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AGRONOMY, SOILS, AND ENVIRONMENTAL QUALITY

Plant Species Diversity of Naturalized Roughs as Affected by Conversion Strategies

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ABSTRACT

Golf courses can be characterized as plant communities with a simplified botanical composition. Improving roughs to achieve more naturalized areas can help to enhance the botanical biodiversity on golf courses. A 3-yr study was conducted in a Mediterranean climate zone with the objectives of investigating the botanical composition of naturalized roughs by analyzing species richness and effective species number, and assessing the effectiveness of different cultural practices to increase biodiversity. Two sites dominated by either *Elytrigia repens* (L.) Nevski (Site 1) or by *Festuca rubra* L. (Site 2) were selected for the study. Three management practices were randomly assigned to plots within each site in May 2013: (i) mowing followed by biomass removal and verticutting, and subsequent supply of hay to provide seeds of local species; (ii) mowing followed by biomass removal and verticutting; and (iii) areas left unmowed (control). Cultural practices had a significant effect on biodiversity in the short-term. The number of plant species at Site 1 was higher in plots receiving Management Practices A and B, and at Site 2 in plots receiving Management Practice A. In contrast, management practice had no effect on the percentages of dominant species. The principal component analysis (PCA) indicated a shift in botanical composition in plots receiving treatments A and B in the second year, while in the last year of the study, the botanical composition of all plots returned to its original state. A single cut in spring was not sufficient to counteract the dominance of highly competitive species.

Core Ideas

- Natural rough areas on a golf course contained 131 plant species.
- The botanical composition of the naturalized areas is dominated by only a few species.
- Cultural practices can improve species richness and botanical composition.
- The efficacy of cultural practices in naturalized roughs depends on the dominant species.
- A single cut can improve biodiversity, but can not reduce dominant species.

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The public perception of the impact of golf courses on natural landscapes and the environment largely depends on an individual's level of involvement in the game of golf. Gange et al. (2003) reported that golfers cited preservation of natural habitat most often as an asset of golf courses, while non-golfers associated golf courses with destruction of natural habitat. Golf courses are often criticized for their impact on the environment, which is mainly related to habitat loss, water use depletion, and chemical contamination (Gange et al., 2003). Although golf course construction and maintenance strategies are often implemented in a way to minimize these negative impacts, the public is unaware of these strategies. Moreover, the numerous documented environmental and social benefits of golf courses, particularly those located in highly urbanized areas, are not widely recognized (Balogh and Walker, 1992; Beard and Green, 1994).

In recent years, there has been growing interest in reducing inputs and increasing biodiversity of mowed golf course rough areas by replacing them with low maintenance habitats such as mulched beds, naturalized rough, and wildflower banks (Brame, 2012; Gross and Eckenrode, 2012; Dobbs, 2013). Little information is available on the importance of naturalized rough for the increase of plant and wildlife biodiversity and habitat complexity of golf courses (Dobbs, 2013). Indeed, it is well documented that increasing diversity in simplified habitats has a beneficial effect on wild fauna and flora (Green and Marshall, 1987; Sorace and Visentin, 2007; Dobbs, 2013; Pornaro et al., 2013). The increase of plant species and vegetation structural diversity, defined as the distribution in space of herbaceous shrubby and woody layers, can also lead to an increase in arthropod abundance and diversity (Raupp et al., 2010). However, the decision by golf course management to create naturalized rough is not always well accepted by players (Voigt, 1996). Problems linked to naturalized areas mainly concern playability; therefore, they are usually confined to out-of-play areas (Gange et al., 2003). Moreover, naturalized roughs are often poorly integrated

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Abbreviations: Hr, herbaceous layer without shrubs or trees; HT, herbaceous layer with scattered trees; HST, herbaceous and shrubby layers occasionally with scattered trees; T, dominant woody layer (ground cover of 100%), comparable to a forest structure; Dp, ditches and ponds; PCA, principal component analysis.

into the golf course landscape due to reduced aesthetic value and enhanced risk of weed invasion in putting greens and fairways (Voigt, 1996). Naturalized areas on golf courses can contain non-native turfgrass species, native grasses, native forbs, and sedges, all developing differently under completely unmanaged conditions (Voigt and Tallarico, 2004).

Plant species, their morphology, and canopy characteristics affect plant competition within the habitat (Busey, 2003). However, maintenance practices play a key role in the succession of most plant communities since they influence botanical composition and competition among species. Mowing height and frequency may have a greater impact on perennial species dependent on vegetative propagation (Hephner et al., 2013). In rhizomatous and stoloniferous species, resources are often reallocated to the regeneration of leaves at the expense of stolon production as a consequence of frequent mowing (Wilen and Holt, 1996). However, since unmowed turfgrass communities are rarely found in recreational and aesthetic turfgrasses, we found only few studies comparing plots mowed at a standard turf height to unmowed plots. Summerlin et al. (2000) observed an increase in the amount of growth and reproductive structure of sedges in unmowed plots compared to turf mowed at 38 and 13 mm. In an 18-yr experiment on roadsides, Parr and Way (1988), found a gradual increase in overall species diversity with increasing numbers of cuts per year. However, Dickinson and Polwart (1982) found that cessation of mowing led to high litter accumulation, reduction in belowground biomass, and forbs invasion. The date at which the mowing occurs may also affect species composition as a delayed cutting allows for seeds to be released into the soil which can improve the species seed bank (Williams, 1984). However, Parr and Way (1988) delayed the date of a single cut from June to July but found no differences in long-term species richness.

The existing vegetation and soil characteristics at the site can affect vegetation changes over time (Tasser and Tappeiner, 2002; Kardol et al., 2006; Van Gils et al., 2008). Yet, there have been few studies to document the temporal shifts in botanical composition of roughs subsequent to management changes and the influence of low-input management practices on their species succession (i.e., Dernoeden et al., 1994; Diesburg et al., 1997; Voigt, 2000, 2001; Cavanaugh et al., 2011). This lack of knowledge hinders efforts to enhance species diversity and habitat quality of roughs. Furthermore, the progression of naturalized roughs is hard to predict and may lead to a simplified habitat with only a few plant species and poor diversity. The objective of this study was to characterize the vegetation of recently naturalized roughs in a Mediterranean transition-zone climate, and to evaluate management options for improving their plant species diversity. To address this aim we investigated the botanical composition, species richness and effective species number of roughs in a golf course in the Venetian Valley in northeastern Italy. In addition, the vegetation in two selected areas of the above-mentioned roughs, characterized by low plant diversity, was studied for 3 yr (2013–2015) to evaluate the effect of three different management options on plant species richness and abundance.

MATERIALS AND METHODS

A field study was conducted at La Montecchia Golf Course (Selvazzano Dentro, Padova), in northeastern Italy (45°23′ N, 11°45′ E, 18 m above sea level) from April 2013 to May 2015. The area has a humid subtropical climate with a mean annual temperature of 12.3°C and a mean rainfall of 820 mm y^{-1} (1963–2007).

The entire golf course was delineated using a GPS receiver (GMS-2; Topcon, Tokyo, Japan) and total surface area was then characterized using ArcGIS 10.1 (ESRI). Standard rough management practices had been suspended in 2009 to improve biodiversity and reduce costs. They consisted of approximately 29 cuts per year (four cuts per month in April, May, June, September, and October; two cuts per month in July, August, March, and November; one cut per month in February) with rotary mowers without clipping removal. Pesticides and fertilizers has not been applied for 20 yr. The roughs were divided into 101 sections that were homogeneous in vegetation structure, sections were labeled with a serial number, and botanical surveys were conducted in each section using the Braun-Blanquet method (Braun-Blanquet, 1964), recording all plant species and their percent abundances. Effective species numbers of orders q = 0 and q = 1 (Jost, 2007) were calculated for each naturalized section. The order q determines a diversity measure's sensitivity to rare or common species. Effective species number of order q = 0 corresponds to species richness, while that of order q = 1 takes into account the influence of species rarity, down-weighing species with low abundance. Each section was classified on the basis of its vegetation structure taking into account spatial distribution of herbaceous, shrubby and woody layers: (i) Hr, herbaceous layer without shrubs or trees; (ii) HT, herbaceous layer with scattered trees; (iii) HST, herbaceous and shrubby layers occasionally with scattered trees; (iv) T, dominant woody layer (ground cover of 100%), comparable to a forest structure; and (v) Dp, ditches and ponds.

The matrix of species was subjected to hierarchical cluster analysis: the distance matrix was computed with the Euclidean method and the average linkage method (Ward, 1963) was used for the cluster analysis.

With the aim of contrasting dominant species and compare the effects of three management practices on species diversity, two sections were chosen as representatives of poor habitat complexity because of their low number of species (<10), and single-species dominance (ground cover >50%). These were labeled as Site 1 and Site 2. For Site 1, the dominant species was *Elytrigia repens* (L.) Nevski, while Site 2 was dominated by *Festuca rubra* L. At both sites, all management practices had been withheld for 5 yr before starting the experiment. Prior to the onset of the experiment, soil samples (0–20 cm depth) were collected in each area and analyzed for soil pH (1:5 soil/water solution), total N content (Kjeldahl method), available P content (Olsen method), exchangeable K content (barium chloride method), and soil organic matter (Walkley and Black method). The C/N ratio was measured according to the Italian standard soil analysis techniques (G.U., 1999). Additionally, particle size analyses (sand, silt, and clay percentages) were conducted (G.U. 1999) and are reported in Table 1. Monthly mean air temperatures and monthly precipitations of the experimental period collected from public weather station (ARPA Veneto, Montegalda) nearest to the golf course are reported in Table 2.

At both sites, three management practices were conducted in May 2013 and were compared in a randomized complete block design. Plots measured 4 × 3 m and treatments were replicated three times. Management Practice A consisted of mowing with

Table 1. Soil characteristics of 0 to 20 cm depth of two naturalized rough areas of La Montecchia Golf Course (Padova, Italy) dominated by *Elytrigia repens* (Site 1) and *Festuca rubra* (Site 2).

Soil characteristics	Site 1	Site 2
Sand (%)	10.8	18.8
Silt (%)	64.7	60.7
Clay (%)	24.4	20.4
Organic matter (%)	5.19	4.46
USDA soil class	Silt loam	Silt loam
pH	8.08	8.37
N content (g kg^{-1})	2.6	2.2
C/N	11.61	11.79
P content (mg kg^{-1})	6.3	2.6
K content (mg kg^{-1})	236.6	125.8

Table 2. Monthly mean air temperatures and monthly precipitations of 2013, 2014, 2015, at the La Montecchia Golf Course (Padova, Italy).

	Air temperature (°C)			Precipitation (mm)		
Month	2013	2014	2015	2013	2014	2015
Jan.	3.7	6.5	4.3	113	229	26
Feb.	3.9	8.3	5.8	88	207	64
Mar.	7.6	11.2	9.6	274	76	75
Apr.	13.5	14.6	13.5	100	79	109
May	16.2	17.5	18.7	182	104	61
June	21.7	22.1	22.9	46	111	96
July	25.1	22.5	26.9	36	179	34
Aug.	24.0	21.9	24.9	146	99	48
Sept.	19.4	19.2	19.9	40	95	87
Oct.	15.2	16.5	14.6	97	40	113
Nov.	9.9	11.7	8.6	122	137	10
Dec.	4.6	6.2	3.9	33	80	5

a rotary mower (HRD536; Honda Europe Power Equipment, Ormes, France) at a height of 65 mm followed by the complete removal of the biomass. Subsequently the area was verticut twice with vertical blades 2.5 cm apart to thin out the existing stand and to promote the establishment of new species by reducing competition through weakening of the dominant species. Hay derived from a nearby meadow was harvested in May 2013 and immediately scattered on top of the area to provide seed of local species. The hay was harvested when *Vicia cracca* L., *Trifolium pratense* L., *Salvia pratensis* L., and the major grasses seeds reached full maturity. Scotton et al. (2012) published guidelines to use hay as seed source for the re-establishment of herbaceous vegetation and we followed these guidelines for sites at the same altitude, environment, and similar vegetation. Hay was distributed a rate of about 330 g m^{-2} (80.7 g m^{-2} of dry matter), and the hay collection was done when most species reached maximum seed production. The hay had not undergone any kind of manipulation such as cutting or seed extraction. Management Practice B consisted of mowing, biomass removal, and verticutting (similar to Management Practice A) but no hay was scattered onto the existing stand. Management Practice C served as the untreated control. The stand was left uncut and no verticutting was applied. No irrigation was applied to the trial during the experimental period.

Botanical surveys were conducted in spring 3 wk after the application of management approaches in 2013, and in May 2014 and May 2015. In each plot, all species were recorded and

Table 3. Botanical composition of the meadow from which donor hay was collected for the trial at La Montecchia Golf Course (Padova, Italy).

Species name	Ground cover (%)
Avena fatua L.	8
Capsella bursa-pastoris (L.) Medicus	+
Convolvulus arvensis L.	5
Dactylis glomerata L.	1
Daucus carota L.	3
Erigeron annuus (L.) Pers.	+
Galium anisophyllum Vill.	1
Holcus lanatus L.	15
Leucanthemum vulgare Lam.	5
Lolium arundinaceum (Schreb.) Darbysh.	15
Lotus corniculatus L.	20
Medicago lupulina L.	1
Plantago lanceolata L.	10
Poa trivialis L.	10
Ranunculus acris L.	4
Rumex acetosa L.	1
Salvia pratensis L.	5
Stellaria media (L.) Vill.	2
Taraxacum officinale Weber	5
Trifolium pratense L.	25
Veronica serpyllifolia L.	15
Vicia cracca L.	5

for each species the percentage of ground cover was visually estimated. Effective species number of order q = 1 was calculated for every survey and subtracted from number of species to calculate the difference between the effective species richness of order q = 1 and q = 0. A botanical survey was also conducted in the nearby meadow (Table 3) before harvesting the hay used in Management Practice A.

The number of species, percentages of dominant species, and difference between effective species richness of order q = 0 and q = 1 in both sites were subjected to analysis of variance (ANOVA). Species matrices were used to perform principal component analysis (PCA) for each site. All statistical analyses were performed in R 3.1.3 (R Development Core Team, 2015) using the libraries “vegan”, “mefa”, and “hierDiversity”.

RESULTS

Overall Characterization of Biodiversity

The golf course surface area is approximately 64 ha, of which 19% is naturalized rough comprised of a total of 131 species. Based on vegetation structure, 40 homogeneous rough sections were classified as type T (dominant woody layer, ground cover of 100%), while 16, 11, 22, and 8 sections were classified as types Hr, HT, HST, and Dp, respectively (Fig. 1).

The cluster analysis identified four groups, with Group 1 including most sections classified as type T that were clearly separated from the others (Fig. 2). The other three groups were less distinct and included different vegetation types. The botanical composition of sections that fell into Group 2 featured *E. repens* as the dominant species and a significant presence of *Cynodon dactylon* (L.) Pers. (abundance 30%), while Group 3 included sections dominated by *C. dactylon*, *E. repens,* and *F. rubra*. Sections that fell into Group 4 were dominated by *F. rubra* with *Lolium*

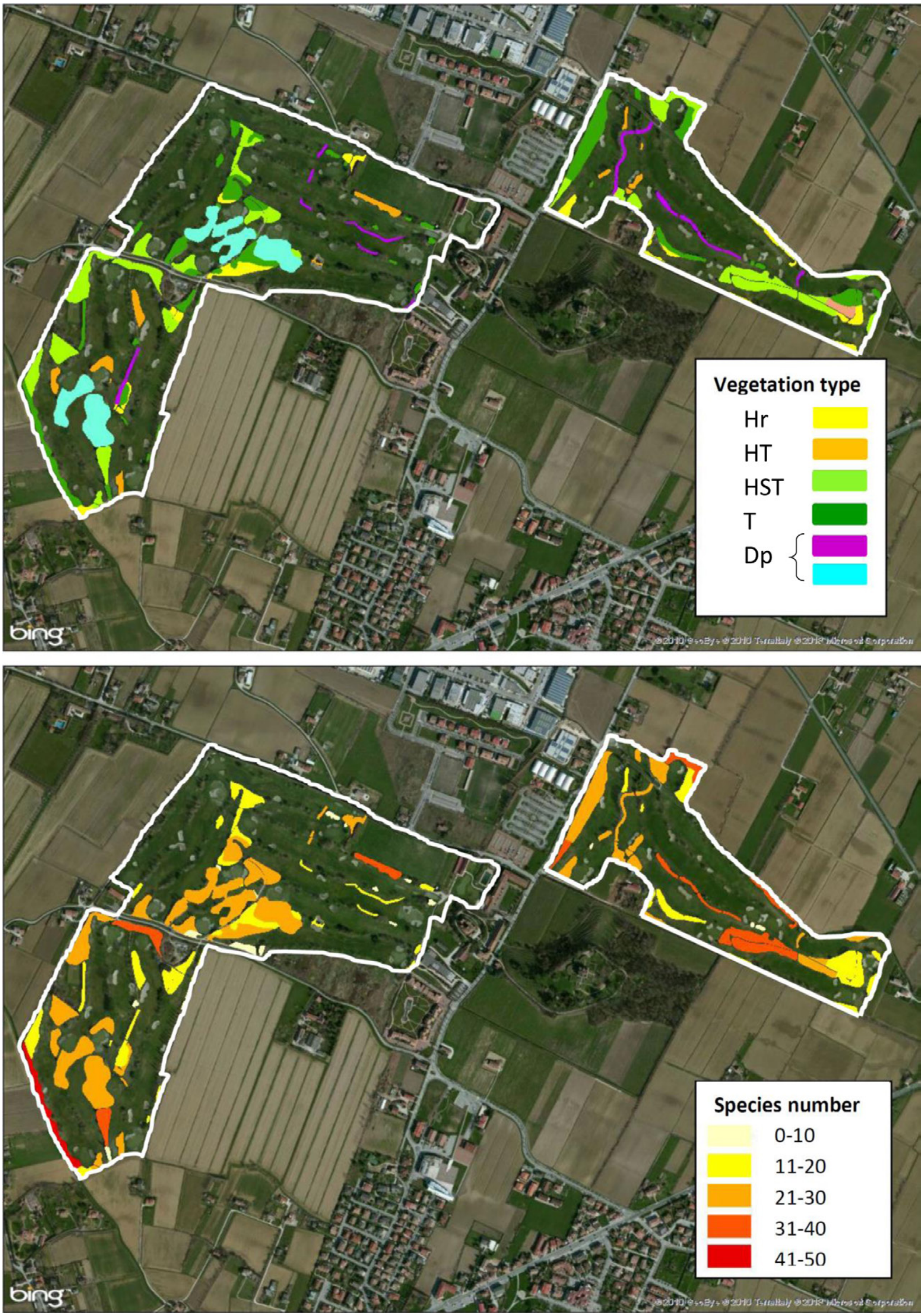


Fig. 1. Ortophoto of La Montecchia Golf Course (Padova, Italy) (white line) and naturalized rough sections (colored areas). In the upper panel vegetation types are reported: Hr = herbaceous layer without shrubs or trees; HT = herbaceous layer with scattered trees; HST = herbaceous and shrubby layers occasionally with scattered trees; T = dominant woody layer (ground cover of 100%), comparable to a forest structure; Dp = ditches and ponds. Number of species are reported in the lower panel.

arundinaceum (Schreb.) Darbysh. (formerly *Festuca arundinacea* Schreb.) and *C. dactylon* ranging in abundance from 10 to 60%. The sections differed in size and effective species number of both orders (q = 0 and q = 1). Effective species number of order q = 0 (equivalent to species richness) ranged from 5 to 43 with lower values in Group 1, while the effective species number of order q = 1 ranged from 2 to 27 (Fig. 2). Since the value of effective species number of order q = 1 is mainly based on high-abundant species (Jost, 2007), a small difference between the two orders indicates a botanical composition characterized by few species of high abundance. On the basis of this evidence, a simplified botanical composition with vegetation dominated by only one or two species was observed in all groups (Fig. 2). In Group 2, the differences between the two orders reflected the dominance of *C. dactylon* while in Group 4, where differences were more marked, we observed the dominance of *F. rubra* together with *L. arundinaceum* and *C. dactylon*.

Management Trial

Results of the plot trial indicate that the type of cultural practice used on naturalized rough areas influenced species diversity. The ANOVA revealed that number of species was significantly affected by year and management practice ($P < 0.05$ and $P < 0.001$, respectively) at Site 1. A higher number of species was observed on plots receiving Management Practices A and B compared to those receiving Management Practice C (9.6, 10.0, and 6.1, respectively), with highest species numbers occurring in the last year of investigation (Fig. 3). On plots receiving Management Practice A, species recorded in 2015 but not present in 2013 included *Cirsium vulgare* (Savi) Ten., *Stellaria media* (L.) Vill., and *Taraxacum officinale* Weber. New species on plots receiving Management Practice B included *Daucus carota* L., *Glechoma hederacea* L., and *T. officinale*. For Site 2, the ANOVA revealed that the interaction between management practice and year significantly affected species richness. Plots receiving Management Practice A had the highest number of species in 2014 and 2015. Except for 2014, no significant differences were observed between plots receiving Management Practice B and control plots. On plots receiving Management Practice A, species recorded in 2015 but not present in 2013 were, *S. media*, *T. officinale*, *T. pratense*, whereas on plots receiving Management Practice B *D. glomerata* and *T. officinale* were recorded in 2015. Among species transferred through hay supply the most effective, especially in Site 2, were *Trifolium pratense* L. and *Vicia cracca* L. while other existing species as *C. vulgare* (Savi) Ten. and *Erigeron annuus* (L.) Pers. seemed to be favored by the mowing.

The percentage of dominant species in Site 1 and Site 2 was affected only by year (Fig. 4). In Site 1, the lowest percentage of *E. repens* was observed in 2013, while the highest occurred in 2014. A different trend was detected in Site 2, where the percentage of *F. rubra* steadily increased over time. A single cut was not able to limit the dominance of *E. repens* or *F. rubra,* regardless of the addition of external seed. However, in Site 2, the increased species richness of plots receiving Management Practice A demonstrated that the introduction of external seeds could be considered a practical strategy to improve plant diversity and enhance botanical composition in naturalized roughs.

The difference between effective species richness of order q = 0 and q = 1 was significantly affected by the interaction of year and management practice ($P < 0.05$) in Site 1. This parameter was lower in 2014 where Management Practices A and C were applied than in 2015 where Management Practice A was applied (Fig. 5), indicating a more complex botanical composition. In Site 2, only the effect of year was significant ($P < 0.01$), showing that in 2015 the parameter was lower than in other years. Site 2 had a similar number of species but a lower difference between effective species richness of order q = 0 and q = 1 than Site 1. This suggests that vegetation in Site 2 is more simplified than in Site 1 and this is confirmed by the dominant species percentage. In fact, when the difference between effective species richness of order q = 0 and q = 1 was lower, the percentage of dominant species was higher.

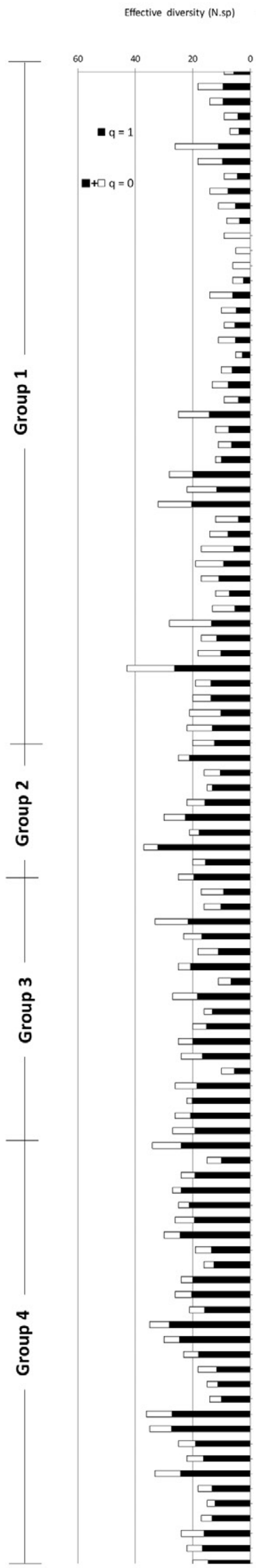
The PCA showed that botanical composition of all plots at both sites was similar in 2013 and that the composition shifted in 2014 on plots that received Management Practices A and B. Marked changes were observed in Site 2 plots in response to Management Practice A. Over the course of the third year of the study, the botanical composition of plots receiving Management Practices A and B slowly returned to the original species composition of both sites, a trend that was more pronounced in Site 2 (Fig. 6).

DISCUSSION

The naturalized roughs of La Montecchia Golf Course consist of vegetation that is heterogeneous in terms of both structure and species richness. These habitats may enhance the landscape complexity of the Venetian Valley, where agricultural land use and urban intensification have led to a decline in habitat biodiversity (Veneto Region, 2017). However, the botanical composition in many of the studied naturalized roughs was dominated by a few *Poacea* species such as *F. rubra* and *L. arundinaceum* that were included in the original seed mixtures used for sowing the roughs. The high shoot density typical of turf-type cultivars together with good soil fertility mainly due to high organic matter content and high C/N ratio (Table 1) may led to their dominance in the sward. The shaded environment created by trees may have additionally contributed to the dominance of these shade-tolerant species (Beard, 1973; Roberts, 1990; Meyer and Watkins, 2003).

As reported in other studies (Voigt, 1996, 2000, 2001; Voigt and Tallarico, 2004) our results indicate that mowing is necessary to increase the number of species, promote the complexity of botanical composition, and combat (mitigate) the aggressiveness of grasses. Voigt (1996, 2000, 2001) proposed mowing naturalized rough at least once a year, followed by removal of clippings to avoid lodging of foliage. Our findings also support those of Parr and Way (1988), who found that unmowed grasslands on roadsides had lower species richness compared to those cut once or twice a year.

Studies on grassland restoration have demonstrated the successful use of hay from permanent meadows (donor meadow) for revegetation of degraded areas (Scotton et al., 2009, 2012, 2015). These studies mainly focused on the quantity of seeds produced by the donor meadow. Seed production of *Arrhenatherion elatioris* and *Festuco-Brometalia* hay-meadows at mid-June harvest was reportedly between 14,000 and 38,000 seeds m^{-2} (Scotton et al., 2012). Most of the species found in the hay used in our study were also present in the donor meadows used in the Scotton et al. (2012) study. However, unlike the aforementioned study,



vegetation vertical srtructure	woody and shrubby cover (%)	*Lolium perenne* L. (%)	*Agrostis stolonifera* L. (%)	*Elytrigia repens* (L.) Beauv. (%	*Festuca rubra* L. (%)	*Lolium arundinaceum* Schreber (%)	*Cynodon dactylon* (L.) Pers. (%)	ID
T	100		0				1	1
P	80				1	1	3	2
T	100	0			1		0	3
T	100						1	4
T	100						0	5
T	100				1	1	1	6
T	100			0	1	2	2	7
T	100		0	1		2		8
HT	10				1	2		9
T	100					0	1	10
T	100				0		0	11
T	100						0	12
T	100						0	13
T	100						0	14
T	100				1			15
T	100		0		1		1	16
T	100				1			17
T	100		0				0	18
T	100						1	19
T	100							20
T	100			0	0			21
T	100		0			0	0	22
T	100		0			1		23
P	80							24
T	100				11	8		25
T	100				10	4		26
T	100				10	1		27
P	0							28
P	0				2		2	29
P	90				1	2	0	30
T	100				1			31
T	100				4		0	32
P	80				1			33
T	100	1	1		5	3	2	34
T	100	2			4	1	4	35
T	100				4		1	36
T	100				8			37
T	100			4		4	10	38
HST	40			10		10		39
T	100				10		20	40
T	100		1	0	2	0	6	41
P	0						10	42
P	0						10	43
P	5				5		5	44
T	100			2	1	1	8	45
P	0				5		10	46
HST	50			20		30	70	47
H	0			10		20	50	48
HT	10			3	4		70	49
T	100			4			40	50
HST	20			10	10	5	100	51
HST	10		5	2		8	100	52
HST	10			2	20	30	100	53
H	0		5	30	20	30	90	54
H	0			20	20	40	100	55
P	0			10	40			56
T	100			5	20	5	8	57
HST	10			1	40	2	8	58
HT	10	20			40		3	59
HT	15	30	4		40		20	60
HST	70	2		5	60	1	10	61
H	0	10	20	20	50	1	4	62
HST	80			1	5		5	63
T	100					3		64
HST	85				20	40	5	65
HT	5		5		20	30	20	66
H	0				10	30	20	67
H	0	5	1	30	10	0	20	68
HST	5		10	50	40	30	20	69
HST	90			0	2	2	1	70
P	0							71
P	0							72
HST	50	20		10	60	40		73
HT	10		2		40	30	5	74
HT	10	10	1	1	50	30		75
HST	10			0	20	80	0	76
HST	5			4	60	70	1	77
HST	30			10	80	40	20	78
HST	15			0	70	60	40	79
HST	5				90	60	30	80
HST	5			4	90	30	120	81
HT	10				80	30	70	82
H	0		5	8	80	40	80	83
T	100	40	60		50		3	84
H	0	40	60		50	0	50	85
T	100			2	80	0	10	86
T	100	0		10	90	8	10	87
H	0	20	5	8	40	20	60	88
H	0				40	30	50	89
H	0				40	30	40	90
HST	10	40		8	80	8	60	91
HT	5	3	20	10	60	3	40	92
H	0	10	10		60	2	50	93
HT	5			10	30	8	40	94
HST	10		1	5	50	10	40	95
HT	15			10	60		40	96
HST	5				80	1	40	97
H	0			10	80	5	60	98
HST	80			10	60		30	99
H	0		5	20	80	20	30	100
H	0			20	60	20	30	101

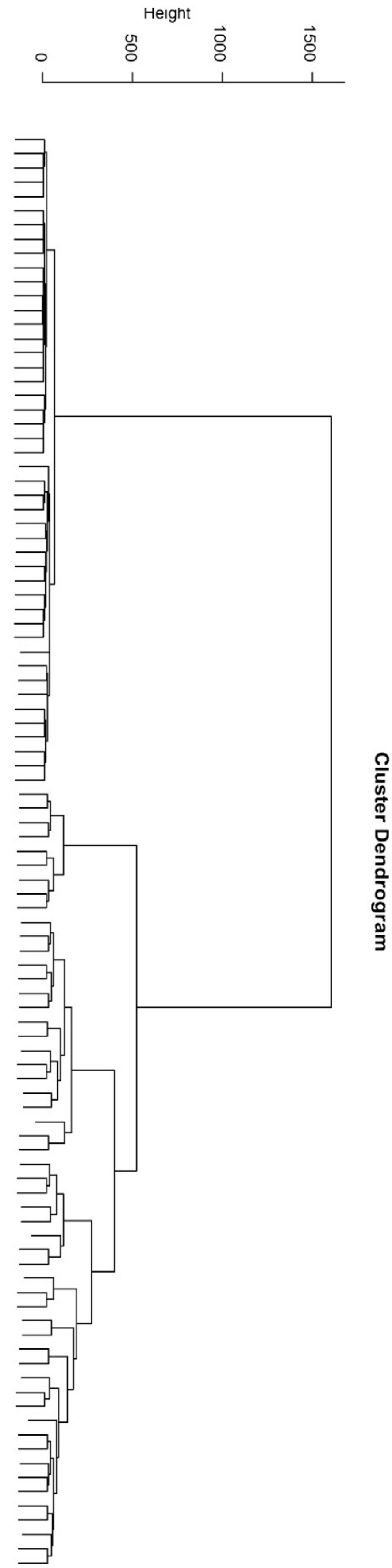


Fig. 2. Dendrogram from Cluster analysis of the studied sections of naturalized rough in La Montecchia Golf Course. Vegetation structure, percentage of woody and shrubby ground cover, and percentage of dominant grasses are reported for each section. Histogram (on the left) represents effective species number of order q = 0 and q = 1.

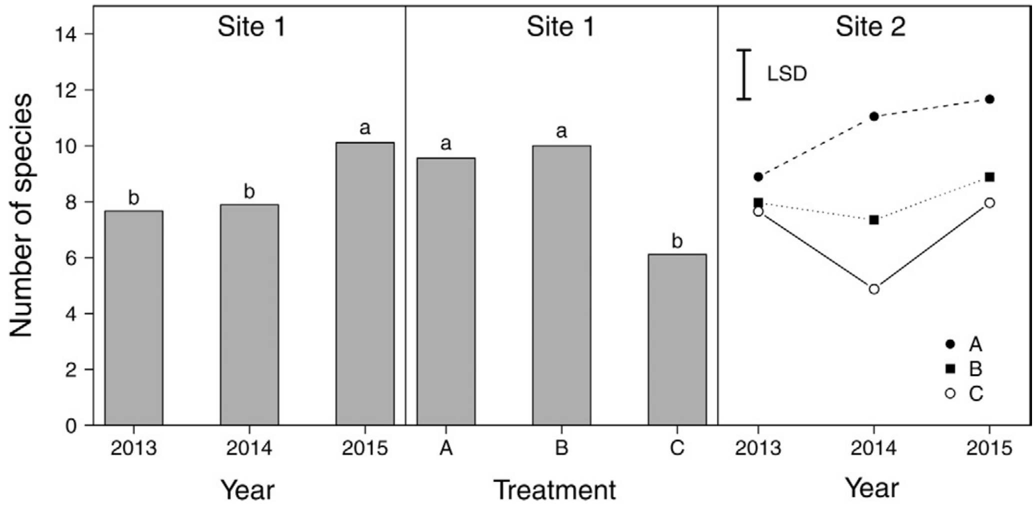


Fig. 3. Year and management practice main effects and their interaction for the number of species in two naturalized rough areas of La Montecchia Golf Course (Padova, Italy) dominated by *Elytrigia repens* (Site 1) and *Festuca rubra* (Site 2); A, B, and C = management practice A: mowed and seed supply, management practice B: mowed, and management practice C: control. Bars with the same letter are not significantly different according to the least significant difference test at 0.05 level of probability. Error bar represents the least significant difference at $P = 0.05$ for comparing means within interaction.

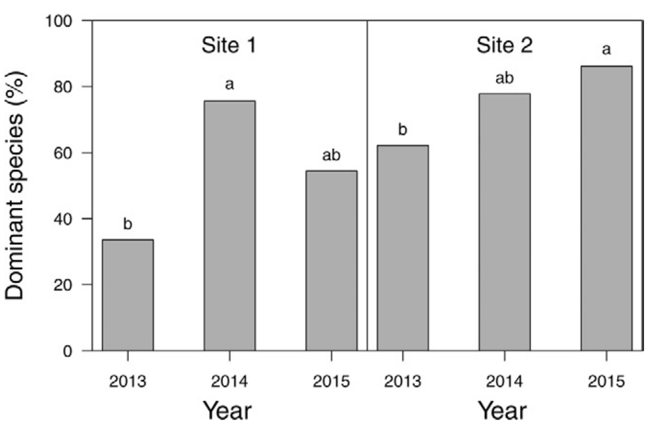


Fig. 4. Year effect on percentage of dominant species in two naturalized rough areas of La Montecchia Golf Course (Padova, Italy) dominated by *Elytrigia repens* (Site 1) and *Festuca rubra* (Site 2). Bars with the same letter are not significantly different according to the least significant difference test at 0.05 level of probability.

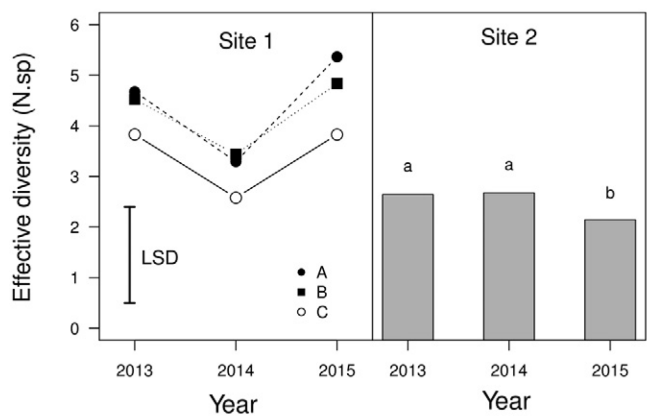


Fig. 5. Year and management practice interaction and year main effect for the effective species number in two naturalized rough areas of La Montecchia Golf Course (Padova, Italy) dominated by *Elytrigia repens* (Site 1) and *Festuca rubra* (Site 2); A, B, and C = management practice A: mowed and seed supply, management practice B: mowed, and management practice C: control. Error bar represents the least significant difference at $P = 0.05$ for comparing means within interaction. Bars with the same letter are not significantly different according to the least significant difference test at 0.05 level of probability.

which reported that 70% of the species in the donor meadow were transferred to the recipient site when hay derived from the meadow was applied to bare soil to restore a plant stand, long term establishment of introduced species was not achieved in our study. Despite air temperature and precipitation being favorable for germination of the seeds supplied from hay until middle of June (Table 2) and the base water potential required for germination not varying greatly among species composing the meadow (Baskin and Baskin, 2014), the species introduced to the golf course rough did not establish over the long-term. We believe that in our study the regrowth after mowing of the dominant grass species was more rapid than the germination of seeds, creating strong competition with the introduced seedlings.

In Site 1, *E. repens* was the dominant species with percent abundances of 50% or more. Other species found in Site 1 were *Bromus sterilis* L., *Dactylis glomerata* L., *Galium aparine* L., and *Geranium dissectum* L. In Site 2, *F. rubra* accounted for more than 60% of the species composition in all plots, followed by *Carex hirta* L., *Dactylis glomerata* L., *Lolium arundinaceum*, and *Poa pratensis* L. The impacts of the management practices in botanical composition seems to be limited to the second year of the study (Fig. 6). Our results indicated that Management Practices A and B had a positive effect on species richness (Fig. 3). However, this effect was different depending on the site and, as a consequence, on dominant species. In Site 1, the increase of species richness appear to be more related to the effect of mowing than to the supplying of seed, while in Site 2 the increase of number of species with the year is due to Management Practice A. These findings concur with other studies that have documented the role of mowing in increasing plant species population of natural roughs and roadsides (Parr and Way, 1988; Voigt, 1996, 2000, 2001), by allowing the perennial species to survive (Hephner et al., 2013). Nevertheless, our study showed that a single mow was not sufficient to reduce the abundance of dominant species

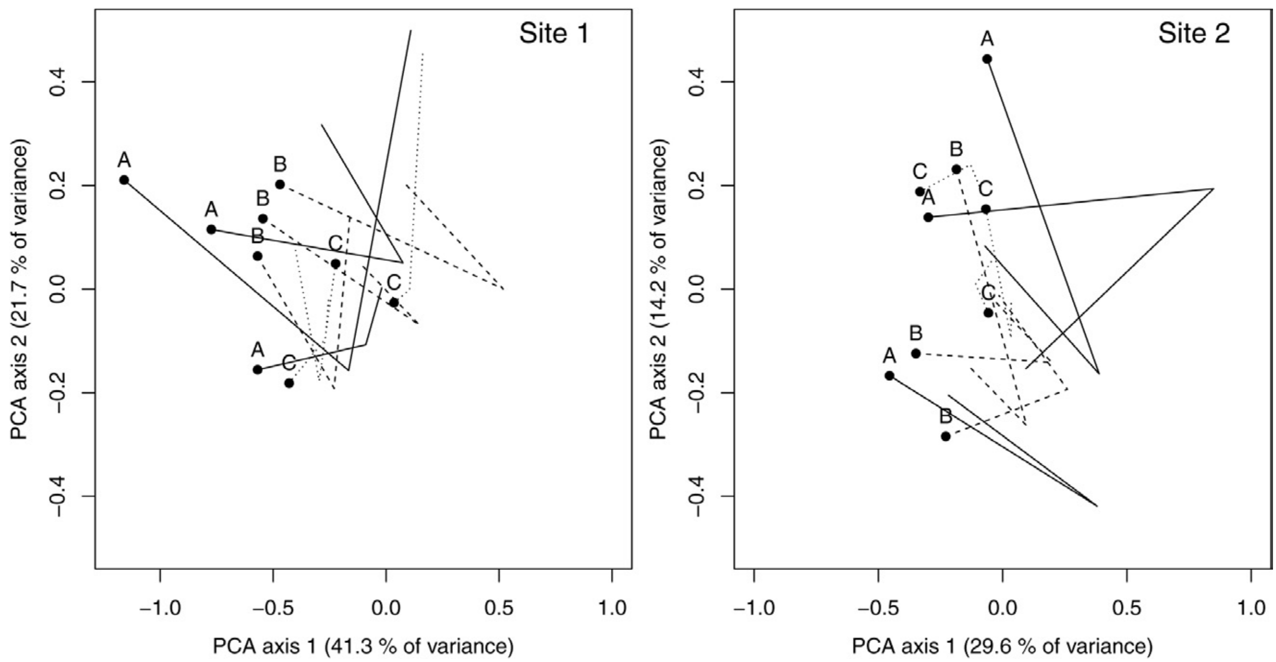


Fig. 6. Ordination biplot of field trial plots along the first two axes of principal component analysis (PCA) in two naturalized rough areas of La Montecchia Golf Course (Padova, Italy) dominated by *Elytrigia repens* (Site 1) and *Festuca rubra* (Site 2). For each axis, the percentage of variance explained is reported. Full dots are plots surveyed in 2013; second and third vertex of the line are plots surveyed in 2014 and 2015. Letters A (mowed and seed supply), B (mowed), and C (control) indicate cultural practices. Dots of each parcel are joined with a line along time gradient.

(*E. repens* and *F. rubra*) even when hay was added as an external seed source. Moreover, in the third year of the study the vegetation structure reverted back to its original botanical composition and this trend was most pronounced in the site dominated by *F. rubra*. Further differences were found between the two sites regarding their responses to management approaches, indicating that management practices should be adjusted to the grass species dominating the naturalized rough botanical composition.

CONCLUSIONS

The results of our study suggest that the effectiveness of cultural practices aimed at increasing plant biodiversity on golf course rough areas depends on the dominant plant species that are initially present. A single spring cut was effective at increasing the number of species present and enhancing the complexity of botanical composition of the studied naturalized rough only in the short term. However, it was not sufficient to break the dominance of highly competitive species such as *E. repens* and *F. rubra*, even if external seeds were imported. Since the positive effects produced by a cut were only apparent in the first 2 yr, more research is needed to investigate if mowing more frequently, such as two or three times per year and/or over several years would help to increase plant diversity more rapidly. Moreover, the supply of external seed may have an additional positive effect, but its efficacy seems to be related to the competitive ability of existing species.

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REFERENCES

Balogh, J.C., and W.J. Walker. 1992. Golf course management and construction: Environmental issues. CRC Press, Boca Raton, FL.

Baskin, C.C., and J.M. Baskin. 2014. Seeds: Ecology, biogeography and evolution of dormancy and germination. 2nd ed. Elsevier/Academic Press, San Diego, CA.

Beard, J.B. 1973. Turfgrass: Science and culture. Prentice Hall, Upper Saddle River, NJ.

Beard, J.B., and R.L. Green. 1994. The role of turfgrasses in the environmental protection and their benefits to humans. J. Environ. Qual. 23:452–460. doi:10.2134/jeq1994.00472425002300030007x

Brame, R.A. 2012. Tall grass rough… or natural rough? USGA. http://www.usga.org/course-care/2012/06/tall-grass-roughor-natural-rough-21474847128.html (accessed 30 Aug. 2016).

Braun-Blanquet, J. 1964. Pflanzensoziologie. Springer-Verlag, Wien, Austria. doi:10.1007/978-3-7091-8110-2

Busey, P. 2003. Cultural management of weeds in turfgrass: A review. Crop Sci. 43:1899–1911. doi:10.2135/cropsci2003.1899

Cavanaugh, M., E. Watkins, B. Horgan, and M. Meyer. 2011. Conversion of Kentucky bluegrass rough to no-mow, low-input grasses. Appl. Turfgrass Sci. 8. doi:10.1094/ATS-2011-0926-02-RS.

Dernoeden, P., M.J. Carroll, and J.M. Krouse. 1994. Mowing of three fescue species for low-maintenance turf sites. Crop Sci. 34:1645–1649. doi:10.2135/cropsci1994.0011183X003400060041x

Dickinson, N.M., and A. Polwart. 1982. The effect of mowing regime on an amenity grassland ecosystem: Above- and below-ground components. J. Appl. Ecol. 19:569–577. doi:10.2307/2403489

Diesburg, K., N. Christians, R. Moore, B. Branham, T. Danneberger, Z. Reicher, T. Voigt, D. Minner, and R. Newman. 1997. Species for low-input sustainable turf in the US Upper Midwest. Agron. J. 89:690–694. doi:10.2134/agronj1997.00021962008900040024x

Dobbs, E.K. 2013. Enhancing beneficial insect biodiversity and biological control in turf: Mowing height, naturalized roughs, and operation pollinator. M.S. thesis, University of Kentucky, Lexington.

Gange, A.C., D. Lindsay, and M. Schofield. 2003. The ecology of golf courses. Biologist 50:63–68.

Green, B.H., and I.C. Marshall. 1987. An assessment of the role of golf courses in Kent, England, in protecting wildlife and landscapes. Landscape Urban Plan. 14:143–154.

Gross, P., and T. Eckenrode. 2012. Turf reduction template: A guideline for reducing turf acreage while maintaining golf course quality. USGA. Green Section Record 50:1–5.

Gazzetta Ufficiale dello Stato Italiano (G.U.). 1999. Approval: Metodi ufficiali di analisi fisica del suolo. D.M., 13th September 1999, suppl. G.U., 248, 21 Oct. 1999.

Hephner, A.J., T. Cooper, L.L. Beck, and G.M. Henry. 2013. Khakiweed (*Alternanthera pungens* Kunth) growth response to mowing height and frequency. HortScience 48:1317–1319.

Jost, L. 2007. Partitioning diversity into independent alpha and beta components. Ecology 88:2427–2439. doi:10.1890/06-1736.1

Kardol, P., T.M. Bezemer, and W.H. van der Putten. 2006. Temporal variation in plant–soil feedback controls succession. Ecol. Lett. 9:1080–1088. doi:10.1111/j.1461-0248.2006.00953.x

Meyer, W.A., and E. Watkins. 2003. Tall fescue (*Festuca arundinacea*). In: M.D. Casler and R.R. Duncan, editors, Turfgrass biology, genetics, and breeding. John Wiley & Sons, Hoboken, NJ. p. 107–127.

Parr, T.W., and J.M. Way. 1988. Management of roadside vegetation: The long-term effects of cutting. J. Appl. Ecol. 25:1073–1087. doi:10.2307/2403767

Pornaro, C., M.K. Schneider, and S. Macolino. 2013. Plant species loss due to forest succession in Alpine pastures depends on site conditions and observation scale. Biol. Conserv. 161:213–222. doi:10.1016/j.biocon.2013.02.019

Raupp, M.J., P.M. Shrewsbury, and D.A. Herms. 2010. Ecology of herbivorous arthropods in urban landscapes. Annu. Rev. Entomol. 55:19–38. doi:10.1146/annurev-ento-112408-085351

R Development Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Roberts, E.C. 1990. Fine fescue. A kinder, gentler lawngrass. Seed World 128(9):16–19.

Scotton, M., A. Kirmer, and B. Krautzer. 2012. Practical handbook for seed harvest and ecological restoration of species-rich grasslands. CLEUP, Padova, Italy.

Scotton, M., L. Piccinin, and M. Coraiola. 2015. Seed production of a subalpine Festuca nigrescens–Agrostis capillaris semi-natural grassland in the eastern Italian Alps. Plant Biosyst. 149:404–414. doi:10.1080/11263504.2013.853702

Scotton, M., L. Piccinin, M. Dainese, and F. Sancin. 2009. Seed production of an Arrhenatherion elatioris hay-meadow in the eastern Italian Alps. Grass Forage Sci. 64:208–218. doi:10.1111/j.1365-2494.2009.00684.x

Sorace, A., and M. Visentin. 2007. Avian diversity on golf courses and surrounding landscapes in Italy. Landsc. Urban Plan. 81:81–90. doi:10.1016/j.landurbplan.2006.10.014

Summerlin, J.R., Jr., H.D. Coble, and F.H. Yelverton. 2000. Effect of mowing on perennial sedges. Weed Sci. 48:501–507. doi:10.1614/0043-1745(2000)048[0501:EOMOPS]2.0.CO;2

Tasser, E., and U. Tappeiner. 2002. Impact of land use change on mountain vegetation. Appl. Veg. Sci. 5:173–184. doi:10.1111/j.1654-109X.2002.tb00547.x

Van Gils, H., O. Batsukh, D. Rossiter, W. Munthali, and E. Liberatoscioli. 2008. Forecasting the pattern and pace of Fagus forest expansion in Majella National Park, Italy. Appl. Veg. Sci. 11:539–546. doi:10.3170/2008-7-18568

Veneto Region. 2017. Rural development plan 2014–2020. http://www.regione.veneto.it/web/agricoltura-e-foreste/sviluppo-rurale-2020 (accessed 27 June 2018).

Voigt, T. 1996. Native grasses flourish on Midwestern golf courses. Golf Course Manag. 64(11):58–62.

Voigt, T. 2000. Native Midwestern plants for golf course landscapes. Erigenia 18:56–63.

Voigt, T. 2001. Native plants for Midwestern golf courses. Golf Course Manag. 69(12):63–67.

Voigt, T., and J. Tallarico. 2004. Turf and native grasses for out-of-play areas. Golf Course Manag. 72(3):109–113.

Ward, J.H. 1963. Hierarchical grouping to optimize an objective function. J. Am. Stat. Assoc. 58(301):236–244. doi:10.1080/01621459.1963.10500845

Wilen, C.A., and J.S. Holt. 1996. Spatial growth of kikuyugrass (*Pennisetum clandestinum*). Weed Sci. 44:323–330.

Williams, E.D. 1984. Changes during 3 years in the size and composition of the seed bank beneath a long-term pasture as influenced by defoliation and fertilizer regime. J. Appl. Ecol. 21:603–615. doi:10.2307/2403432