

The use of native turf transplants for roadside revegetation in a subarctic area

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ABSTRACT

Most road construction projects involve roadside revegetation to control soil erosion and improve road aesthetics. Using native species for roadside revegetation may reduce biodiversity losses and maintenance costs compared to traditional seeding of fast-growing species. We assessed the transplantation of large (> 50 cm diameter), fresh turfs for the revegetation of road verges at a high-elevation subarctic site in SW Iceland by comparing their vegetation composition to adjacent heathland. The road verges had 65% of the vegetation cover of adjacent heathland after two years and 93% after five years. Vascular heathland species had 85% transplant success after five years, but grasses were more abundant in the road verges than the heathland. The most common moss and lichen species survived the transplantation, but with reduced cover compared to the heathland. Thus, transplantation of fresh turfs can quickly establish vegetation cover and diverse plant communities, although the relative abundance of some species may diverge from the donor sites.

Keywords: Biodiversity, ecological restoration, heathland, Iceland, vegetation dynamics

YFIRLIT

Nýting á stórum gróðurtorfum við uppgræðslu vegfláa á hálendi

Uppgræðsla vegfláa er yfirleitt fylgifyskur vegagerðar. Hlutverk uppgræðslunnar er að draga úr rofi og fella vegina betur að umhverfi sínu. Notkun staðargróðurs við uppgræðslu vegfláa getur dregið úr umhverfisáhrifum og viðhaldskostnaði samanborið við hefðbundnar aðferðir er byggja á sáningu fljótsprottinnu tegunda. Við mátum árangur af uppgræðslu á Helligshéiði — þar sem stórar, ferskar gróðurtorfur úr vegstæði voru fluttar í vegfláa — með því að bera saman gróðurfur í vegfláanum og aðliggjandi mólendi. Eftir tvö ár var heildarþekja vegfláans 65% af þekju mólendisins og 93% eftir fimm ár. Eftir fimm ár fundust 85% af háplöntutegundum mólendisins í vegfláanum en þekja grasa var umtalsvert hærri í vegfláanum. Algengustu mosa- og fléttutegundir mólendisins fundust einnig í vegfláanum, þó þekja þeirra væri þar umtalsvert lægri en í mólendinu. Niðurstöðurnar benda til þess að uppgræðsla með tilfallandi gróðursverði stuðli að hraðri endurheimt fjölbreyttra plöntusamfélaga, þó að þekja einstakra tegunda geti orðið nokkuð frábrugðin því sem gerist á gjafasvæðunum.

INTRODUCTION

Roads are an important component of modern landscapes. They have wide-ranging environmental impacts, including degradation of indigenous vegetation and habitat fragmentation, biodiversity loss, soil erosion, reduced

landscape aesthetics, and traffic noise. (e.g., Forman & Alexander 1998, Petersen et al. 2004, Coffin 2007). Road verges and other areas disturbed by road construction are commonly revegetated in order to control soil erosion and to improve road aesthetics (Skrindo &

Halvorsen 2008). Fast-growing species that provide quick cover and control erosion are traditionally used for the revegetation (e.g., Karim & Mallik 2008). Often these species are non-native and can contribute to loss of biodiversity or even become invasive (Tinsley et al. 2006), although in some cases they facilitate colonization of local plant species (Magnússon 1992). Furthermore, road verges are commonly maintained as “lawns” by intensive inputs, such as fertilization, mowing and use of herbicides (Harper-Lore 1996), with associated environmental and monetary costs.

A need for a more ecological approach in roadside policy has long been recognized in order to mitigate some of the adverse effects of road construction and use, reduce maintenance costs and improve roadside aesthetics (Harper-Lore 1996, Steinfeld et al. 2007, Karim & Mallik 2008, Skrindo & Halvorsen 2008). Such an ecological approach often involves the establishment of locally native plant species on areas disturbed during road construction, offering greater ecological benefits than seeding of non-native species (Skrindo & Pedersen 2004, Tinsley, et al. 2006, Bochet et al. 2010).

Locally native species can potentially be established by: (a) seeding and/or planting (Mallik & Karim 2008), (b) transfer of seed-containing hay from native vegetation (Kiehl et al. 2010), (c) transfer of seed-containing topsoil (Skrindo & Halvorsen 2008, Kiehl, et al. 2010), (d) transfer of whole turfs from native vegetation (Bay & Ebersole 2006, Aradottir 2012), and (e) spontaneous colonization of native species from neighbouring areas (Bochet et al. 2007). The choice of methods and species assemblages depends on a number of factors, such as site conditions and adjacent vegetation communities and the availability of seed, turfs or seed containing hay, but also on roadside policies and traditions as well as scientific and technological knowledge. An improved understanding of the advantages and shortcomings of each method under different conditions should facilitate ecological approaches to roadside revegetation and aid their

design. Revegetation experiments are essential in this regard, but monitoring of actual revegetation projects can also give valuable information.

Revegetation by transplantation of turfs of native sward salvaged from areas disturbed by road construction and mining, for example, can quickly establish diverse plant communities, although the vegetative composition following transplantation commonly diverges from that of the donor sites (e.g., Bullock 1998, Bruelheide 2003). Transplant survival may range from 50 to 100% of species at the donor sites (reviewed by Kiehl, et al. 2010). Furthermore, transplants usually contain a number of species, including moss and lichen species that are infrequently included in revegetation projects. Transfer success, however, depends on many factors, including growth form, turf size and conditions at the receptor sites (Aradottir 2012). The aim of our study was to evaluate the transplantation of large, fresh turfs from local vegetation into road verges at a high-elevation subarctic site in SW Iceland after two and five years. Our main objectives were to assess the transplantation success of heathland species and answer whether the vegetation composition of revegetated road verges converges with or diverges from the surrounding local vegetation with time.

MATERIALS AND METHODS

Site description

The study was carried out at Hellisheiði, SW Iceland (64°00' N, 21°20' W), elevation 350 m, along an approximately 900 m long gravel road to a drilling platform belonging to the Hellisheiði geothermal power plant. The contractor building the road was instructed to minimize disturbance to the nearby vegetation and transfer a part of the natural sward from the roadbed and the drilling platform in order to revegetate the road verges (Herdís Friðriksdóttir, personal communication). The fresh turfs were transferred in May and June 2007. The road verges had a gravelly surface, were

1.5 m wide (± 0.05 m SE) and had mostly a 15–20° inclination. As the turf transplantation was part of an actual revegetation measure and not an experiment, neither the turf size nor turf density was standardized or measured at the time of transfer. Based on photographs from the turf transfer and observations in 2009, the turf/receptor area ratio ranged mostly from 1:2 and 1:1, but was lower in some places. The turf sizes varied considerably, but were usually over 50 cm in diameter. Turf thickness also varied greatly because the site had a hummocky surface; photographs and site observations indicate that this ranged from 10 to 50 cm. The turfs were put directly on top of the gravel of the verges. The road verges have not received any additional treatment, but clearing of snow during winter caused relocation of some gravel from the road to the verges (Herdís Friðriksdóttir, personal communication).

The vegetation at the site was characterized by hummocky moss and grass heath (Guðjónsson et al. 2005), with a substantial component of mosses and lichens and intermittent erosion spots. At an automatic weather station 2.5 km NNW of the site (elevation 370 m), the average annual precipitation for 2001–2011 was 2296 mm and the average monthly temperature was highest in July, 9.2°C, and lowest in February, -2.2°C (Icelandic Meteorological Office, unpublished data).

Assessment of vegetation composition

Transect pairs were established at three random positions along an approximately 400 m stretch of the road. At each position 50 m fixed transects were laid out on both sides of the road along the junction between road verge and undisturbed heathland. At five random points on each transect, the vegetative cover was estimated in two 0.5 x 0.5 m quadrats. One of the quadrats at each point was located in the centre of the road verge, unrelated to the placement of individual turfs, and the other in the native heathland vegetation, 2 m from the transect. We estimated total vegetative cover,

cover of individual vascular plant species and the most abundant moss and lichen species in the quadrats, using the following scale: 1: <1%, 2: 1–5%, 3: 6–10%, 4: 11–15%, 5: 16–25%, 6: 26–50%, 7: 51–75% and 8: 76–100%. The vegetative cover was surveyed on 14–15 July 2009 and 23–24 August 2012, two and five years after revegetation of the road verges.

Data analysis

Cover scores were transformed to percentages by using the central value of each cover class. Location within transects was used as the unit of study and hence all statistical analysis was performed on values averaged over the five quadrats at each location (road verge and heathland) within transect.

We used ANOVA (Generalized Linear Models) to test the effect of location and aspect (northwest vs. southeast) on vegetation parameters within each year (2009 and 2012), using a split-plot design with aspect as a whole-plot effect and location as a split-plot effect. Vegetation parameters tested included total vegetative cover, species richness and sum of cover of all species within each growth form. ANOVA for repeated measures was used to test the interactive effects of location, aspect and year on these same parameters. Cover of lichens was square-root transformed to meet the assumptions of equal variances and normal distribution of residuals, but back-transformed mean values are presented.

Unconstrained PCA ordination was performed on the average cover of vascular plant species in all transects measured in 2009 and 2012. Species occurring in fewer than three transects were not included in the analysis. We used constrained RDA (redundancy analysis) with Monte Carlo permutation tests (999 permutations) on the species cover data for each year, 2009 and 2012, to test the effects of location and aspect, using the transects as covariates. SAS 9.2 for Windows (SAS Institute Inc., Cary, NC, USA) was used for the ANOVAs, but the PCA and RDA analysis were carried

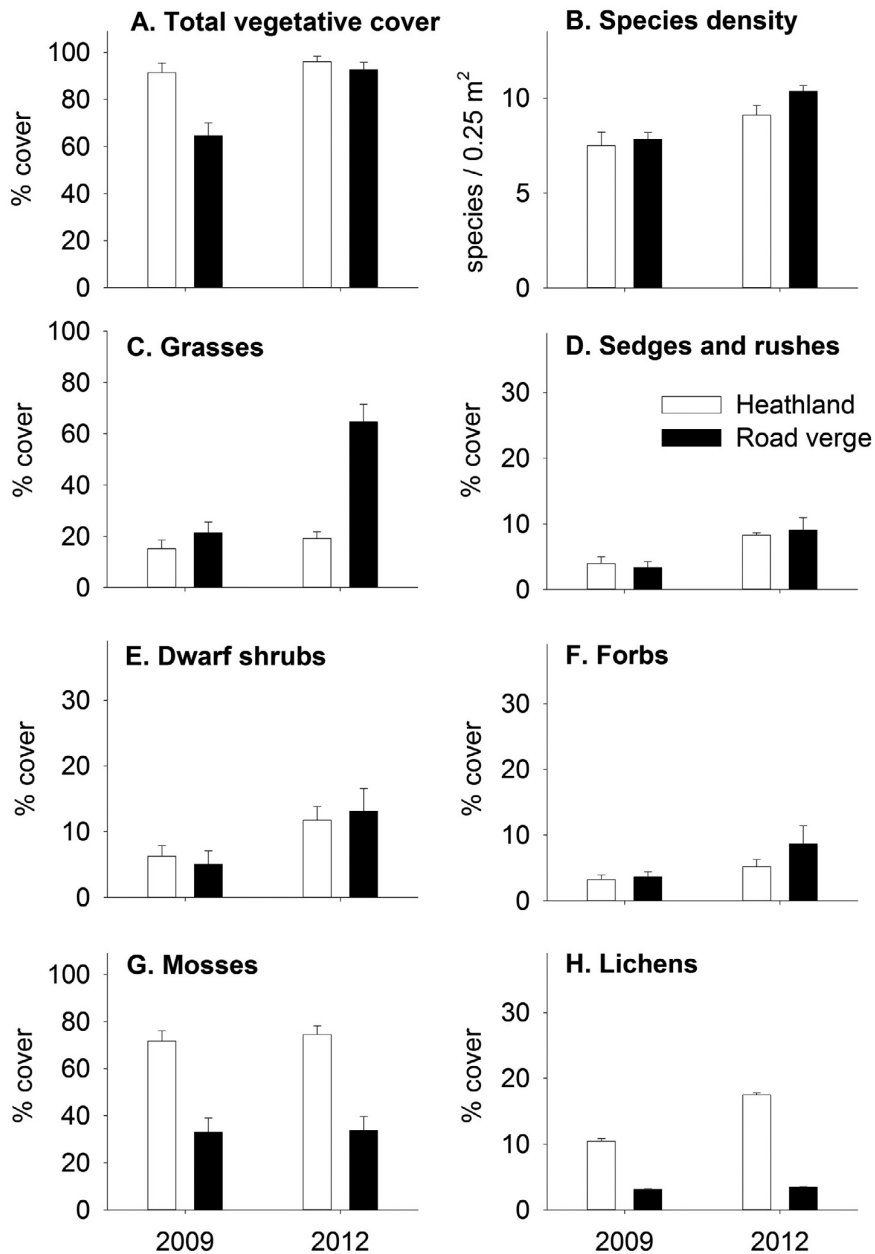


Figure 1. (A) Total vegetative cover, (B) density of vascular plant species and (C-H) percent cover (mean and 1 SE) of different species groups in road verges and adjacent heathland averaged over both aspects (northwest and southeast) (N=6). Note that the scale on the Y axis varies among species groups.

out with CANOCO 4.5 (ter Braak & Smilauer 2002).

RESULTS

Total vegetative cover in the road verges was significantly lower than in the adjacent heathland in 2009 ($F=12.8$, $P=0.023$), but had increased in 2012 when this difference was not significant (Figure 1A). The average density of vascular plant species increased slightly between 2009 and 2012, but the effect of location (road verges vs. heathland) was not significant (Figure 1B, Table 1). The cover of grasses was higher on the road verges than in the adjacent heathland in 2009, and had tripled on the road verges in 2012 while remaining similar in the heathland (Figure 1C), accounting for both the significant main effects and the interaction between location and year (Table 1). The cover of sedges and rushes, forbs and dwarf shrubs was not significantly affected by location, but increased slightly between 2009 and 2012 on both the road verges and in the heathland (Figure 1 D-F, Table 1). On the other hand, the cover of mosses was consistently lower on the road verges than in the heathland (Figure 1G). The same pattern applied for lichens (Figure 1H), but the difference was only significant in 2012 ($F=8.5$, $P=0.044$), accounting for a significant interaction between location and year (Table 1). Aspect did not have a signi-

ficant effect on any of the vegetation parameters measured, but there was a weak interaction between aspect and location for mosses (Table 1).

Among individual species, the difference between road verges and heathland was greatest for the grasses *Avenella flexuosa* (L.) Drejer, *Festuca richardsonii* Hooker, *Festuca vivipara* (L.) Sm and *Agrostis vinealis* Schreb, which were all more abundant on the road verges in 2012. The other vascular plant species with higher cover on the road verges than in the heathland in 2012 were *Luzula spicata* (L.) DC., *Salix herbacea* L., *Empetrum nigrum* L., *Taraxacum* spp. and *Raununculus acris* L. On the other hand, the cover of *Galium verum* L. and *Carex bigelowii* Torr. Ex Schwein. was considerably lower on the road verges than in the heathland. Three of the 27 vascular plant species found in the heathland were never reported on the road verges: *Silene acaulis* (L.) Jacq., *Omalotheca supina* (L.) DC. and *Anthoxanthum odoratum* L., but they were all rare in the heathland. Furthermore, *Viola palustris* L. was reported in the heathland in both 2009 and 2012, and on the road verge in 2009 but not in 2012. Conversely, *Luzula multiflora* (Retz.) Lei., *Salix arctica* Pall., *Potentilla crantzii* (Crantz) G. Beck ex Fritsch., *Thymus praecox* Opis subsp. *arcticus* (E. Durand) Jalas and *Veronica* sp. found on the road verges in

Table 1. Repeated analysis of variance of location (road verge or heathland) and aspect effects at Hellisheiði, SW Iceland in 2009 and 2012. *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$; ns=not significant.

	Aspect (A)	Year (Y)	Location (L)	A*Y	A*L	Y*L	A*Y*L
Df for F tests	F (1, 2)	F (1, 8)	F (1, 4)	F (1, 8)	F (1, 4)	F (1, 8)	F (1, 5)
Species density	ns	46.6***	ns	ns	ns	ns	ns
Total vegetation cover	ns	25.8***	12.4*	ns	ns	13.4**	
% cover of:							
grasses	ns	81.2***	85.4***	ns	ns	56.3***	ns
sedges and rushes	ns	28.5***	ns	ns	ns	ns	ns
forbs	ns	6.7*	ns	ns	ns	ns	ns
dwarf shrubs	ns	22.0**	ns	ns	ns	ns	ns
mosses	ns	ns	103.5***	ns	10.7*	ns	ns
lichens	ns	10.0**	ns	ns	ns	6.5*	ns

2012 were not reported in the heathland in either year. *Racomitrium lanuginosum* (Hedw.) Brid. and *Racomitrium ericoides* (Brid.) Brid. were by far the most common moss species in both locations, but their combined cover on the road verge was only about half of what it was in the heathland. *Cladonia arbuscula* (Wallr.) Flot was the most common lichen species and *Cetraria islandica* (L.) Ach. came in second, but the cover of both species on the road verges was only about a quarter of what it was in the heathland.

PCA ordination showed very similar vascular species composition on the road verges and in the adjacent heathland in 2009, but in 2012 the species composition had diverged, especially along the first ordination axis, which explained much greater variation than the second axis (Figure 2). The difference in species composition between road verges and heathland was not significant in 2009 but had become highly significant in 2012, while the effects of aspect were not significant in either year (Table 2).

DISCUSSION

Five years after revegetation of road verges by transfer of turfs from local native vegetation, 23 out of the 27 vascular plant species found in the adjacent vegetation were reported on the road verges. As the turfs were salvaged from the roadbed and the site of the nearby drilling platform, we assume that the species composition of the adjacent heathland vegetation is representative of the turfs used for revegeta-

tion. The transfer success of 85% for vascular plant species after five years is comparable to the results of other studies (see review by Kiehl, et al. 2010). The heathland species not reported on the road verges in 2012 were all rare in the heathland (<0.2% cover), but rare species are less likely than common ones to be successfully transferred with whole turfs (Buckner & Marr 1988, Aradottir 2012). The missing species may not have been transferred with the turfs to the road verges; they may have been transferred but did not survive; or they may have been successfully transferred but our sample size was too small to detect them. The most common moss and lichen species of the heathland were successfully transferred with the turfs, although their cover was much reduced (Figure 1 G-H). As we only recorded the most abundant moss and lichen species, we cannot estimate the transfer rate of mosses and lichens in general.

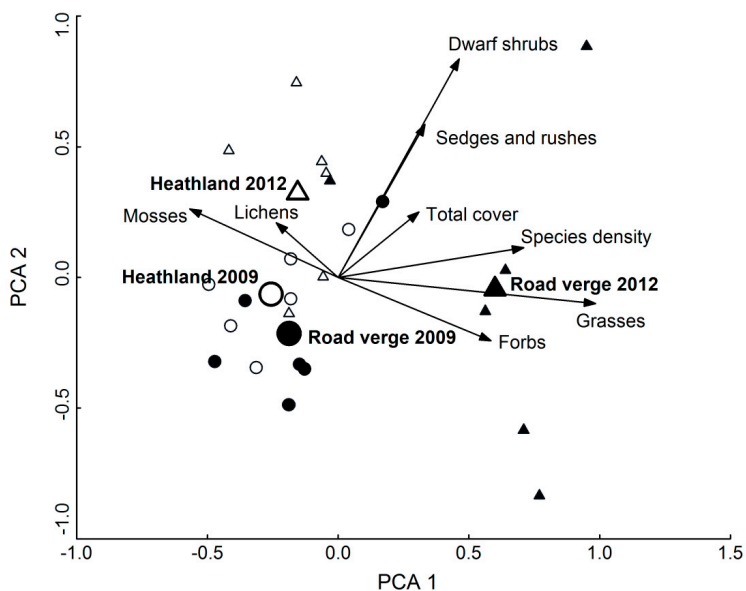


Figure 2. Ordination diagram of first and second PCA axis; the eigenvalue for PCA 1 equals 0.695 and the eigenvalue for PCA 2 equals 0.136. Small symbols show location within individual transects, large symbols show centroids of locations within a year. Filled symbols = road verge; open symbols = heathland, circles = 2009 measurements, triangles = 2012 measurements. Vectors indicate correlation of species groups with the first two PCA axes.

Table 2. Results of constrained redundancy analyses (RDA) on the cover of vascular plant species in 2009 and 2012. Shown are Monte Carlo permutation tests of the first ordination axis and percent of explained variance in the data.

Independent variables	Covariables	2009			2012		
		%	F	P	%	F	P
Location and aspect	Transect	14.2	1.71	0.092	55.5	6.6	0.001
Location	Transect and aspect	8.1	2.04	0.099	51.4	12.2	0.002
Aspect	Transect and location	6.1	1.50	0.187	4.1	1.0	0.433

Two years after revegetation of the road verges, their vascular species composition was very similar to the heathland (Figure 2). After five years, the vascular species composition of the road verges had diverged from the heathland, mainly due to a great increase in grass cover (Figure 1C). This was probably due both to the colonization of grasses in the spaces between the turfs and the tillering of grasses in the turfs and at their edges (cf. Aradottir 2012), as the increase in grass cover (from 21 to 65%) exceeded the increase in total vegetative cover (65 to 93%). Such an increase in grass abundance has commonly been reported after turf transplantation (see e.g., Bay & Ebersole 2006, Cole & Spildie 2006, Trueman et al. 2007, Aradottir 2012). The disturbance associated with turf transplantation can accelerate mineralization and hence nutrient supply (Bruehlheide 2003), but grasses are the functional group responding most rapidly to nutrient additions in arctic and alpine areas (Graglia et al. 2001, Gough et al. 2002, Kelley & Epstein 2009, Aradottir et al. 2010). If increased nutrient supply is responsible for the observed response of grasses in our study, this trend could possibly be reversed to some degree with time.

A few species found on the road verges in 2012 were not reported in the heathland. Some probably colonized from seed in the propagule bank of the turfs, such as *Thymus praecox* and *Luzula multiflora*, which have been reported in heathland seed banks (Gudmundsson 2008) and in a related study *L. multiflora* colonized readily from shredded turfs (Aradottir 2012). On the other hand, *Salix arctica* with its short-lived seed more likely colonized from wind

dispersed seed (cf. Svavarsdottir 2006).

A significantly lower cover of mosses and lichens on the road verges compared to the adjacent heathland could have been caused by physical damage during the transplantation and/or adverse growing conditions on the road verges. The negative effects on mosses were much larger than observed in a recent experiment at Hellisheiði (Aradottir 2012) where the turfs were transferred by hand; but at our study site the turfs were transferred by large machinery. Other contributing factors may be road dust, which has an adverse effect on some moss and lichens species (Walker & Everett 1987), and disturbances associated with clearing the snow from the road during winter.

Revegetation by large turfs at Hellisheiði led to much faster recovery of the vegetative cover and native species than traditional revegetation by seeding and fertilization (Magnússon 1992). Visually, the revegetated road verges blended well with the adjacent heathland vegetation, although grasses were more prominent on the road verge. This was not only due to the similarities in vegetation composition, but also because of the irregular thickness of the turfs transferred to the road, thus contributing to surface roughness on the road verge that harmonised with the hummocks of the heathland. Such roughness is preferable to the smooth road verges frequently left by contractors that often discord with natural surroundings and may hamper plant establishment (Steinfeld, et al. 2007).

Species density on the road verge was comparable to experiments using a much lower turf to receptor area ratio (1:22 and 1:50; Aradottir 2012), but recovery of the vegetative cover

was predictably much faster using a turf/receptor area of 1:2 to 1:1. Thus, large turfs and a high turf/receptor area ratio can have advantages over smaller turfs and a lower turf/receptor area ratio. On the other hand, the availability of salvaged turfs may be limited and disturbance of natural vegetation for turf extraction is generally not acceptable. Thus, transferring turfs with a lower turf/receptor ratio to accelerate the establishment of native species—perhaps in combination with more traditional revegetation methods to prevent erosion—may be preferable if salvaged turfs are in short supply (cf. Aradóttir 2012).

CONCLUSIONS

The use of large fresh turf transplants for revegetation of road verges provided quick vegetative cover and establishment of many native species that would be expected to colonize road verges slowly after traditional revegetation by grass seed and fertilizers. The vascular species composition of the revegetated road verges diverged from the adjacent heathland vegetation between two and five years after the turf transplantation, primarily as the abundance of grasses on the road verges increased. Aside from that, the overall species composition was in many ways similar to the adjacent heathland and no exotic or weedy species gained a foothold on the road verge during the five years of the study. Thus, the turf transfer promoted conservation and restoration of local biodiversity on the road verges.

Our results confirm the value for roadside restoration of turfs salvaged from roadbeds and other areas disturbed during road construction. The potential to salvage and use such material should be considered in the planning of all road construction.

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