Appendix S1: Vegetation types at Cass

Seven broad vegetation types and the various subtypes within them are identified. For each broad type, the percentage of the total plots that the type comprised is given; this provides an indication of the relative abundance of this vegetation type in the Cass landscape. For each subtype the number of plots and the percentage of the total plots the subtype comprised, is presented. Vegetation and site attributes are given for broad types and subtypes with species richness presented as 10 × 10 m plot means.

A. Grasslands (34.5%): A widespread and common vegetation type with diverse subtypes ranging from dense sward-forming, exotic-dominated (*Agrostis capillaris*, *Anthoxanthum odoratum*, *Festuca rubra*) to more native tussock-rich (*Festuca novae-zelandiae*) grasslands, most with shrub species (*Discaria toumatou*, *Ozothamnus leptophyllus*, *Hebe brachysiphon*, *Leptospermum scoparium*) at varying sizes. Some subtypes most likely represent different stages of shrub invasion (e.g. A.1 to A.2 below). Moderate species richness (30.7 ± 1.8) with moderately low percent native species (56 ± 3%). Associated mainly with lower elevation alluvial terraces and lower hill slopes (611 ± 14 m) on gently sloping (12.5 ± 2.5º), moderately drained sites.

A.1 Dense exotic grassland (*A. capillaris*, *A. odoratum*) with a moderate density of native tussocks (*F. novae-zelandiae*, *Poa colensoi*); matagouri (*D. toumatou*) consistently present at low densities. Sloping (17 ± 4°), well-drained, mid-elevation (684 ± 30 m) sites (n=10 plots, 8.4%).

A.2 Dense exotic grassland (*A. capillaris*, *A. odoratum*) with a low density of native tussocks (*F. novae-zelandiae*), but a high abundance of matagouri (*D. toumatou*). Sloping (13 ± 6°) well-drained low elevation (580 ± 118 m) sites (n=6, 5%).

A.3 Dense exotic grassland (*A. capillaris*, *A. odoratum*) with scattered low-density grey scrub (*Corokia cotoneaster*, *Coprosma propinqua*, *D. toumatou*). Sloping (14 ± 5°) well-drained low-elevation (581 ± 34 m) sites (n=10, 8.4%).

A.4 Dense exotic grassland (*A. capillaris* with minor *Festuca rubra*) and wetland species (*Schoenus pauciflorus*). Flat (6 ± 2°), moderately-drained, low-elevation (591 ± 7 m) sites (n=11, 9.2%).

A.5 Grassy herbfield (*Pilosella officinarum*, *A. capillaris*, *Racomitrium lanuginosum*, sparse *F. novae-zelandiae*, *P. colensoi*, *A. odoratum*) with a diverse native grass, herb and prostrate shrub component. Gently sloping (13 ± 6°), well-drained, southeast facing sites at low elevation (603 ± 146 m) (n=4, 3.4%).

B. Mixed shrublands (21.8%): Mixed shrubland consisting of predominantly native grey-scrub species and less commonly *Hebe* species and *O. leptophyllus*. A widespread and common vegetation type with diverse subtypes ranging from dense simple *D. toumatou* stands through to mixed assemblages where several shrub species dominate (*D. toumatou*, *C. cotoneaster*, *C. propinqua*, *O. leptophyllus* and *H. brachysiphon*). Exotic grasses (*A. odoratum* and *A. capillaris*) and locally, *Pteridium esculentum*, occur between the shrubs. High species richness (40.0 ± 2.4) with moderately low percent native species (61 ± 3%). Associated mainly with lower-elevation (665 ± 24 m) steeper hill slopes (28.7 ± 2.6º) on well-drained sites.

B.1 Dense *D. toumatou* shrubland with a minor component of *C. propinqua*; exotic grasses (*A. capillaris*, *A. odoratum*) dominant in gaps. Well-drained, steep sloping (29 ± 5º) sites at the base of hills (630 ± 19 m) (n=9, 7.6%).

B.2 Dense mixed grey shrubland (*C. cotoneaster*, *D. toumatou*, *C. propinqua*) with *H. brachysiphon*. Mid-elevation (738 ± 43 m) faces and gullies (30 ± 3º), mostly northwest facing with high broken rock cover (n=9, 7.6%).

B.3 Sparse grey shrubland (*C. cotoneaster*, *D. toumatou*, *C. propinqua*) with *P. esculentum* understory; exotic grasses (*A. capillaris*, *A. odoratum*) in gaps; sparse *Pittosporum tenuifolium*. Very steep (41 ± 4º), low elevation (565 ± 24 m), north facing sites at the base of hill slopes (n=3, 2.5%).

B.4 Dense *C. propinqua* shrubland with some *D. toumatou* and a strong vine element (*Muehlenbeckia complexa*, *Rubus schmidelioides*). Mid-elevation (656 ± 78 m), moderately sloping, well-drained sites (n=5, 3.4%).

C. Mānuka shrublands (9.2%): *Leptospermum scoparium* dominated shrubland forming a dense canopy above a sparse understorey. Other shrubs (*D. toumatou*, *O. leptophyllus*, *C. cotoneaster*, *C. propinqua*), exotic grasses (*A. capillaris*, *A. odoratum*), native tussocks (*F. novae-zelandiae*, *P. colensoi*) and native and exotic herbs occur at low densities in canopy gaps. High total species richness (38.5 ± 1.6) with moderately high percent native species (76 ± 2%). Mid-elevation (747 ± 49 m) sites on well-drained steep slopes (22.5 ± 3.7º).

D. Mountain beech forest (3.4%): *Fuscospora cliffortioides* forest with a dense canopy cover and very sparse, mostly native shrub and herb understory. Characterised by adult or regenerating trees with a species-poor understorey (but richer in gullies). Low total species richness (18.8 ± 4.6) but high percent native species (91 ± 4 %). Restricted to small mid-elevation (726 ± 29 m) remnants on mostly steeply sloping sites (25.8 ± 10.6º) centered on gullies. Even though small, these forests are similar in composition and structure to the more extensive mountain beech forests in the adjacent Craigieburn Range.

E. Gorse shrubland (3.4%)

E.1 Exotic gorse (*Ulex europeaus*) shrubland with some *Cytisus scoparius* and minor tall rank exotic grasses (*Holcus lanatus*, *Dactylis glomeratus*). Very low total species richness (14.5 ± 2.2) and percent native species (25 ± 13%). Low elevation (512 ± 12 m), level sites on alluvial terraces.

F. Wetlands (5.0%): Diverse assemblages of moisture-tolerant species occurring on moderate to poorly drained sites at low elevations (560 ± 14 m) on mostly flat to gently sloping sites. While *S. pauciflorus* is a common species across these plots, species assemblages differ considerably between the wetland subtypes and species richness statistics are given for each of the subtypes. (Note: several important but localised wetland subtypes were by chance not covered in the plot grid sampling system, but are discussed later).

F.1 *Carex coriacea* wetland with a strong exotic grass and herb component (*Lotus pedunculatus*, *A. odoratum*). Medium total species richness (24.0 ± 2.0) and low percent native species (38 ± 16 %). Low elevation (565

± 0 m) flat, moderately-drained sites (n=2, 1.7%).

F.2 *Phormium tenax* - *S. pauciflorus* wetland. High total species richness (45.0 ± 6.0) and medium percent native species (66 ± 7 %). Low elevation (565 ± 30 m), gently sloping, poorly-drained sites (n=2, 1.7%).

F.3 *Schoenus pauciflorus* wetland with exotic grasses (*A. capillaris*, *A. odoratum*) and regenerating *L. scoparium*. High total species richness (39.5 ± 6.5) and medium percent native species (61 ± 6 %). Low elevation (552 ± 44 m) gently sloping, poorly-drained sites (n=2, 1.7%).

G. Subalpine shrubland, grassland and herbfield (18.5%): A diverse mix of higher-elevation sites comprising low-growing native shrubs, native herbs and grass species. *Celmisia spectabilis* present in all plots, with *P. colensoi*, *A. odoratum*, *Gaultheria depressa* and *Blechnum penna-marina* occurring in most plots. Lower-elevation subtypes consist of dense, short hebe-dracophyllum dominated shrubland interspersed with native herbs and native and exotic grasses while higher-elevation subtypes consist of prostrate subalpine shrubs (*Podocarpus nivalis*, *Myrsine nummularia*), and/or a rich native herb and grass element. Tall tussocks (*Chionochloa* species) represent a degraded component of the vegetation due to ongoing grazing pressure. High total species richness (38 ± 2.3) with high percent native species (83 ± 1%). Associated with high elevation (1032 ± 27 m), rocky hill country on steeply sloping (32.8 ± 2.5º), well-drained sites.

G.1 Open *H. brachysiphon* - dracophyllum (*D. uniflorum*, *D. longifolium*) - *O. leptophyllus* shrubland with a strong moss, native grass and herbaceous component (*R. lanuginosum*, *P. colensoi*, *C. spectabilis*). Found on steep, rocky, well-drained sites at high elevations (996 ± 8 m) (n=7, 5.9%).

G.2 Dense *H. brachysiphon* dominated shrubland; other shrubs (mostly *O. leptophyllus*) form only a minor component. Exotic grasses (*A. capillaris*, *A. odoratum*) and *C. spectabilis* common. Steep, well-drained sites at mid-high elevations (860 ± 33 m) (n=4, 3.4%).

G.3 *Coriaria sarmentosa* dominated with sparse mixed shrubland species (*H. brachysiphon*, *D. longifolium*, *L. scoparium*, *O. leptophyllus*). High elevation sites (1000 ± 40 m) on steep rocky slopes with high bare ground cover (n=3, 2.5%).

G.4 Dense *P. nivalis* shrubland with *M. nummularia* and sparse, short *H. brachysiphon*. Rocky, high elevation (1183 ± 84 m), west-facing sites n=3, (2.5%).

G.5 Degraded tall tussock grassland - herbfield (*C. spectabilis* and *G. depressa* dominant); less abundant *P. colensoi* and snow tussock (*Chionochloa macra*, *Chionochloa pallens*). High elevation (1150 ± 24 m), steep sloping sites with a south to east aspect (n=5, 4.2%).

Appendix S2: Species richness in the Cass flora

One feature of the current vegetation at Cass is a surprisingly high total vascular plant species richness (370 species), with a strong dominance of native species (73% of species and 76% of total abundance). As one comparison, 574 species were recorded from the 70,700 ha Aoraki Mt Cook National Park (AMCNP), of which 76% are native (Wilson 1976). Given the small area of Cass (1775 ha) and the limited elevational range (480–1359 m) compared with the size and elevational range (600–3724 m) of AMCNP, total vascular plant species richness, especially native richness at Cass is high (270 cf. 436 native species at AMCNP). Even though creating a full species list was not the goal of this study, our grid-based sampling design was able to detect 80% of the vascular plant species known from Cass based on wider botanical surveys (http://www.biol.canterbury.ac.nz/cmra-checklist/).

Despite being a small area, the high species richness at Cass is likely due to a range of factors including topographic diversity (especially aspect and landform), a mix of western and eastern floristic elements, and the nearly 800-year impact of humans on the environment. One consequence of human impacts is the presence of species typical of both higher (subalpine) and lower elevations co-occurring across different vegetation types. This pattern was also apparent in the 1950s when Burrows (1960) commented that several species typical of subalpine vegetation were present through lower elevation grasslands and shrublands at Cass. This is still the case today with species such as *Gaultheria depressa*, *Racomitrium languinosum* and *Anisotome aromatica* widespread through low-elevation grassland, especially where *Agrostis capillaris* cover is low. Burrows (1960) attributed this mixing of floristic elements to the loss of extensive *Fuscospora cliffortioides* forest due to burning, allowing species that did not previously co-exist to migrate into novel vegetation types that formed after disturbance. This pattern has been further confounded by the more recent invasion of exotic species.

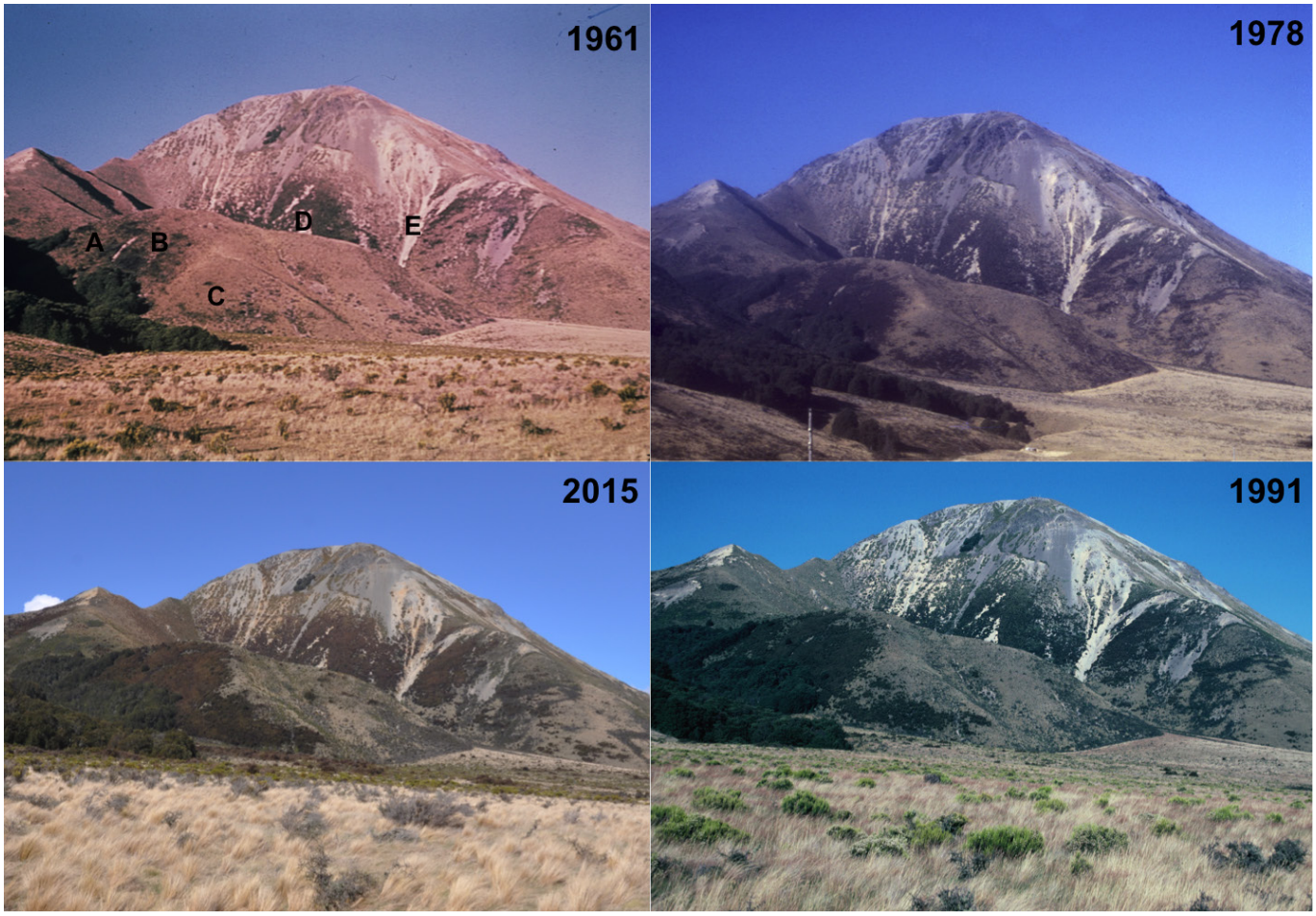
References

Burrows CJ 1960. Recent changes in vegetation of the Cass area of Canterbury. New Zealand Geographer 16: 57–70.

Wilson HD 1976. Vegetation of Mt Cook National Park. National Parks Authority Scientific Series No. 1. 138 p.

Appendix S3: Woody vegetation expansion

While there are no permanent vegetation data from Cass to quantify the expansion of woody vegetation over the period considered in this study, there is a reasonable photographic record that allows for qualitative assessment of change. The following example shows the view from the Cass field station towards Sugarloaf from 1961–2015 (54 years) and highlights the continuous process of woody vegetation expansion. The areas indicated by letters A–E on the 1961 image appeared devoid of woody vegetation in Foweraker's 1914 photo (Figure 6). By 1961, sparse woody vegetation is present at A, B, C and on both sides of the slip at E, while the area at D supported a continuous cover of woody vegetation (*Leptospermum scoparium* is the species present at these sites today). By 1978 the woody cover at B was continuous, while that present at A, C and E was thicker than in 1961 but not continuous. Woody vegetation continued to thicken at these sites through to 1991, but is still not continuous, while woody vegetation at B continued to expand outwards. By 2015, area A, B and C formed a solid block of *L. scoparium* shrubland and apart from the gully at E, *L. scoparium* shrubland is also continuous across the flanks of Sugarloaf from D to E. Permanent plots have now been established (2013–2015) at Cass which will allow for long-term change of future vegetation to be quantified (LY & DN unpubl. data).



Sugarloaf (the central peak in the photo) viewed from near the Cass field station. 1961 photo by C. Mackintosh, other photos by D. Norton.