface, no seedling plants were found and it showed no signs of spreading onto peaty soil. There were no signs of vegetation begining to spread form the windthrow area into the remainder of the clearfell.

3.2.4 Other Microhabitats.

We encountered many drainage ditches during the visit. Most were unremarkable in that they lacked many of the species that were encountered in the surounding area, while only contributing a lusher bryophyte cover with very few extra species. They typically contained Sphagnum recurvum, Polytrichum commune, Mnium hornum, Dryopteris dilitata and Juncus spp. and little else. However, where the presence of a ditch had caused a slight break in the canopy

we found more diverse vegetation, not only in the bottom of the ditch but also on it's banks. Table 8 gives a species list recorded from a 30m length of such a ditch found at site 7 along which a narrow strip of Deschampsia flexuosa grew, probably also a survivor from when the crop was standing.

One practice of which we became aware, and which must be borne in mind, is that of clearing out ditches and depositing wet subsoil on their banks. These deposits proved to be very inhospitable places for plants to grow on, and they were found to be largely unvegetated.

Plough ridge and furrows were not detected as often as we would have expected, and this is perhaps an indicator that they are not readily distinguished as microhabitats. It may be that at wetter sites some species may distinguish between the two, such as Campylopus introflexus on the ridges and Sphagnum in the furrows, but we found no conclusive evidence of this.

One small area that had not been planted in the first rotation was encountered at site 13. The soil was found to be a non-peaty gley and the vegetation was dominated by Pteridium aquilinum and Deschampsia cespitosa. This was the only area in which Pteridium was found, and it did not extend beyond the area without stumps.

Many examples of local soil disturbance were found, some of which have been dealt with already. It seems likely that these areas may be important as centres for early buried seed germination. They may be formed by a variety of different means; examples were found created by general disturbance during felling, vehicle tracks, overturning of turves for replanting, and erosion. The species most often encountered growing in such spots were Calluna, Juncus

squarrosus, j. bulbosus, Eriophorum vaginatum, Carex spp., and on mineral soil Deschampsia cespitosa. Eventually however, they rarely become microhabitats in their own right. It is only when soil is disturbed to such an extent that a peaty surface is removed are species that would not normally be able to grow at a site able to utilize them.

4. Conclusions

4.1

There is no clear evidence of colonization of clear-fell sites being held back by lack of seed, or of areas close to seed sources being colonized earlier than remote ones.

Why this should be so is not clear for every species, but plants can use a variety of dispersal strategies, and we have seen evidence of several of these on clear-fell sites. They include:

- Wind-blown seed (Epilobiuim angustifolium, Betula spp., Salix spp.). Some light-seeded grasses (Agrostis spp. for example) may also blow in.

- Buried seed. There are several species which have seeds without obvious adaptations for migration into new ground, but which nonetheless appear in quantity. The likely mechanism is survival as buried seed, and it is certainly established that some (Calluna, Juncus spp.), can remain viable for many years. From our observations though it seems that the number of such species is larger than is generally thought. It may be that the conditions for seed preservation are especially favourable on peaty soils.

Since the plant are already *in situ*, they are among the first to appear on a newly cleared site, and are usually able to produce their own seed long before the new crop begins to close-in. They therefore replenish the seed bank at the end of each rotation and, in principle, should be able to maintain themselves indefinately.

Apparent survival for very long periods may also arise through seeds entering the crop during the later stages of growth, and then germinating at clear-felling, perhaps after a relatively short period of burial.

- The ability to maintain themselves vegetatively in heavy shade, and then resume normal growth after clear-felling (*Vaccinium myrtillus*, *Dryopteris dilitata*, *Deschampsia flexuosa*, *Galium saxatile*).

- Transport by animals. *Deschampsia cespitosa* is an early coloniser on mineral soils, and often achieves high cover within three or four years. Exactly how this happens is not clear, but it does seem that a scatter of plants can be present in the first season after clear-felling, and that these provide nuclei for rapid expansion thereafter. There seems to be no indication from published work that *D. cespitosa* has a particularly long lived seed, and we suspect that it may be carried in on the fur of small mammals - probably voles. The seed does possess a persistant awned glume which would provide for this kind of dispersal.

  Some shrubs are dispersed through bird droppings (*Sorbus aucuparia*, *Sambucus nigra*).

It seems that species associated with micro-habitats such as cut stumps, deep brash cover, or ditches do not add greatly to the overall diversity of a site. We found only a single instance of a species that occurred in one micro-habitat only. This was the relatively uncommon Corydalis claviculata which was always associated with deep brash. Epilobium angustifolium and some bryophyte species were merely commoner on stumps and among brash than else where.

4.3

The vegetation that develops on clear-fell sites is seldom completely uniform. Variations are often are often related to soil type and management factors (brash distribution for example) but, as in many natural communities, there is also a random element (or at least an element without obvious causes).

Figure 1 shows how the vegetation can vary across a site, some of the variation can be accounted for, but the remainder is unexplained.

Table 1. The relationship between the number of species per quadrat and brash depth at a range of sites of different ages and soil types.

Site 7 (G.Ref. 627885) near The Forks.

Brash	NPG	PG	Overall
0	7.0 (3)	6.0 (4)	6.4 (7)
1	5.3 (4)	3.5 (4)	4.4 (8)
2	3.5 (6)	3.5 (2)	3.9 (8)
3	1.8 (5)	1.0 (2)	1.4 (7)

Site 13 (G.Ref. 674910) below Pithouse Crags.

Brash	NPG	PG	Overall
0	5.6 (7)	6.4 (8)	6.0 (15)
1	5.0 (1)	5.1 (7)	5.1 (8)
2	4.5 (2)	4.0 (4)	4.2 (6)
3	- -	4.0 (1)	4.0 (1)

Site 10 (G.Ref. 672853) above Bull Crag Edge.

Brash	PG
0	5.8 (13)
1	5.1 (8)
2	5.3 (7)
3	5.0 (2)

Site 8 (G.Ref. 623902) Ferny Knowe.

Brash	DP
0	5.3 (17)
1	6.0 (4)
2	6.0 (4)
3	3.8 (5)

Overall

Brash	
0	5.8 (52)
1	5.0 (28)
2	4.7 (25)
3	2.9 (15)

Brash depth.. 0 = no brash, 1 = up to 5cm, 2 = 6 to 20cm, 3 = over 20cm.
Soil types... NPG = non-peaty gley, PG = peaty gley, DP = deep peat.
() = number of quadrats.

Table 2. Plant species distribution with differing brash depth on non-peaty gley soil at site 7, expressed as pecentage constancy in available quadrats.

Species	no brash(2)	1-5cm(4)	6-20cm(6)	>20cm(5)
Deschampsia cespitosa	100	50	17	-
Cardamine flexuosa	100	-	-	-
Eurhynchium praelongum	100	-	-	20
Plagiomnium undulatum	100	-	-	-
Ajuga reptans	50	-	-	-
Juncus bulbosus	50	-	17	-
Juncus effusus	50	75	-	-
Poa trivialis	50	-	-	-
Potentilla erecta	50	75	17	20
Thuidium tamariscanum	50	50	33	-
Luzula multiflora	-	50	-	-
Agrostis capillaris	-	25	17	-
Carex binervis	-	25	-	-
Dicranella heteromalla	-	25	-	-
Digitalis purpurea	-	25	-	-
Hypnum jutlandicum	-	25	-	40
Lophocolea cuspidata	-	25	50	-
Plagiothecium undulatum	-	25	83	-
Pleurozium schreberi	-	25	-	-
Agrostis canina	-	-	17	-
Holcus lanatus	-	-	17	-
Mnium hornum	-	-	17	-
Sphagnum spp	-	-	17	-
Dicranum scoparium	-	-	-	40
Plagiothecium denticulatum	-	-	-	20

()......number of quadrats recorded.

Table 3. Plant species distribution with differing brash depth on a peaty gley soil at site 7, expressed as pecentage constancy in available quadrats.

Species	no brash(5)	1-5cm(4)	6-20cm(2)	>20cm(2)
Sphagnum spp	100	25	100	-
Deschampsia flexuosa	60	-	50	-
Calluna vulgaris	40	25	-	-
Hypnum jutlandicum	40	25	100	50
Luzula multiflora	40	25	-	-
Plagiothecium undulatum	40	-	-	-
Rhytidiadelphus loreus	40	-	-	-
Agrostis capillaris	20	-	-	-
Bryum spp	20	25	-	-
Calypogeia muellariana	20	-	-	-
Carex pilulifera	20	50	-	-
Dicranella heteromalla	20	50	-	-
Juncus effusus	20	50	50	-
Juncus squarrosus	20	25	-	-
Lophocolea cuspidata	20	-	-	-
Pleurozium schreberi	20	-	-	-
Polytrichum commune	20	-	-	-
Polytrichum formosum	20	-	-	-
Vaccinium myrtillus	20	-	-	-
Campylopus piriformis	-	25	50	-
Dicranum scoparium	-	25	-	50
Holcus mollis	-	-	50	-
Juncus bulbosus	-	-	50	-
Potentilla erecta	-	-	50	-

().....Numbers of quadrats recorded.

Table 4. Plant species distribution with differing brash depth on a peaty gley soil at site 10, expressed as pecentage constancy in available quadrats.

Species	no brash(13)	1-5cm(8)	6-20cm(7)	>20cm(2)
Calluna vulgaris	69	-	-	-
Vaccinium myrtillus	62	63	14	-
Dicranum scoparium	54	38	57	-
Sphagnum spp.	54	13	-	-
Deschampsia flexuosa	46	63	71	-
Molinia caerulea	46	-	-	-
Polytrichum commune	39	50	29	-
Campylopus introflexus	31	-	-	-
Campylopus piriformis	31	25	-	-
Hypnum jutlandicum	31	38	57	100
Eriophorum vaginatum	23	13	-	-
Plagiothecium undulatum	23	50	43	50
Epilobium angustifolium	15	13	71	50
Agrostis capillaris	8	-	-	-
Barbilophozia floerkeii	8	-	-	-
Campylopus paradoxus	8	25	29	-
Carex echinata	8	-	-	-
Dryopteris dilitata	8	-	29	-
Eurhynchium praelongum	8	-	-	-
Juncus squarrosus	8	13	-	-
Lepidozia reptans	8	25	-	50
Lophocolea cuspidata	8	-	43	-
Brachythecium rutabulum	-	13	-	-
Rhytidiadelphus loreus	-	13	-	-
Pohlia nutans	-	-	43	50
Plagiothecium denticulatum	-	-	14	-
Carex nigra	-	-	-	50
Pleurozium schreberi	-	-	-	50

()....number of quadrats recorded.

Table 5. The relationship between Molinia caerulea and Epilobium angustifolium at Site 4 and brash cover, expressed as percentage constancy in the quadrats recorded.

Brash cover (%)	0 - 32	32 - 49	>50
Molinia cearulea	89	50	10
Epilobium angustifolium	67	100	100

Table 6. The distribution of plant species at Site 18, a bench felled site, expressed as percentage constancy in the quadrats recorded.

Species	Stumps	Felling bench	Brash free ground
Epilobium angustifolium	53	88	-
Ceratodon purpureus	37	13	-
Deschampsia flexuosa	37	-	47
Brachythecium rutabulum	33	7	-
Campylopus introflexus	33	10	27
Dicranum scoparium	30	53	7
Calluna vulgaris	23	-	53
Campylopus piriformis	20	20	80
Lepidozia reptans	20	-	10
Pohlia nutans	20	23	10
Hypnum jutlandicum	17	43	-
Eriophorum vaginatum	10	-	57
Eurhynchium praelongum	10	30	-
Agrostis canina	7	-	-
Betula pubescens	7	-	3
Dicranella heteromalla	7	-	-
Anthoxanthum odoratum	3	-	-
Dryopteris dilitata	3	7	3
Polytrichum commune	3	-	-
Hypnogymnae phisodes	-	100	-
Plagiothecium undulatum	-	43	-
Lophocolea cuspidata	-	20	-
Plagiothecium denticulatum	-	20	-
Polytrichum formosum	-	13	10
Campylopus paradoxus	-	7	3
Mnium hornum	-	7	-
Rhytidiadelphus loreus	-	3	-
Juncus squarrosus	-	-	13
Molinia cearulea	-	-	7
Erica tetralix	-	-	3

Table 7. The occurence of species recorded on five cut stumps at Site 3.

Species	Occurences
Campylopus introflexus	4
Polytrichum formosum	4
Epilobium angustifolium	3
Pohlia nutans	3
Brachythecium rutabulum	2
Calluna vulgaris	2
Campylopus piriformis	2
Plagiothecium undulatum	2
Vaccinium myrtillus	2
Campylopus paradoxus	1
Ceratodon purpureus	1
Deschampsia flexuosa	1
Eurhynchium praelongum	1
Hypnum jutlandicum	1

Appendix

Descriptions and notes on the sites visired during this study.

Site 1.

Grid ref. - 659 852, Alt. - 240m, Soil - non-peaty gley, Veg. - MG9a

Opposite where Binky Burn joins Cranecleugh Burn, replanted between 1978 and 1982. Well vegetated with Deschampsia cespitosa but no gradient observed.

Site 2.

Grid ref. - 674 901, Alt. - 200m, Soil - non-peaty gley, Veg. - MG9a

Next to Benny Shanks Jetty - a mature restock, well vegetated with Deschampsia cespitosa, but no gradient observed.

Site 3.

Grid ref. - 699 838, Alt. - 300m, Soil - peaty gley, Veg. - M19a

Near Archy's Rigg, replanted with Sitka Spruce in 1983 and adjacent to an unmanaged Heather moor. Some areas of bare brash, otherwise dominated by Calluna (well past flowering age). No obvious gradient from the edge to the centre. Five random 2x2m quadrats recorded in the middle of the restock. No evidence of plants associated with the road running through the area migrating into the crop (Deschampsia cespitosa, Digitalis, Agrostis canina, Holcus lanatus, H. mollis, Luzula multiflora, Galium saxatile, Juncus effusus and J. squarrosus). A species list recorded from five cut stumps. Very little Epilobium angustifolium here, what there is is associated with brash and cut stumps. No other micro-habitat associations detected.

Site 4.

Grid ref. - 741 761, Alt. - 270m, Soil - varied, Veg. - varied

A complex site (see Figure 2) probably felled for two or three years. Adjacent to a wide fire break leading towards The Haining farm. Along undulating slope, steeper ground without peat, flatter areas with a peaty surface, hollows are wetter with deeper peat. The wide fire break was an actively managed improved pasture. Along the fence line the vegetation of an old ride reflected the soil changes from M19a, through M25a to MG9a.

In the clear-fell area adjacent to the M25a vegetation, five 2x2m quadrats were recorded. The vegetation was patchy with areas of deep brash, very common Epilobium angustifolium, some mossy patches and scattered Molinia tussocks, but no significant overall vegetation cover.

A transect of quadrats recorded from the edge for 100m inwards showed how Agrostis canina and Dryopteris dilitata dissappeared away from the edge, while Molinia and Epilobium angustifolium showed no gradient. Lower brash cover and

denser vegetation near the edge lead us to believe that this was an edge effect where more sun light penetrated to the forest floor when the crop was still standing. Further in Molinia was restricted to where the brash was least thick but that the Epilobium grew even where the brash was thickest. The lack of Dryopteris dilitata away from the edge, along with the dense brash suggest that the crop here was well grown and that very little vegetation survived under the canopy.

A drainage ditch running through the clear-fell had been deepened and was well vegetated both in the ditch and on it's banks. It contained a wide range of species, extras typically including Juncus spp., Sphagnum spp., Carex echinata, Luzula multiflora, Festuca ovina, Anthoxanthum, Salix and Betula spp.. Heaps of soil left after deepening of the ditch remain largely unvegetated, but sometimes have Epilobium angustifolium.

Adjacent to the section of the ride on deeper and wetter peat there was much less brash and extensive Sphagnum cover. The ride exhibited M19a vegetation, and Calluna, Eriophorim vaginatum, Vaccinium myrtillus, V. oxycoccos, Molinia, Erica tetralix and Deschampsia flexuosa were also present in the clear-fell. It seems likely that they had survived throughout the rotation as seed or in a relict condition due to poor tree growth. Very little Epilobiuim angustifolium was found here. No obvious gradients or micro-habitat effects were observed.

Alongside the MG9a vegetation of the section of ride on non-peaty gley soil the crop had been bench felled. The brash free areas were dominated by Deschampsia cespitosa tussocks with Juncus conglometatus and J. effesus as was the ride, except that the ride was much more diverse. The brash covered areas were free of Deschampsia cespitosa but had some Galium saxatile and Epilobium angustifolium. The Epilobium was the only in the clear-fell that did not occur in the ride, it was only seen here in the brashy areas. No obvious gradients were detected.

Site 5.

Grid ref. - 740 880, Alt. - 300m, Soil - varied, Veg. - varied

A large clear-fell area near Green Eye Crags, with variable vegetation cover from Calluna, through Deschampsia flexuosa to D. cespitosa probably reflecting changing soil types. The area was bench felled, with the felling benches largely free of vegetation. No gradients could be seen.

Site 6.

Grid ref. - 742 911, Alt. - 320m, Soil - peaty gley, Veg. - Calluna

A large clear-fell near Pope's Hill. Here the crop was nearing canopy closure, and Calluna was dominant throughout and of flowering age. No gradients were observed.

Site 7.

Grid ref. - 627 885, Alt. - 250m, Soil - varied, Veg. - varied

A very variable clear-fell (see diagram in Figure 1) where felling took place between April and June 1988. This was obviously a site at which the process of recolonization was at an early stage, with large areas of bare ground and scattered seedling plants. The soil varied from non-peaty to peaty gley and the species present reflected the different soil characteristics.

A transect of 30 2x2m quadrats were recorded across an area of chanching soil character (see Tables 1,2 and 3), and a series of ten 2x2m quadrats was used to record the proporions of flowering and non-flowering plants of Deschampsia cespitosa. Many examples of the variation encountered at this site are discussed in the text, but no real evidence of colonization gradients was found.

Site 8.

Grid ref. - 623 902, Alt. - 330m, Soil - deep peat, Veg. - varied

A reasonably well vegetated site felled for several years where Calluna was generally abundant, though young. Some unexplained changes in it's associates were encountered, from Molinia and Erophorum vaginatum to Juncus squarrosus, Carrex echinata and finally Deschampsia flexuosa. Thirty 2x2m quadrats showed how vegetation cover varied with brash depth, but no conclusive evidence of colonization gradients was found.

Site 9.

Grid ref. - 696 852, Alt. - 280m, Soil - peaty gley, Veg. Calluna

Above Elf Kirk Viewpoint. Well marked ridge and furrow but no evidence of species colonizing distinct micro-habitats. No gradient detected.

Site 10.

Grid ref. - 672 863, Alt. - 200m, Soil - peaty gley, Veg - M15d

Station 1404 in the 1987 survey, above Bull Crag Edge, where felling took place over four years ago. A series of 30 2x2m quadrats showed how brash depth affected the diversity of the vegetation, species presence/absence on cut stumps was also recorded. As expected, brash surpressed vegetation, while we found further evidence of the association between Epilobium angustifolium and brash and cut stumps. No gradients were encountered.

Site 11.

Grid ref. - 657 907, Alt. - 200m, Soil - non-peaty gley, Veg. - MG9a

Station 2501 in the 1987 survey, felled for some time but not re-planted. Bench felled, brash free areas were almost completely Deschampsia cespitosa dominated, but the grass was largely absent from the felling benches. Again Epilobium angustifolium was largely restricted to brash and cut stumps. No gradients were observed.

Site 12.

Grid ref. - 639 918, Alt. - 220m, Soil - non-peaty gley, Veg. - sparse

A newly felled, thinned Norway Spruce stand. A largely bare site with a remnant ground flora of Oxalis and Mnium hornum beginning to be augmented by seedlings of various grasses and herbs, especially on disturbed areas of ground. No gradients encountered.

Site 13.

Grid ref. - 674 910, Alt. - 260m, Soil - varied, Veg. - varied

Station 2609 in 1987 survey, below Pithouse Crags. A transect of 30 2x2m quadrats revealed a pattern of Deschampsia cespitosa tussocks on a non-peaty gley soil, with bracken where there were no stumps, Calluna and D. flexuosa on peaty gley soil, and where brash was thickest Epilobium angustifolium, Galium saxatile, Corydalis claviculata and Digitalis. No colonization gradients found.

Site 14.

Grid ref. - 715 924, Alt. - 360m, Soil - deep peaty gley, Veg. - none

South East of Earl's Seat, crop was of Spruce with some pine felled within the last 12 months and adjacent to Calluna/Eriophorum mire. No obvious vegetation, it seems likely that Calluna would originally have been present over the whole area. Digitalis was present on nearby roadsides but no seedlings were found in the clear-fell.

Site 15.

Grid ref. - 716 920, Alt. - 340m, Soil - peaty gley, Veg. - sparse

Down slope of site 14 and felled slightly earlier. The vegetation consisted of a thin, if diverse scattering of seedling over a largely bare bench felled area. We noticed how Calluna and Juncus squarosus seemed to have germinated first where litter had been scraped away leaving bare peat exposed at the surface. Epilobium angustifolium seemed to be associated with cut stumps, but there seemed to be no pattern or gradient in how other species were colonizing the site. There was no sign of Deschampsia cespitosa invading from an adjoining roadside, and significantly no Calluna was present on the roadside.

Site 16.

Grid ref. - 744 823, Alt. - 210m, Soil - peaty gley, Veg. - varied

A large varable site near Rough Side, largely on a shallow peaty gley but some very local disturbed patches without peat. Felling occured in 1986. Galium saxatile dominant over large areas, especially on felling benches, other locally dominant species include Agrostis canina and Juncus effusus. We found

it difficult to account for this variablility, however Epilobium angustifolium was associated with brash, and Deschampsia cespitosa with small peat free patches. No evidence of gradients was detected.

Site 17.

Grid ref. - 775 805, Alt. - 220m, Soil - peaty gley, Veg. - none

Near Pundershaw, a very recently felled clear-fell with no revegetation yet, appart from that in a cleared windthrow area included in the coup. The windthrow area was very confused and heavily disturbed. There were large areas of bare ground with some colonies of Digitalis and Holcus lanatus, and scattered occasoinal specimens of Galium saxatile, Juncus effusus, Luzula multiflora, Molinia, Eriophorum vaginatum amongst others. Dryopteris dilitata was fairly common, especially around blown stumps, while Epilobium angustifolium and Deschampsia cespitosa were very locally present. D. cesitosa was limited to disturbed areas where mineral soil was exposed at the surface, and showed no signs of spreading onto peaty soil. Appart from the Digitalis and Holcus colonies there was no evidence of colonization gradients.

A nearby much older cleared area on a non-peaty gley soil was dominated by Deschampsia cespitosa with Juncus spp., while Digitalis was limited to brashy areas where competition from the tussocky D. cespitosa was greatly reduced.

Site 18.

Grid ref. - 637 925, Alt. - 250m, Soil - peaty gley, Veg. - M15d

Station 2101 in the 1987 survey, bench felled for more than four years ago. Thirty 50x50cm quadrats recorded on each of stumps, felling benches and brash free areas, (see Table 6). No colonization gradients observed, but the micro-habitat effects of the bench felling could be seen clearly. Epilobium angustifolium was limited to the felling benches where it was the only higher plant.

Site 19.

Grid ref. - 677 858, Alt. - 200m, Soil - non-peaty gley, Veg. none

A very recently felled site adjoining the public road along Kielder Water, opposite Bull Crag Peninsula. No vegetation at all was found at this site.

Site 20.

Grid ref. - 757 772, Alt. - 280m, Soil - varied, Veg. - varied

Adjoinig a Calluna/Eriophorum mire near Harelaw. Typical mire species were present on flat peaty ground adjacent to the mire, but where the ground sloped steeply away the vegetation became dominated by Deschampsia cespitosa and the soil changed to a non-peaty gley. The site had been felled for some years and no colonization gradients were observed.

Figure 1. Diagramatic view of Site 7 showing the variability of the vegetation.

D. flexon P.G., Dead sphagnum on P.G., Agrostis on P.G., Galium on P.G., Largely bare P.G.

D. Carp / Juncus / Agrostis flush N.P.G., D. carp / Holcus mollis on N.P.G., Largely bare N.P.G. with D. carp.

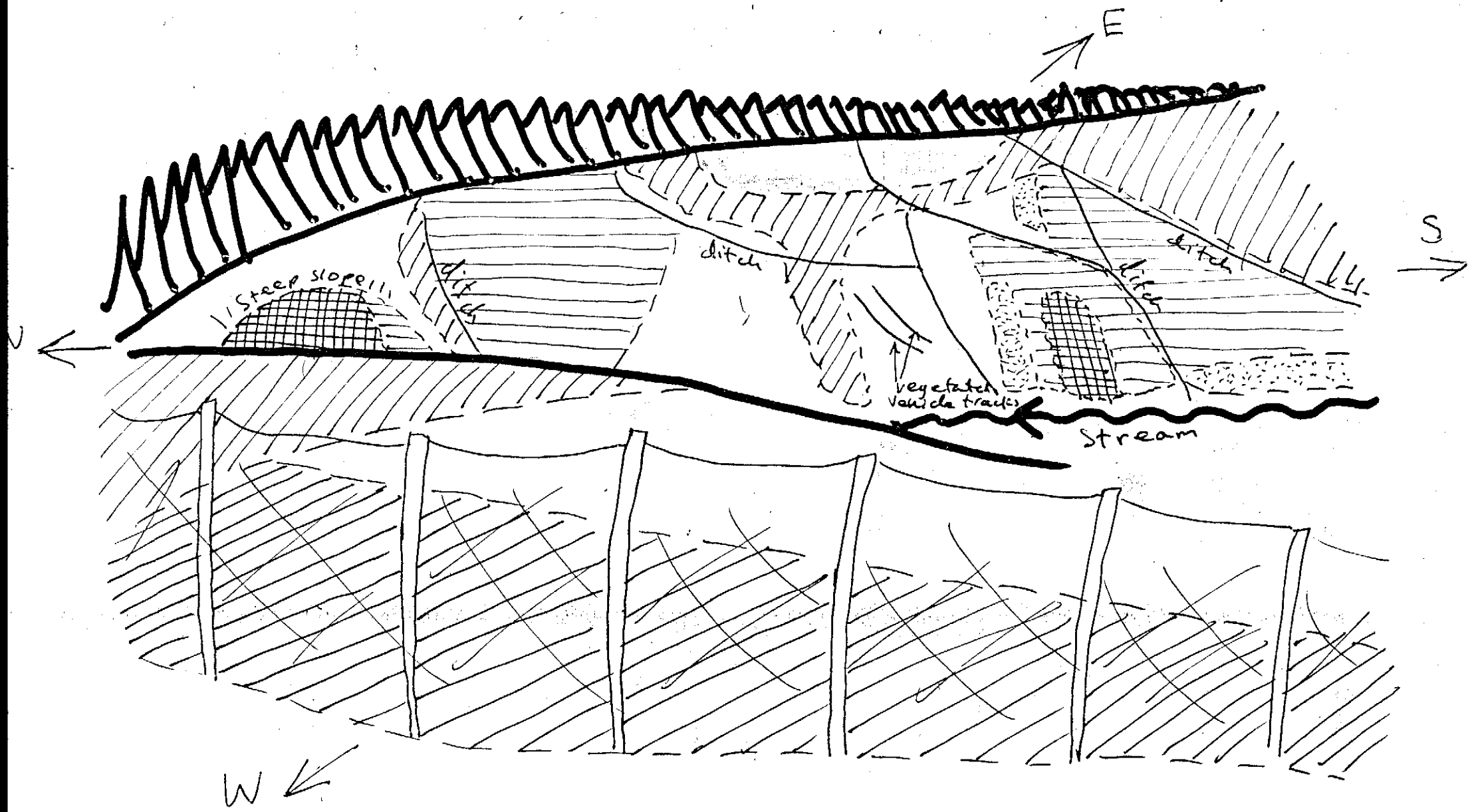

Figure 2 Diagramatic view of Site 4 showing how the vegetation varied with soil type, edge effect and bench felling.